Chapter 8- Discussion

In this chapter the importance of the research carried out is discussed in general while drawing the attention on possible involvement of errors . The future trends in the area of study are also focused.

8.1 Precision and economic factors

There are a number of uncertainties in heat exchanger design and the fact investigated in our experiment is one of them. In such an instance the designer can pursue two approaches. One is to conduct research until satisfactory results are obtained. On the contrary a designer can allow for uncertainties in design by giving some margin of error. Actually speaking the employment of LMTD concept in calculations of heat transfer is also an approximation but has produced very satisfactory results as far as field applications are concerned. That is why it is used by many a manufacturer hitherto in designing heat exchangers.

Most of the heat exchanger design methods have been essentially one dimensional in number of applications. However, flows in the heat exchanger systems are clearly three dimensional. In spite of this known fact, **for designers convenience and speedy design procedures such heat transfer systems are idealized.**

For more accurate and more reliable equipment, a deep understanding of physical phenomena is important. A reasonable compromise between accuracy and relative simplicity is the designers task. The research work reduces the uncertainty and enhance the precision in design particularly in developing empirical formulas. Once we develop ways to analyze such effects and identify critical components or parameters, we can devise modifications that will compensate for, or at least minimize the adverse effects of uncertainty. This can be done either physically or mathematically. Deriving correlation coefficients for parameters with uncertainty is a mathematical mean in converting an unknown to a known.

As heat exchangers are normally utilized for heavy thermal duty it may not be worthwhile to perform precise calculations on point by point basis from the view point of overall cost as far as traditional manufacturing is concerned. However, energy and material saving considerations as well as economic incentives have led to recent expansion of efforts to produce more efficient heat exchangers. There are circumstances when , for thermodynamic reasons, it is essential to transfer a given heat load at the lowest possible temperature driving force. For instance, in currently available solar energy systems the thermal efficiency is very low and hence it may require improvements in thermal energy transfer which needs precision. This is particularly true in Sri Lankan context where solar energy is found in abundance.

The world wide demand for energy efficient equipment is accelerating rapidly, particularly in large scale power and process industry facilities. Hence, advanced analytical and experimental techniques are being directed towards heat exchanger design and development. This increasing sophistication refines the traditional engineering computations as it covers every variable associated with the fine structure of a heat transfer system. For instance, although the behaviour of a fluid that flows through the tubes can be explained with basic fluid dynamic theories to a great extent the flow pattern in the shell is much more complex and greatly depends on the geometrical arrangements and hence is unpredictable. As explained in chapter 3, in a heat exchanger shell there may be several flow streams depending on the baffle and tube configuration such as main , leakage and bypass paths. The formation of eddies at points where the flow pattern is obstructed or flow direction is changed makes the system further complicated. Consequently heat and temperature distribution deviate from the ideals and different distribution profiles are exhibited in practice. Determination of temperature at the shell water / tube surface interface is of great importance as it has a direct bearing on the actual heat transferred across the tube wall.

8.2 Error avoidance

The objective of our experiment is to see how the actuals deviate from the ideals and it was observed in the course of the experiment that the results were not what we normally expect from a U – tube heat exchanger. However, the experiment was continued without being influenced by generalized or idealized conditions in keeping with this objective and the results were verified again by repeating the experiment.

When taking temperature measurements in a shell and tube exchanger it is pertinent that no leaks exist between shell side fluid and tube side fluid. Therefore the exchanger was leak tested at several stages. Transparency of the shell in no way affected the findings of the research but would have helped detection of leaks, if any.

Installation of temperature sensors on the surface of the tube bundle was carefully carried out with binding tapes having strong adhesive properties, ensuring close contact to avoid erroneous readings. However, in spite of the precautions taken one sensor had penetrated the binding tape, thus making loose contact between the tube external surface and the probing end of the sensor. This error was detected when the sensor concerned recorded unrealistic temperature values. After fixing this problem the whole experiment was repeated.

Although the temperature measurements on metal surfaces are normally done with infrared thermometers or pyrometers, the method we employed was the most practicable and the cheapest as far as this experiment and the available resources are concerned. Even welding or brazing was not considered in sensor installation as that would have fused the tube surface partly or completely. The smaller dimensions and the configuration of the exchanger internals too paused restrictions in fixing sensors.

As far as instrumentation is concerned there is one important fact that must be borne in mind. When cold water passes over inward flow tubes, the thermocouple absorbs heat from the external surface of copper tubes and gives out part of that to cold water stream. As such it may read a temperature somewhat lower than the external surface temperature. Similarly when slightly heated cold water flows over return flow tubes that thermocouple may indicate a temperature that may be higher than the external surface temperature of return flow tubes depending on the degree of heating the cold stream is so far subject to.

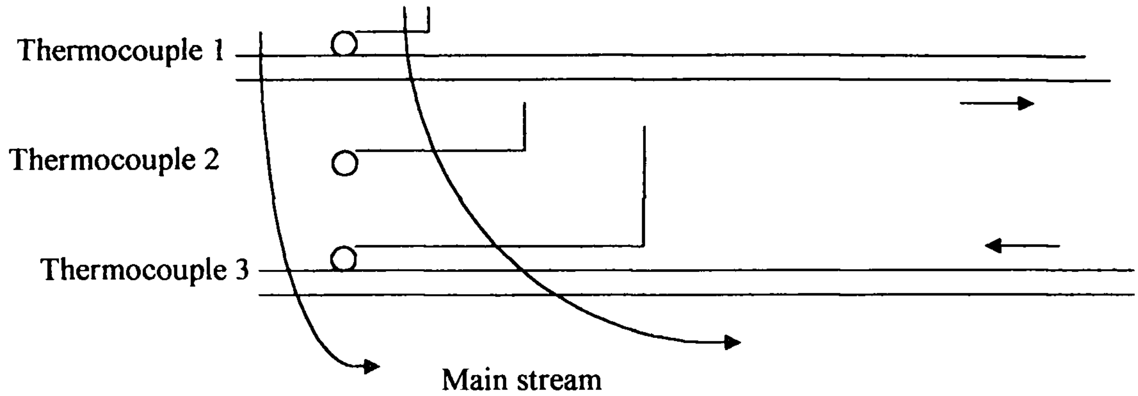

Fig. 8.1 Sensors installed on the heat exchanger model

Further, as thermocouple 2 is located at the mid of the main flow stream it may indicate a higher value than the rest in the region. See Figure 8.1 given above. It would have been possible to eliminate the former if the tube internal temperature had been measured instead of tube external surface temperature. However, this would not have revealed the true nature of the outside temperature profile which dictates the actual heat transferred and indicates the temperature crossings taken place.

By increasing the number of temperature sensors more precise results can be expected. Nevertheless, this may affect the flow pattern of the shell fluid and also creates undesirable paths of heat conduction. If the experiment was carried out when the equipment was fresh a large fouling factor can be utilized. Otherwise if the equipment is left with water inside it for sometime a suitable fouling coefficient should be selected. It is advantageous to develop the software first and obtain some values as a guideline. If large deviations are encountered during the experiment it implies experimental errors that can be corrected then and there. Further, it should be remembered that the methods used to calculate heat transfer coefficients, though apparently the best in the open literature, is not extremely accurate. An exhaustive study carried out in this regard indicates that predicted heat transfer coefficients vary from 50 % low to 100 % high, while the mean error is 15 % for all Reynolds numbers[24].

In a heat exchanger shell the linear and mass velocities of the fluid change continuously across the bundle, since the width of the shell and the number of tubes vary from zero at the top and bottom to the maximum at the center of the shell. The width of the flow area in the correlation used to calculate the heat transfer coefficient, is taken at the hypothetical tube row possessing the maximum flow area and corresponding to the center of the shell. If the inside diameter of the shell is divided by the tube pitch it gives a fictitious number of tubes which may be assumed to exist at the center of the shell. Actually in most layouts found in practice there is no row of tubes in the center but instead two equal maximum rows on either side having fewer tubes than computed for the center. These facts are often neglected but have been a source of errors in heat transfer coefficient calculations.

The 1-2 exchanger is a combination of both, counter and parallel flows and the LMTD for counter flow or parallel flow alone can not be the true temperature difference for a parallel flow- counter flow arrangement. Therefore, a correction factor (F_t) is introduced by the design standards, which takes into account the discrepancies between actual and theoretical values.[21]

$$Q = UA\Delta t = UAF_t \text{ (LMTD)}$$

As the shell fluid proceeds from the inlet to outlet, crossing the tube bundle several times, it may be subjected to the following conditions.

1. Shell fluid is completely mixed due to high turbulence at any distance from the inlet.
2. Turbulence created is so less a selective temperature atmosphere exist about the tubes of each tube pass individually.

First condition is assumed to be in effect when deriving a correction factor (F_t) and based on this the following assumption are made.

1. Shell fluid temperature is an average isothermal temperature at any cross section.

2. Heating surface area is a constant in each pass.

3. Overall heat transfer coefficient is constant throughout the bundle.

4. Flow rate of the fluid is constant.

5. Specific heat of fluid is constant.

6. No phase changes taking place.

7. Heat losses can be ignored.

The failure to fulfill in practice all the assumptions employed in the derivation, assumption 1,3 and 7 in particular may cause serious discrepancies in the calculation of Δt. As far as field applications are concerned the above conditions can not be strictly observed. Therefore it is imperative that more and more research be carried out on this subject.

Further, at very high temperatures radiation heat transfer is the primary mechanism particularly with gases, with the ratio of radiation to convection usually on the order of 3 to 1 or higher. [25] Therefore, some of the equations used have to be suitably modified to accommodate such phenomena that have not been taken into account fully.

8.3 <u>Unresolved problems under investigation</u>

There are many aspects in shell and tube exchanger design that are open for further research. As mentioned previously increasing the heat transfer while decreasing the pressure drop is the primary objective of the heat exchanger design. Selection of a suitable geometrical configuration based on the number of tubes, tube diameter, fin shape, relative location of tubes, spacers, baffles and tie-rods, extent of baffle cuts and also appropriate material will greatly influence the optimum results. From a heat transfer point of view, there are only two types of flow for which calculations are possible namely laminar and turbulent but the critical region is not much amenable to analysis. As far as pressure drop is concerned there could be many other distinct possibilities which encompass critical region as well. Measuring a pressure drop along a heat exchanger is particularly more convenient than heat transfer coefficients. Therefore researchers are in the process of deriving relationship between the pressure drop and heat transfer coefficient which can be utilized to determine the latter from the measurement of the former.

Further, pressure drop calculations are normally done based on the fluid dynamic equations. However, experimental evidence indicates that actual values greatly deviate from the theoretical values obtained from such equations. This requires the development of empirical formulae based on research. [26][27]

Fouling of heat exchangers is another area that has not been fully investigated. Fouling mechanisms involved in some of the fluids are very complex and as a result prediction on fouling coefficients has been difficult. This will ultimately affect the value of overall heat transfer coefficient and then the precision of the design process. Usually the heat transfer coefficient with the least numerical value becomes the controlling resistance. Therefore, selection of individual heat transfer coefficients requires serious judgment. [28]

Moreover, most of the exchanger failures occur due to vibrations taking place in the exchanger tubes which are induced by non-steady separation of fluid flow when it passes the tubes. As the tubes are supported by baffles which are distant apart the magnitude of vibration is normally high. This is also one of the unexplored areas in heat exchanger studies. [29]

Heat exchangers are at times subjected to transient pressure loads in normal operation. Major failures such as high pressure pipe bursts can give rise to high amplitude , short duration pulse loads. For a shell and tube exchanger with a high pressure liquid on the tube side and a low pressure on a shell side, if a tube failure occurs the shell is subject to transient pressure waves. Research is underway to determine shell response over a range of pressure pulse amplitudes with varying duration with the aid of stress transducers as a shell failure under pressure pauses a major safety hazard.[30]

In developed countries such studies are usually carried out by either research and development units in a particular industry itself or else by universities with the industry sponsorship and the findings are applied in design and manufacturing for the economic advantage. Prior to concluding this project report it is pertinent to mention that research activities of engineers in the third world countries are very often hampered by lack of resources, especially finance. On the other hand a nation can not prosper industrially without scientific studies. Thus, it is another form of a vicious cycle which is hard to be severed.

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Appendix A

Thermodynamic data for heat exchanger design

Overall Heat Transfer Coefficients

Shell and tube exchangers

Hot fluid	Cold fluid	U ($W/m^2\,^0C$)
Heat exchangers		
Water	Water	800-1500
Organic solvents	Organic solvents	100-300
Light oils	Light oils	100-400
Heavy oils	Heavy oils	50-300
Gases	Gases	10-50
Coolers		
Organic solvents	Water	250-750
Light oils	Water	350-900
Heavy oils	Water	60-300
Gases	Water	20-300
Organic solvents	Brine	150-500
Water	Brine	600-1200
Gases	Brine	15-250

Heat Transfer Equipment

Hot fluid	Cold fluid	U ($W/m^2\,^0C$)
Heaters		
Steam	Water	1500-4000
Steam	Organic solvents	500-1000
Steam	Light oils	300-900
Steam	Heavy oils	60-450
Steam	Gases	30-300
Dowtherm	Heavy oils	50-300
Dowtherm	Gases	20-200
Flue gases	Steam	30-100
Flue	Hydrocarbon vapours	30-100
Condensers		
Aqueous vapours	Water	1000 -1500
Organic vapours	Water	700-1000
Organics (some non-condensables)	Water	500-700

Vacuum condensers	Water	200-500
Vaporisers		
Steam	Aqueous solutions	1000-1500
Steam	Light organics	900-1200
Steam	Heavy organics	600- 900

Air-cooled exchangers

Process fluid	U ($W/m^2 {}^0C$)
Water	300-450
Light organics	300-700
Heavy organics	50-150
Gases, 5-10 bar	50-100
10-30 bar	100-300
Condensing hydrocarbons	300-600

Immersed coils

Coil	Pool	
Natural circulation		
Steam	Dilute aqueous solutions	500-1000
Steam	Light oils	200-300
Steam	Heavy oils	70-150
Water	Aqueous solutions	200-500
Water	Light oils	100-150
Agitated		
Steam	Dilute aqueous solutions	800-1500
Steam	Light oils	300-500
Steam	Heavy oils	200-400
Water	Aqueous solutions	400-700
Water	Light oils	200-300

Jacketed vessels

Jacket	Vessel	
Steam	Dilute aqueous solutions	500-700
Steam	Light organics	250-500
Water	Dilute aqueous solutions	200-500
Water	Light organics	200-300

Fouling coefficients – typical values

Fluid	Coefficient (W/m^2 ^{0}C)
River water	3000-12000
Sea water	1000-3000
Cooling water (towers)	3000-6000
Towns water (soft)	3000-5000
Towns water (hard)	1000-2000
Steam condensate	1500-5000
Steam (oil free)	4000-10,000
Steam (oil traces)	2000-5000
Refrigerated brine	3000-5000
Air and industrial gases	5000-10,000
Flue gases	2000-5000
Organic vapours	5000
Organic liquids	5000
Light hydrocarbons	5000
Heavy hydrocarbons	2000
Boiling organics	2500
Condensing organics	5000
Heat transfer fluids	5000
Aqueous salt solutions	3000-5000

Specific heat capacities of some common substance (Cp)

Substance	Cp in kJ/kgC^0
Pure water	4.19
Dry air	1.01
Steam	2.01
Water vapour	1.88
Aluminum	0.92
Copper	0.39
Iron	0.48
Ice	2.09

Heat conductivity k of common material

Material	k in Watts/mC^0
Copper	378
Aluminum	212
Iron	50.5
Steel	44.6
Silver	412

Appendix B

Types of heat exchangers

Type of heat exchanger	Application	Thermal duty	Operating conditions	Effectiveness	Maintenance	Cost	Other important features
Shell and tube- Fixed tube sheet	Mainly for petroleum refining, chemical processing and power generation	High.	Moderate temperatures and high pressures.	Up to 80%	Less components and hence less maintenance. Tube external surface requires chemical cleaning. No internal gaskets.	Comparatively lower than other shell and tube exchangers	Thermal stresses caused by differential expansion must be considered in designing due to fixed tube sheet
Shell and tube- U tube	Mainly for petroleum refining, chemical processing and power generation	High	For fairly high temperatures and high pressures.	Up to 80%	Mechanical cleaning of tube interior is not possible. Cleaning of tube exterior with triangular pitch can be done chemically only	Higher than the fixed tube sheet exchanger	Differential thermal expansion is allowed with U tubes to a great extent.
Shell and tube- Floating head, pull through	Mainly for petroleum refining, chemical processing and power generation	Very high	For high temperatures up to 1100 ^{0}C and pressures up to 6000 psig.	Up to 80%	Cleaning of tube exterior with triangular pitch can be done chemically Only. With internal gaskets and more components and hence more maintenance	Expensive	Differential thermal expansion is facilitated with floating head
Shell and tube- Floating head with a backing ring	Mainly for petroleum refining, chemical processing and power generation	Very high	For high temperatures up to 1100 ^{0}C and pressures up to 6000 psig.	Up to 80%	Cleaning of tube exterior with triangular pitch can be done chemically only . With internal gaskets and more components and hence	Most expensive	Differential thermal expansion is facilitated with floating head

					more maintenance.		
Spiral heat exchanger	For cellulose industry in thermosyphon and kettle reboilers	Fairly high. For heavy thermal duty series or parallel arrangement of several units can be considered	Temperatures up to 500 ^{0}C and pressures up to 150 psig	Less than plate exchangers but can be improved with corrugation	Less fouling due to turbulence. Easy inspection, maintenance and cleaning. Field repairs are difficult.	Less expensive compared with shell and tube exchangers	Occupies a large area due to spiral turns
Plate heat exchanger	Dairy, food and pharmaceutical industries, synthetic rubber plants and paper mills	Fairly high particularly with single stacking	Temperatures up to 275 ^{0}C and pressures up to 300 psig	Very high up to 95%	Can be taken apart easily and hence inspection, maintenance and cleaning are facilitated. Less fouling	Less expensive compared with shell and tube exchangers	Can be stacked in several ways for high performance or low pressure drop
Air cooled heat exchanger	For petroleum refining, chemical processing when water is scarce and ambient temperature is fairly constant. Also, in engine jacket cooling, lub oil cooling, compressor discharge gas cooling and reactor cooling	High, but limited by ambient air temperature	Temperatures up to 360 ^{0}C and high pressures	High with finned tubes. In improved designs up to 90%	Mechanical cleaning is possible on both inside and outside surfaces	Rather high due to accessories such as fans, driving mechanism etc, but less than shell and tube exchangers	Electricity prices must be considered when selecting. Favoured by designers over water cooling

Appendix C

Nomenclature

Q, q	-	Heat transferred per unit time
U_0	-	Overall heat transfer Coefficient
A	-	Surface area
T, t, θ	-	Temperature
ΔT	-	Mean temperature difference
h_0	-	Outside convective coefficient
h_{0d}	-	Outside fouling coefficient
hi	-	Inside convective coefficient
h_{id}	-	Inside fouling coefficient
d_o	-	External diameter of tubes
di	-	Internal diameter of tubes
k_w	-	Thermal conductivity of tube walls
k	-	Thermal conductivity of fluid
Nu	-	Nusselt number
$\overline{Nu}$	-	Average Nusselt number
h	-	Heat transfer coefficient
$\overline{h}$	-	Average heat transfer coefficient
Re	-	Reynolds number
Pr	-	Prandtl number
μ	-	Absolute viscosity
μ_w	-	Viscosity of fluid at surface temperature

c_p, c	-	Specific heat at constant pressure
D	-	Diameter of the flow passage
ΔT_{lm}	-	Log mean temperature difference
f	-	Friction factor
P	-	Pressure
ΔP	-	Pressure drop
A_x, s	-	Flow cross section area
D_e	-	Equivalent diameter
e	-	Surface roughness
m, M	-	Mass flow rate
G	-	Mass velocity
g	-	Gravitational acceleration
L, l	-	Length
N, n	-	Number of tubes
v	-	Velocity
ρ	-	Density
a_s	-	Bundle cross flow area
Gr_a	-	Grashof number
β	-	Coefficient of thermal expansion of fluids
η	-	Fin efficiency
e_o	-	Overall surface efficiency
h_f	-	Heat transfer coefficient of finned surface
h_u	-	Heat transfer coefficient of unfinned surface

A_f	-	Surface area of finned surface
A_u	-	Surface area of unfinned surface
A_r	.	Surface area of both finned and unfinned surfaces
A_w	-	Total primary wall area
A_c	-	Area of the cold side
A_h	-	Area of the hot side
f_i	.	Friction factor for flow across an ideal tube bank
M_s	-	Mass flow rate of shell side fluid
N_c	-	Number of tube rows crossed during flow through one cross flow section
N_{cw}	-	Number of effective cross flow rows in each window section
N_b	-	Number of baffles in exchanger
ρ_s	-	Density of shell side fluid
S_m	-	Cross flow area at or near centerline for one cross flow section
S_w	-	Area for flow through window
p_t	-	Tube pitch
D_{ew}	-	Equivalent diameter of the window
R_b	-	Correction factor for effect of bundle bypass on pressure drop
R_l	-	Correction factor for effect of baffle leakage on pressure drop
R_s	-	Correction factor for effect of unequal baffle spacing on inlet and exit sections on pressure drop
P_d	.	Pressure due to differential thermal expansion
P_{Bt}	-	Equivalent bolting pressure when tube pressure is acting
P_{Bs}	-	Equivalent bolting pressure when tube pressure is not acting
P_t	-	Hydrostatic design pressure – Tube side

P_s	-	Hydrostatic design pressure – Shell side
w	-	Tube sheet thickness
σ	-	Allowable working stress
F	-	Thickness multiplier
z	-	Mean diameter of gasket at stationary tube sheet
i	-	Perimeter of tube layout
ρ'	-	Tube spacing
Y	-	Elastic modulus
$\bar{\alpha}$	-	Thermal expansion coefficient of metal
Z_1	-	Total moment acting upon the extension under operating conditions
Z_2	-	Total moment acting under bolting up conditions
D_{si}	-	Inside diameter of shell
D_j	-	Expansion joint bellow inside diameter
D_{el}	-	Equivalent diameter of the tube center limit perimeter
x	-	Effective channel cover thickness
d_s	-	Nominal bolt diameter
h_g	-	Radial distance between mean gasket diameter and bolt circle
A_s	-	Bolt cross sectional area
σ_s	-	Shell longitudinal stress
σ_t	-	Tube longitudinal stress
C	-	Heat capacity
R	-	Capacity ratio
E, ε	-	Effectiveness

NTU	-	Number of transfer units
W	-	Volumetric flow rate
α	-	Thermal diffusivity
ν	-	Kinematic viscosity
F_t	-	Correction factor for LMTD

* Symbols are listed on the order of appearance in the report.

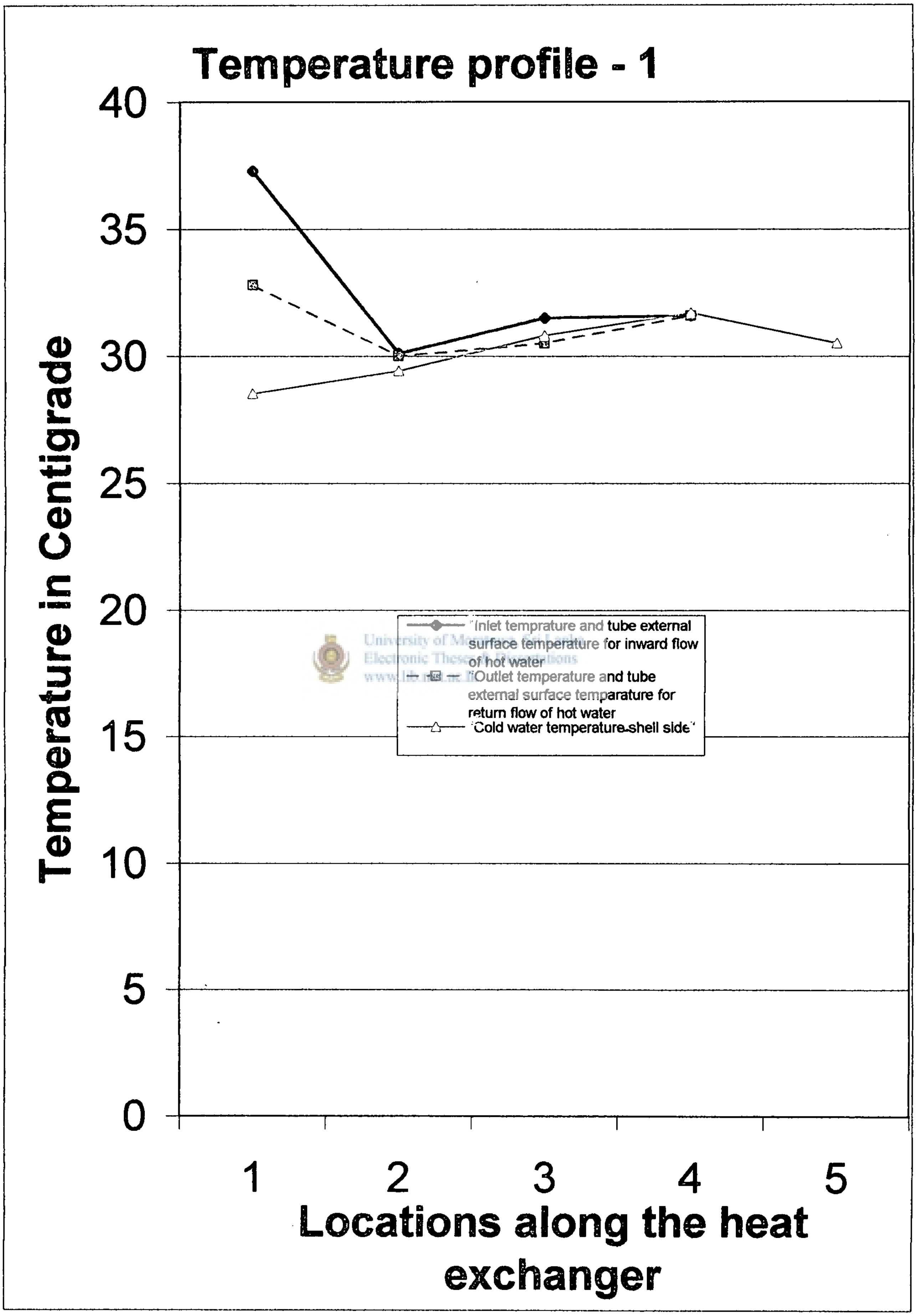
Appendix D

Measured Temperature profiles

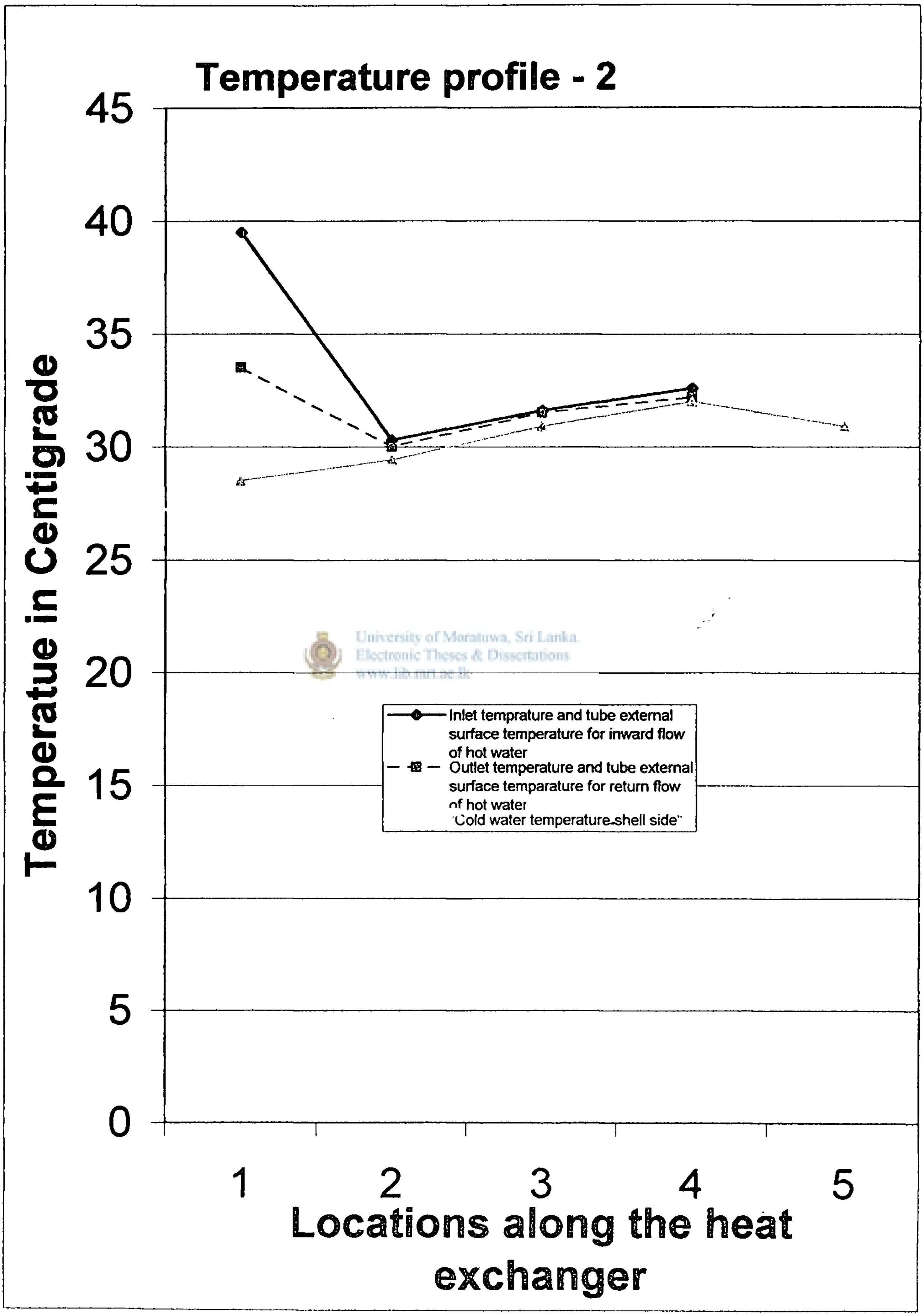
Series 1 - Inlet temperature and tube external surface temperature for inward flow of hot water

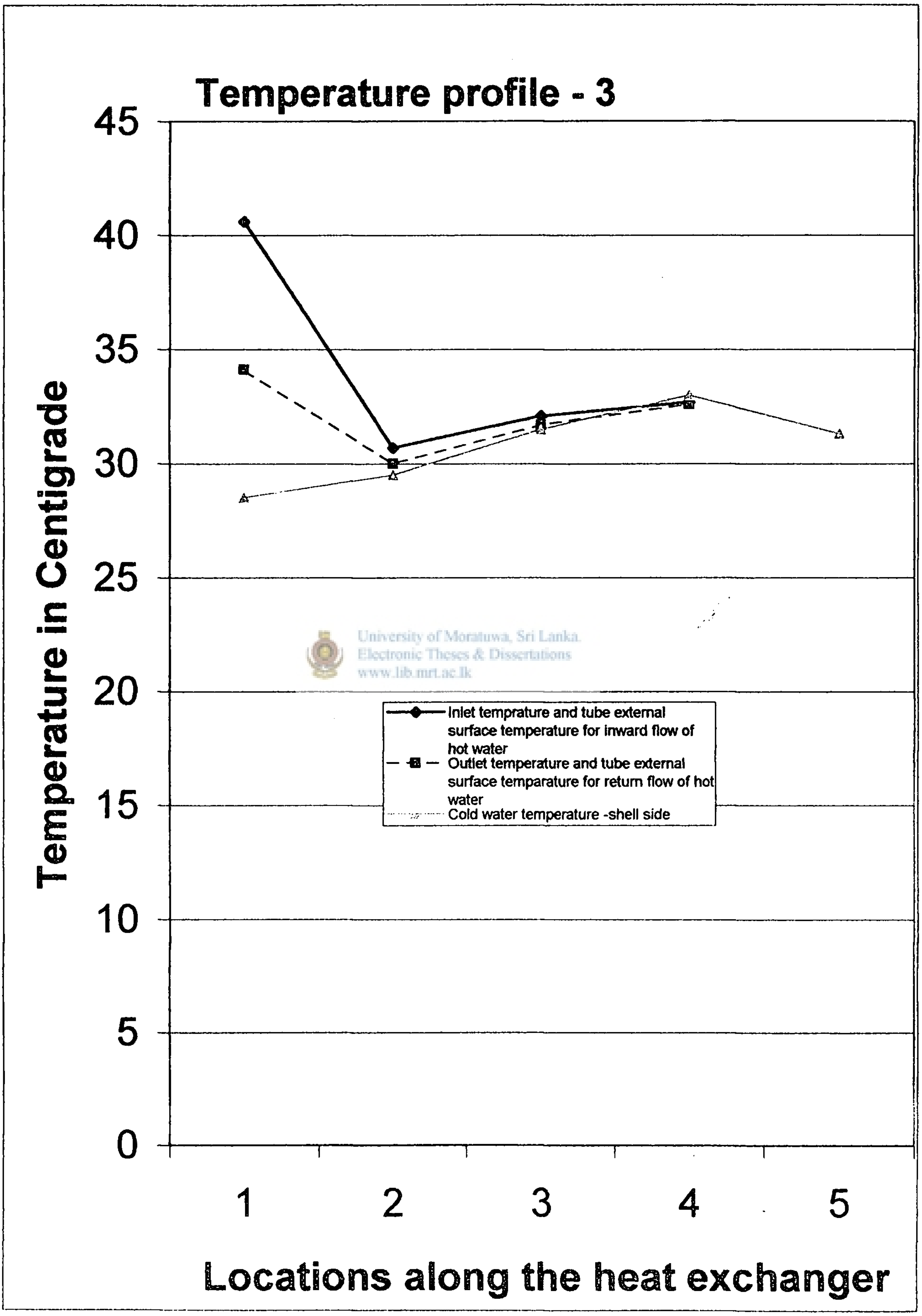
Series 2 - Outlet temperature and tube external surface temperature for return flow of hot water

Series 3 - Cold water temperature on shell side

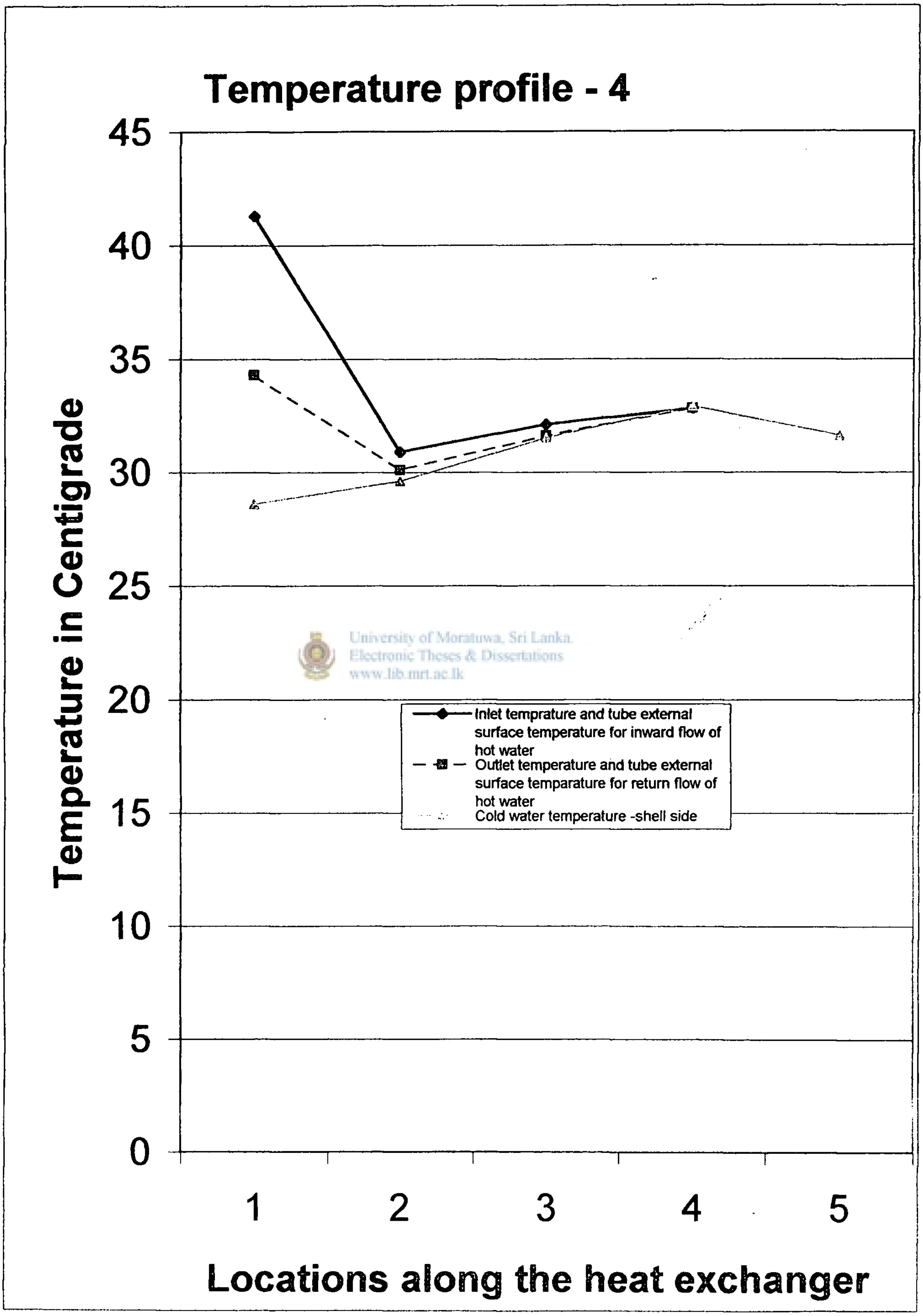


Temperature profile - 1
40
35
30
25
20
15
10
5
0
Temperature in Centigrade
"Inlet temprature and tube external surface temperature for inward flow of hot water"
"Outlet temperature and tube external surface temparature for return flow of hot water"
"Cold water temperature-shell side"
1
2
3
4
5
Locations along the heat exchanger

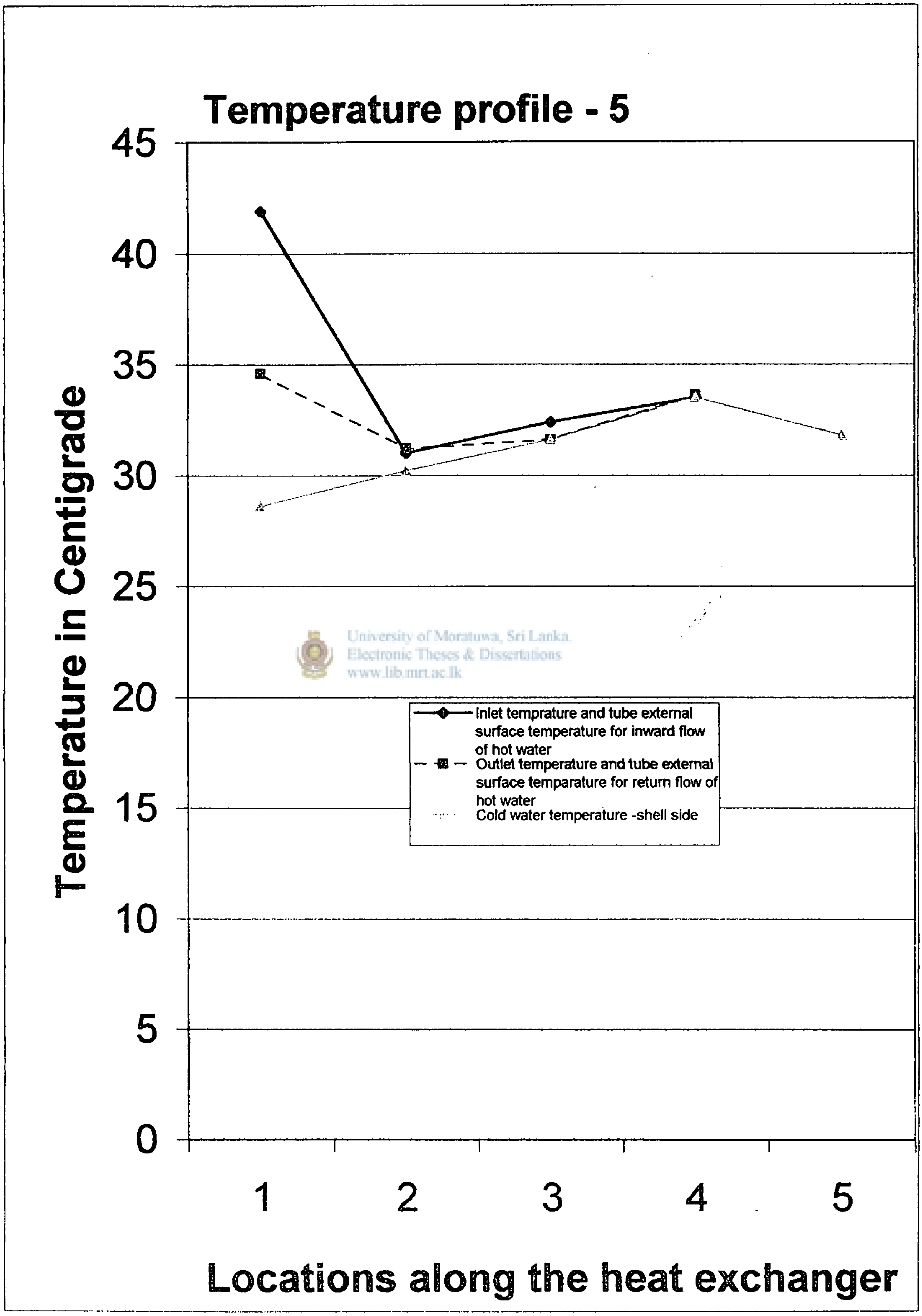

Temperature profile - 2
45
40
35
30
25
20
15
10
5
0
Temperatue in Centigrade
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature shell side

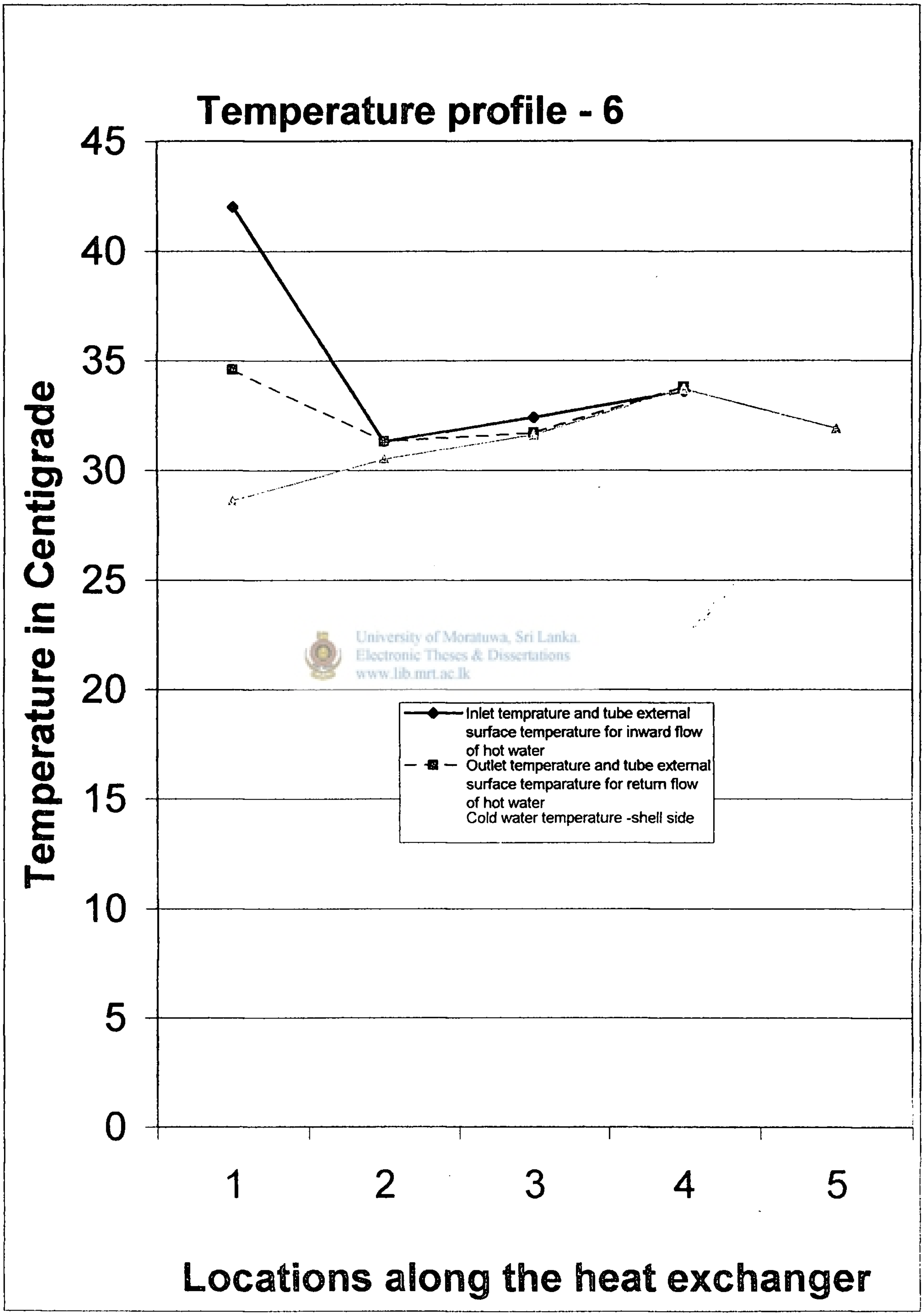


Temperature profile - 3
45
40
35
30
25
20
15
10
5
0
Temperature in Centigrade
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side

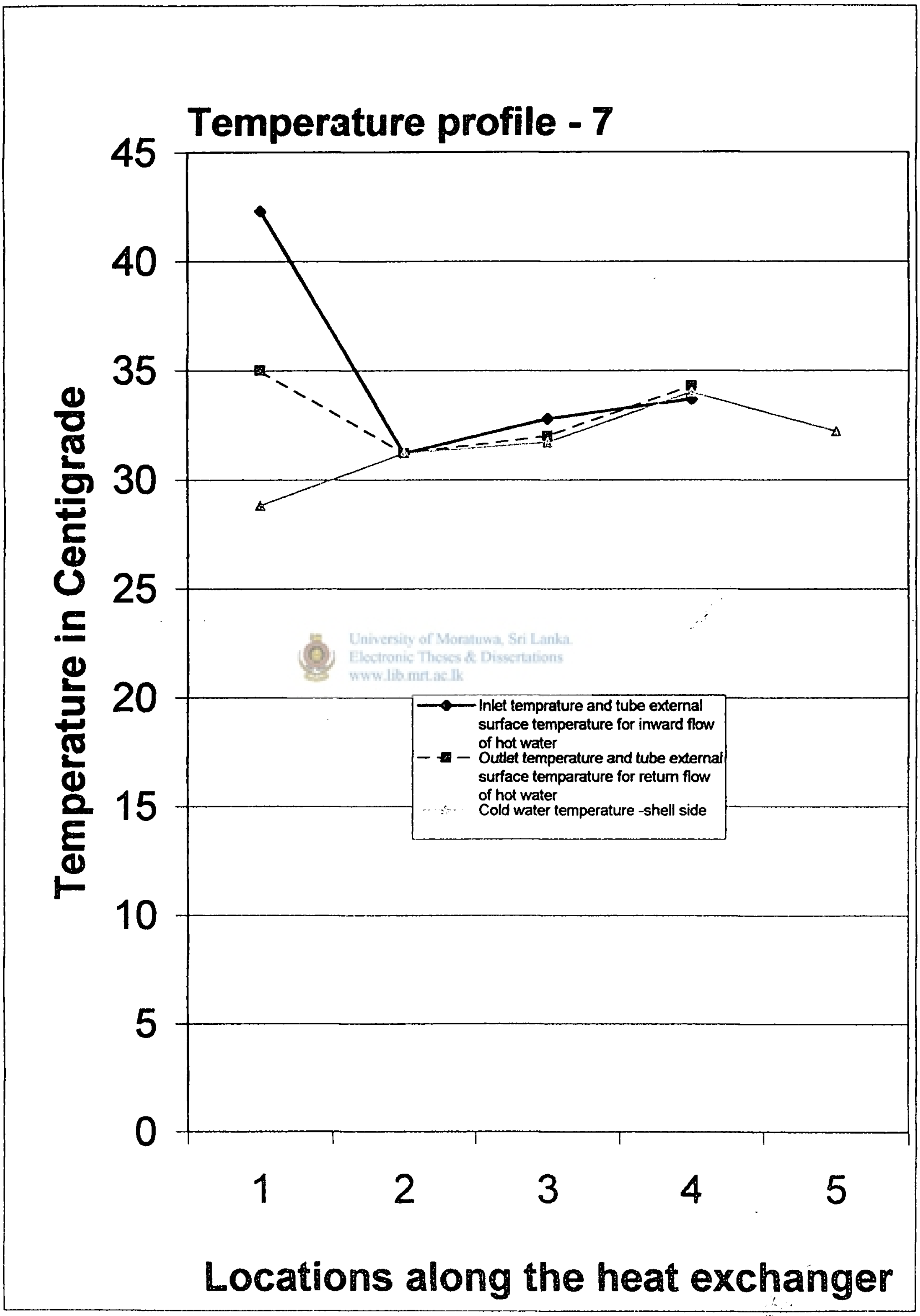


Temperature profile - 4
45
40
35
30
25
20
15
10
5
0
Temperature in Centigrade
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side

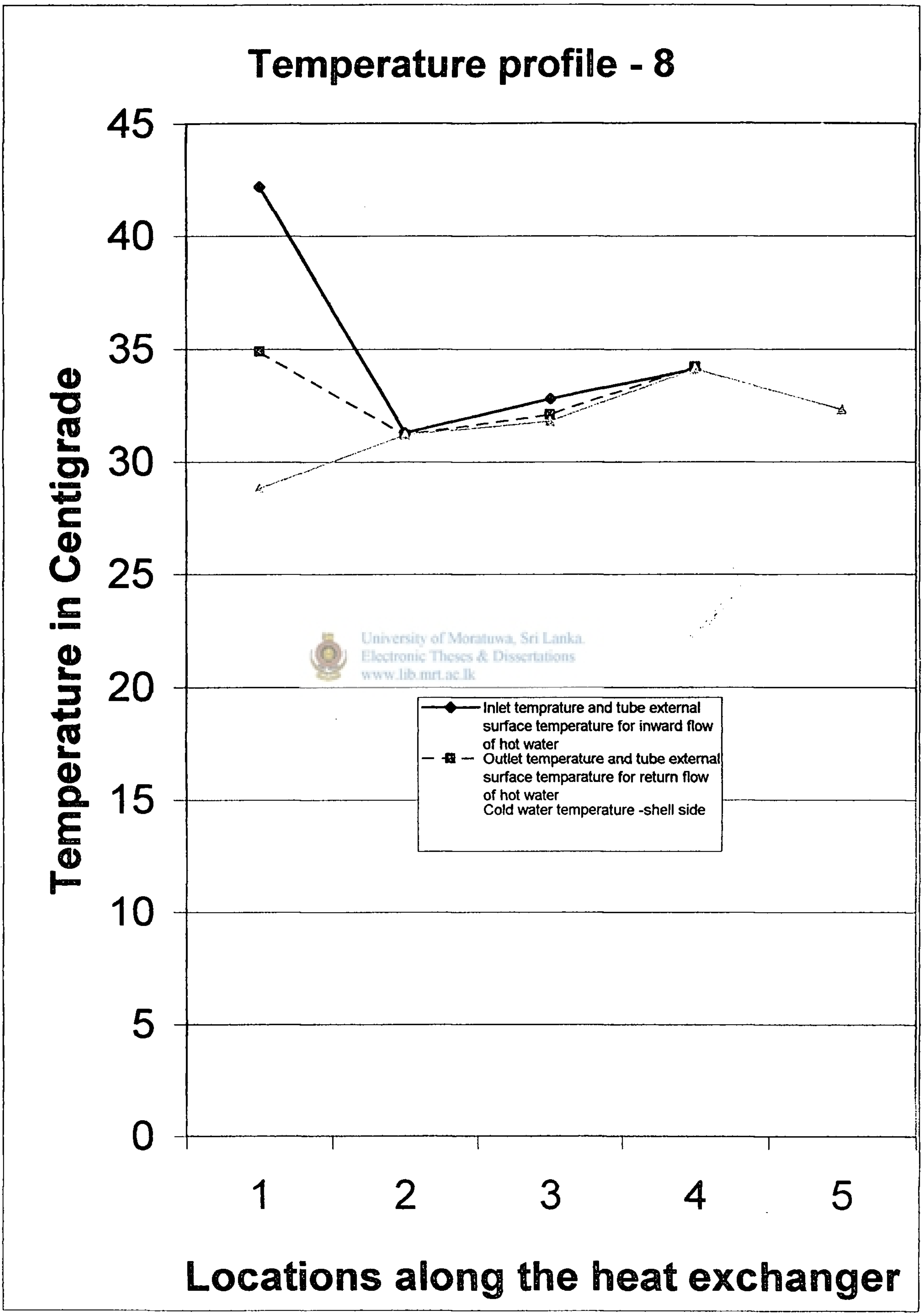

Temperature profile - 5
45
40
35
30
25
20
15
10
5
0
Temperature in Centigrade
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side
1
2
3
4
5
Locations along the heat exchanger



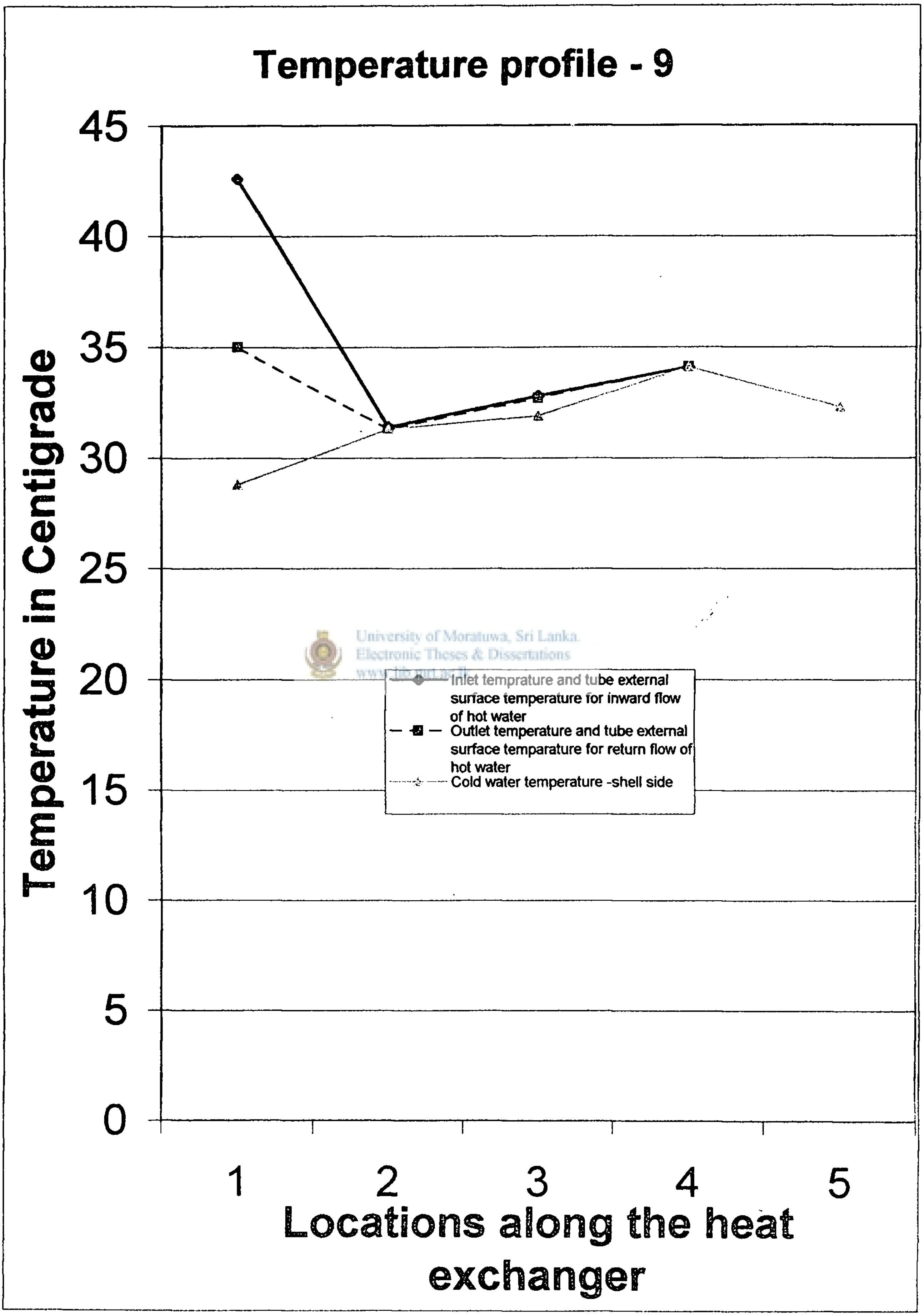
Temperature profile - 6
45
40
35
30
25
20
15
10
5
0
Temperature in Centigrade
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side



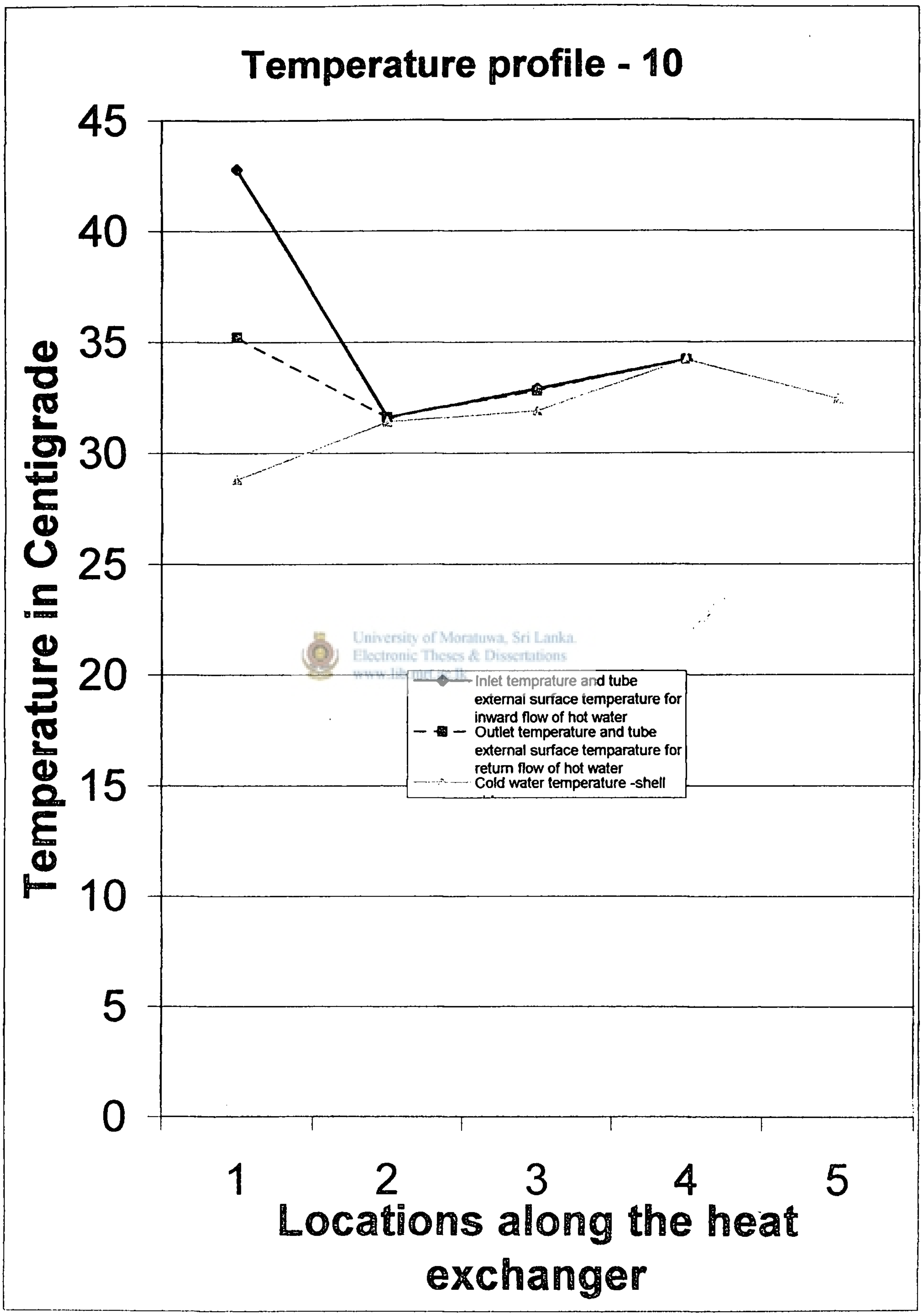
Temperature profile - 7
Temperature in Centigrade
45
40
35
30
25
20
15
10
5
0
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side



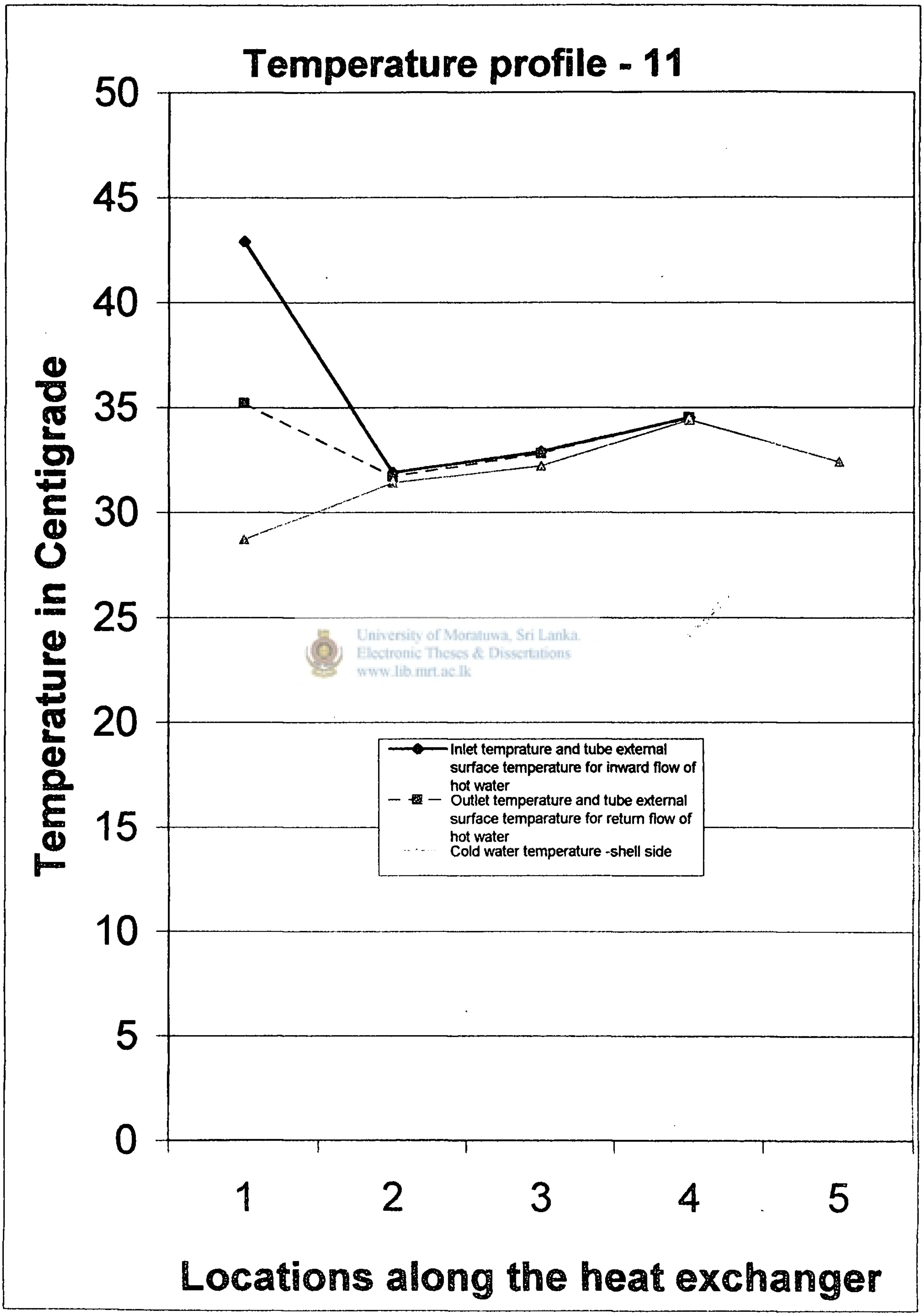
Temperature profile - 8
Temperature in Centigrade
45
40
35
30
25
20
15
10
5
0
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side



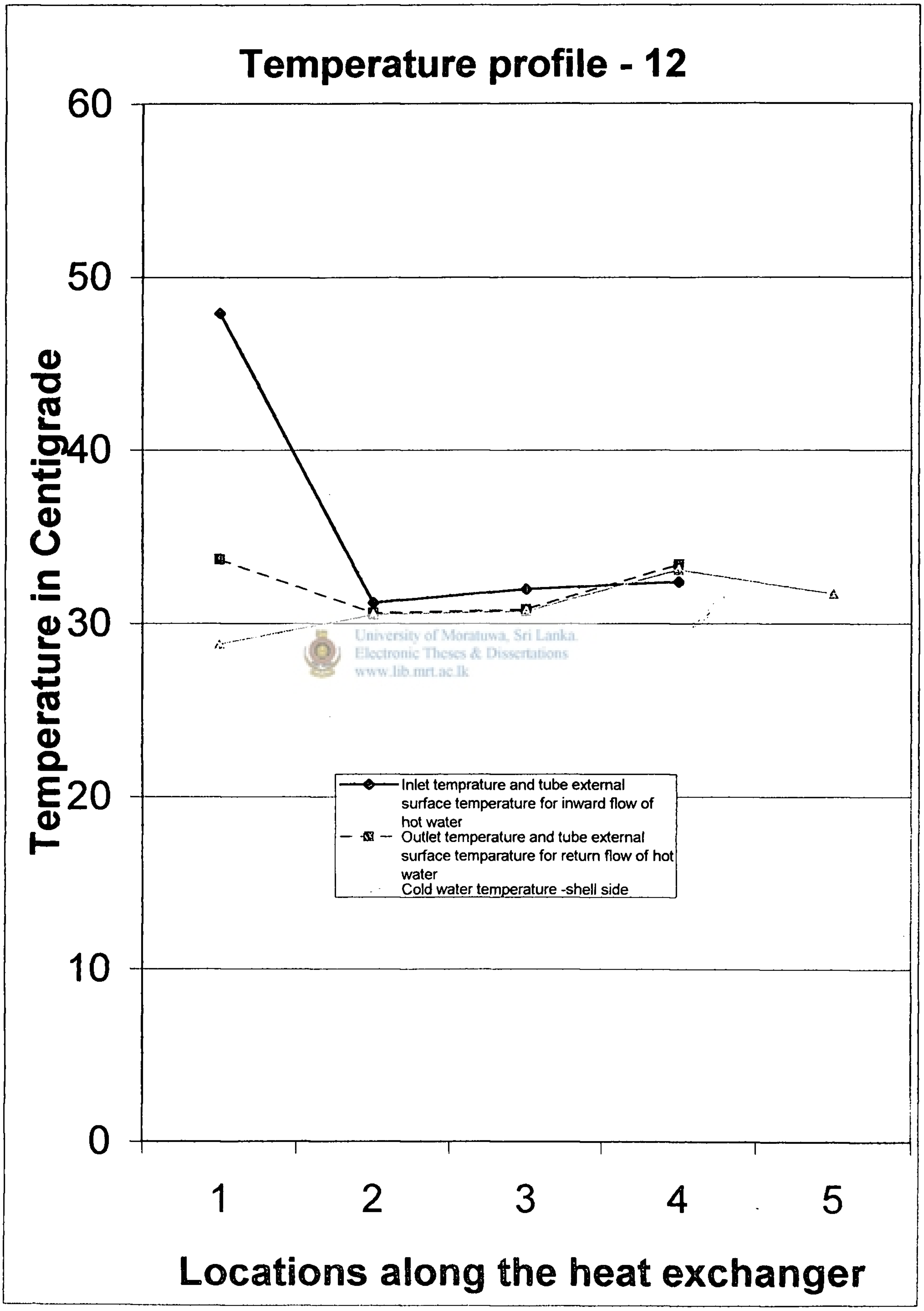
Temperature profile - 9
45
40
35
30
25
20
15
10
5
0
Temperature in Centigrade
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side



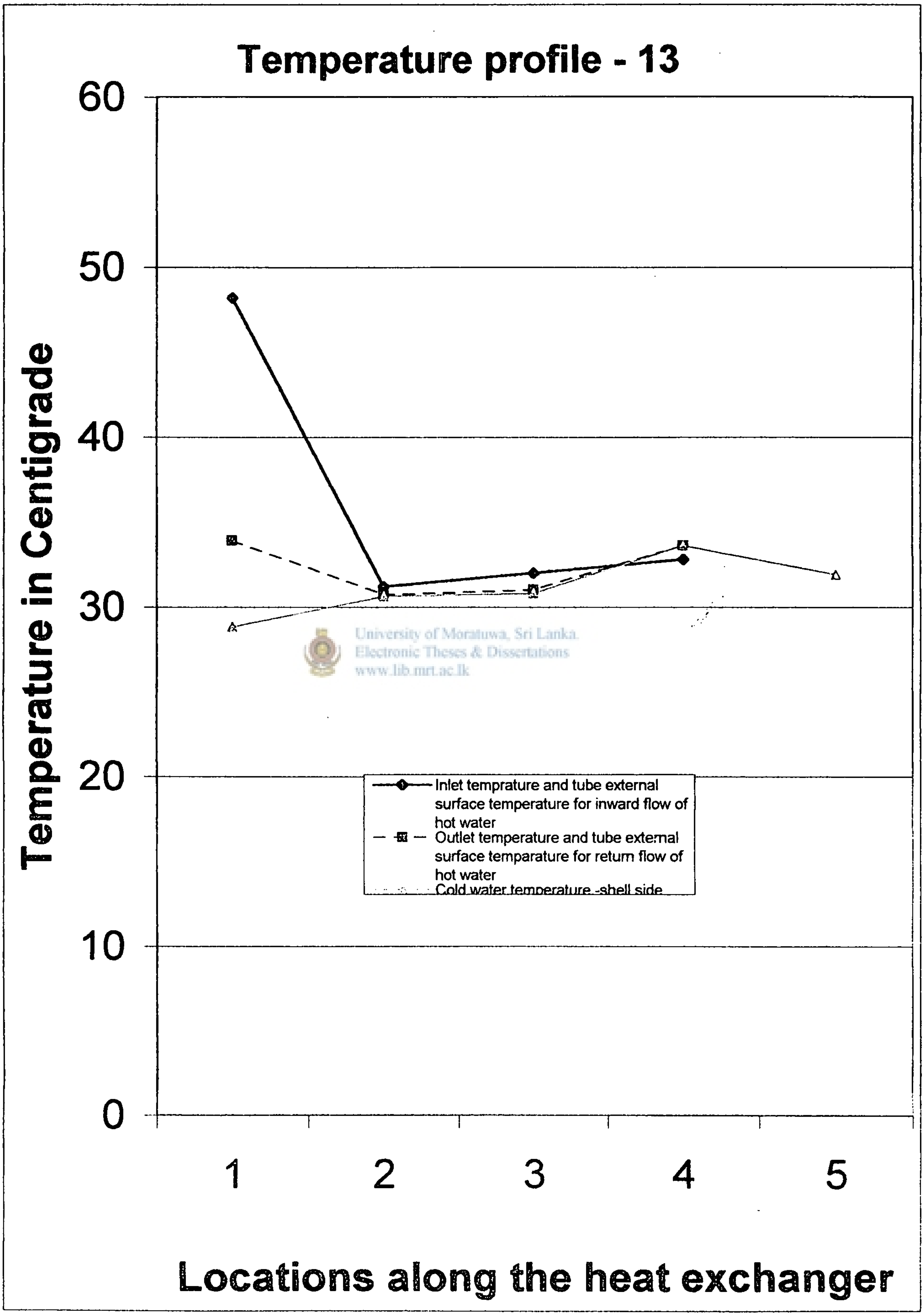
Temperature profile - 10
Temperature in Centigrade
45
40
35
30
25
20
15
10
5
0
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell



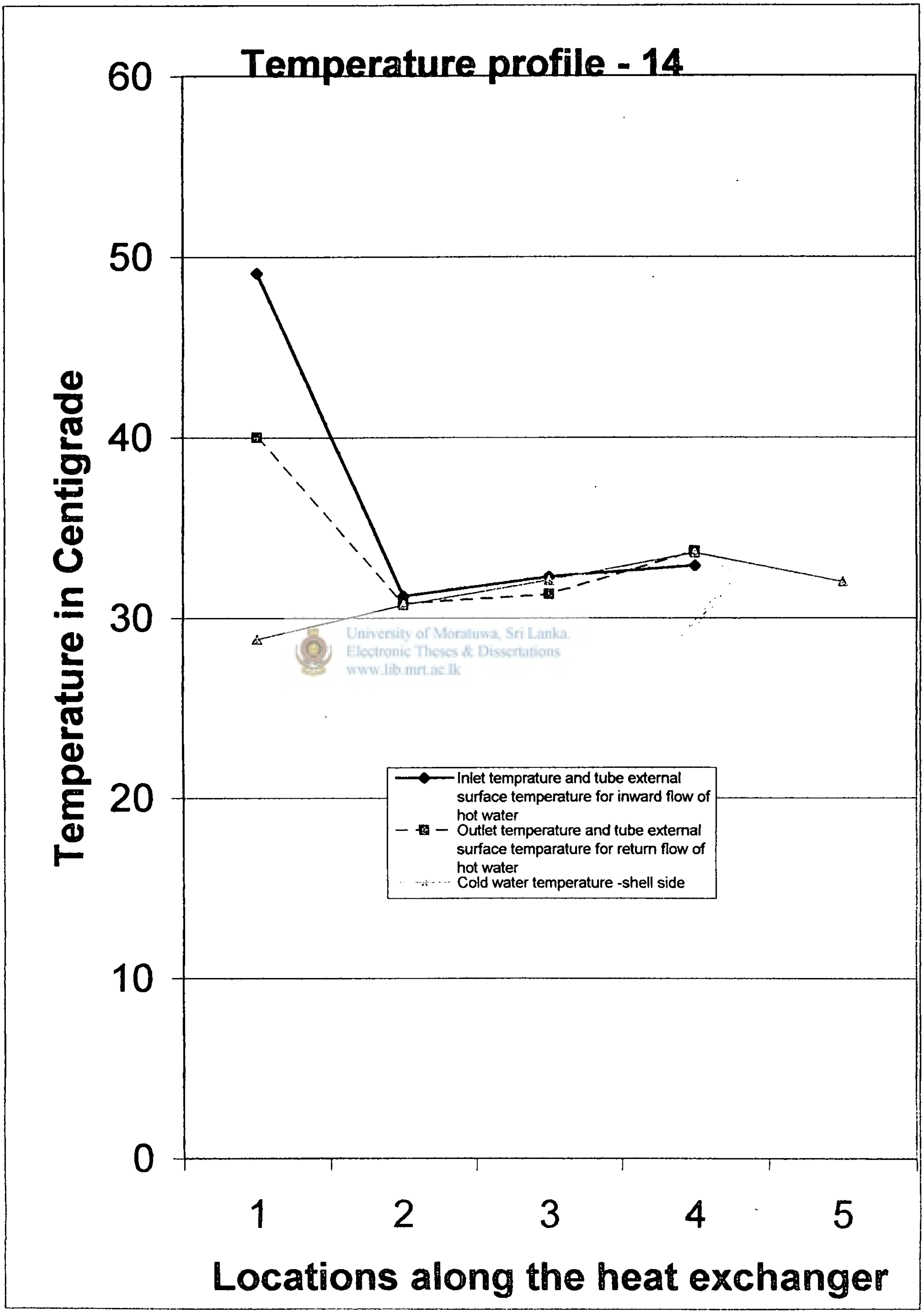
Temperature profile - 11
Temperature in Centigrade
50
45
40
35
30
25
20
15
10
5
0
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side



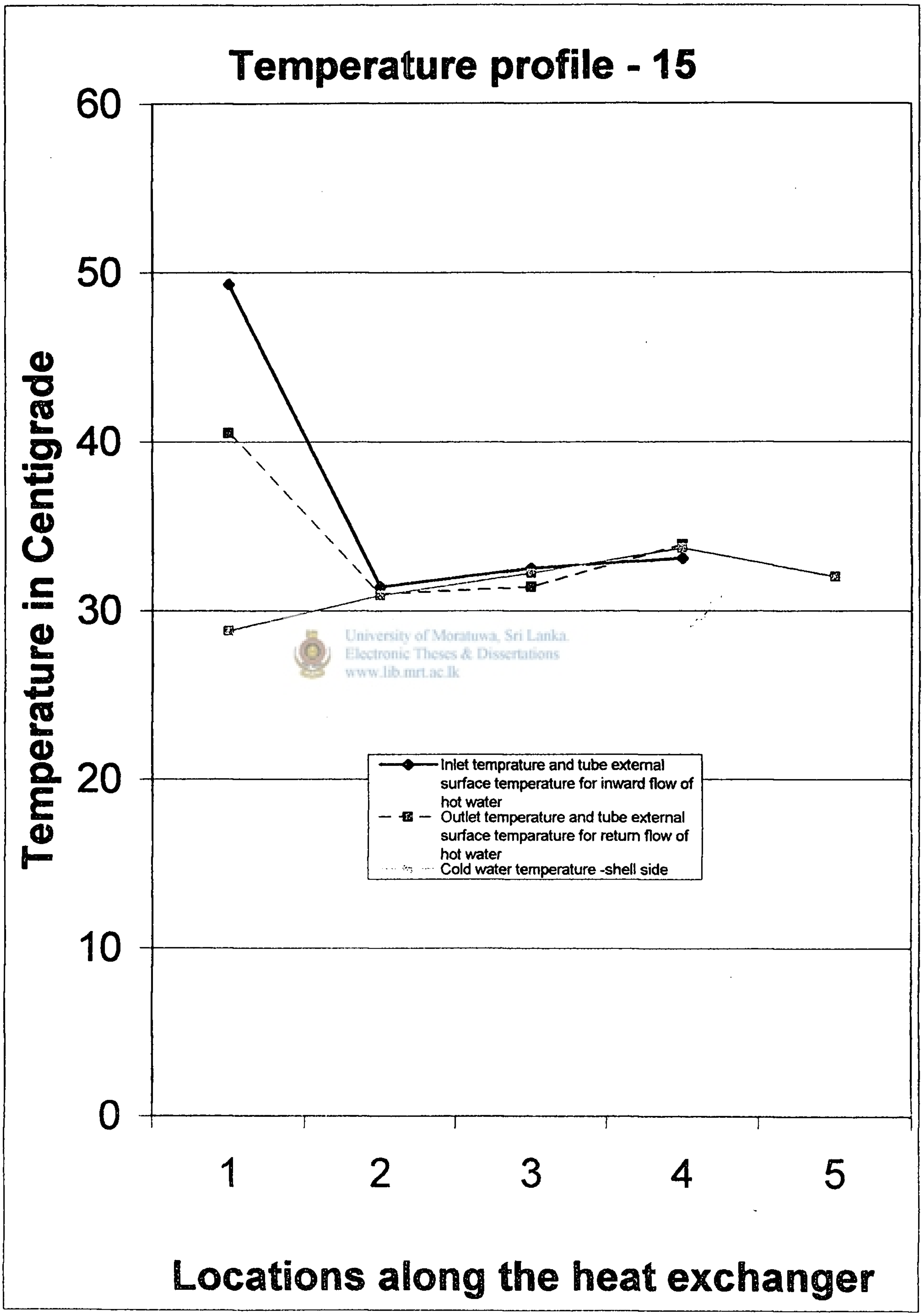
Temperature profile - 12
Temperature in Centigrade
60
50
40
30
20
10
0
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side



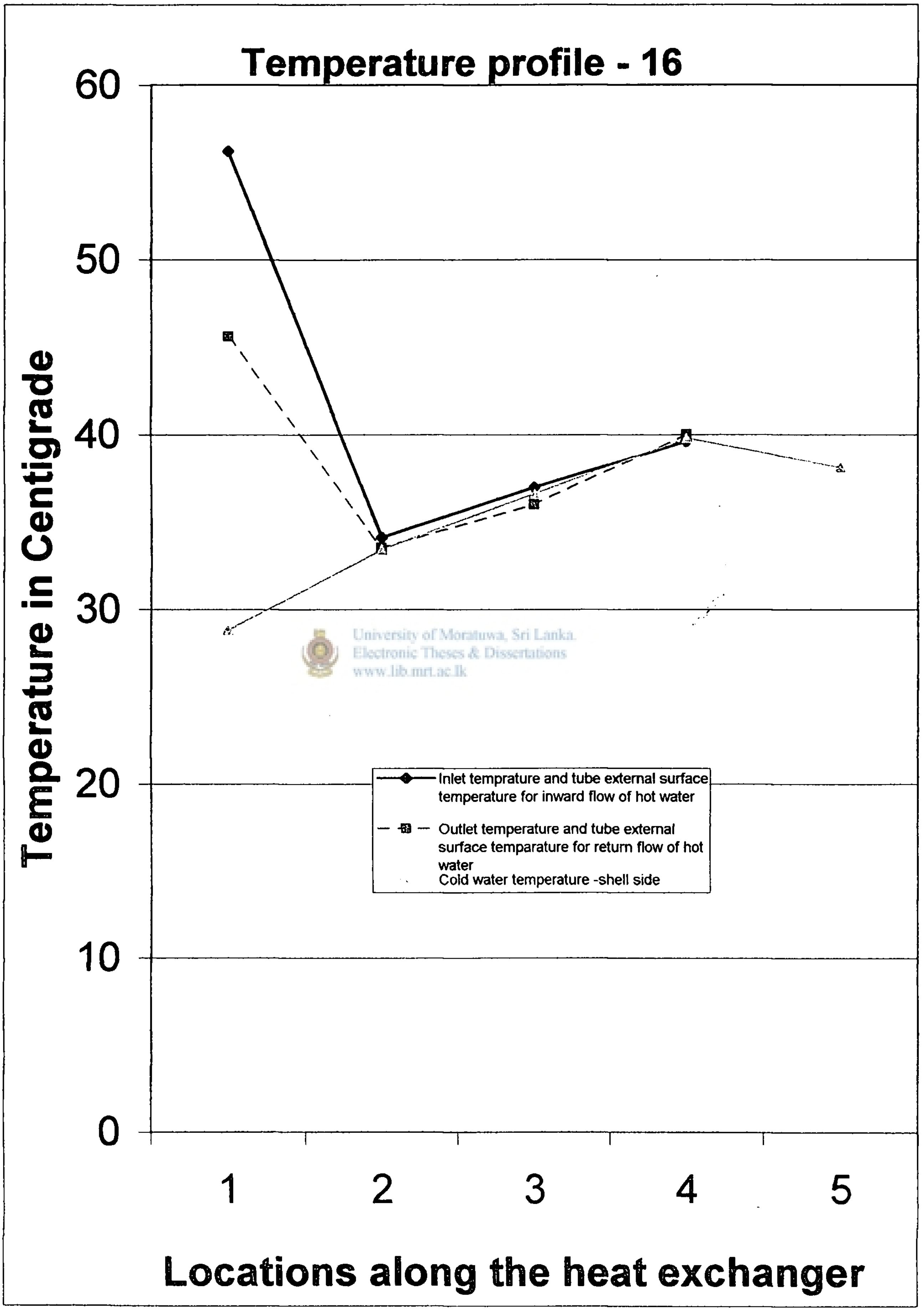
Temperature profile - 13
Temperature in Centigrade
60
50
40
30
20
10
0
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side



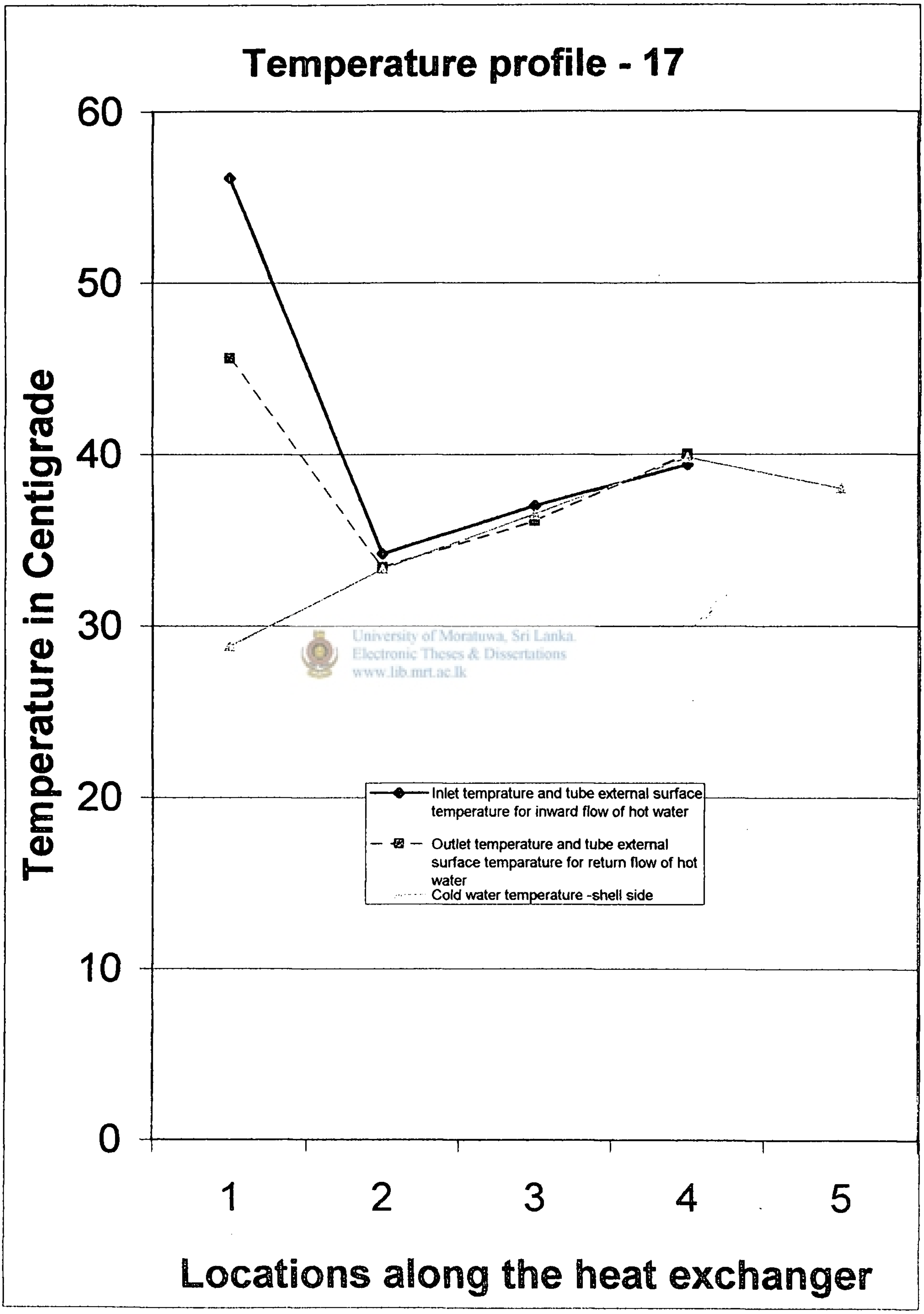
Temperature profile - 14
60
50
40
30
20
10
0
Temperature in Centigrade
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side

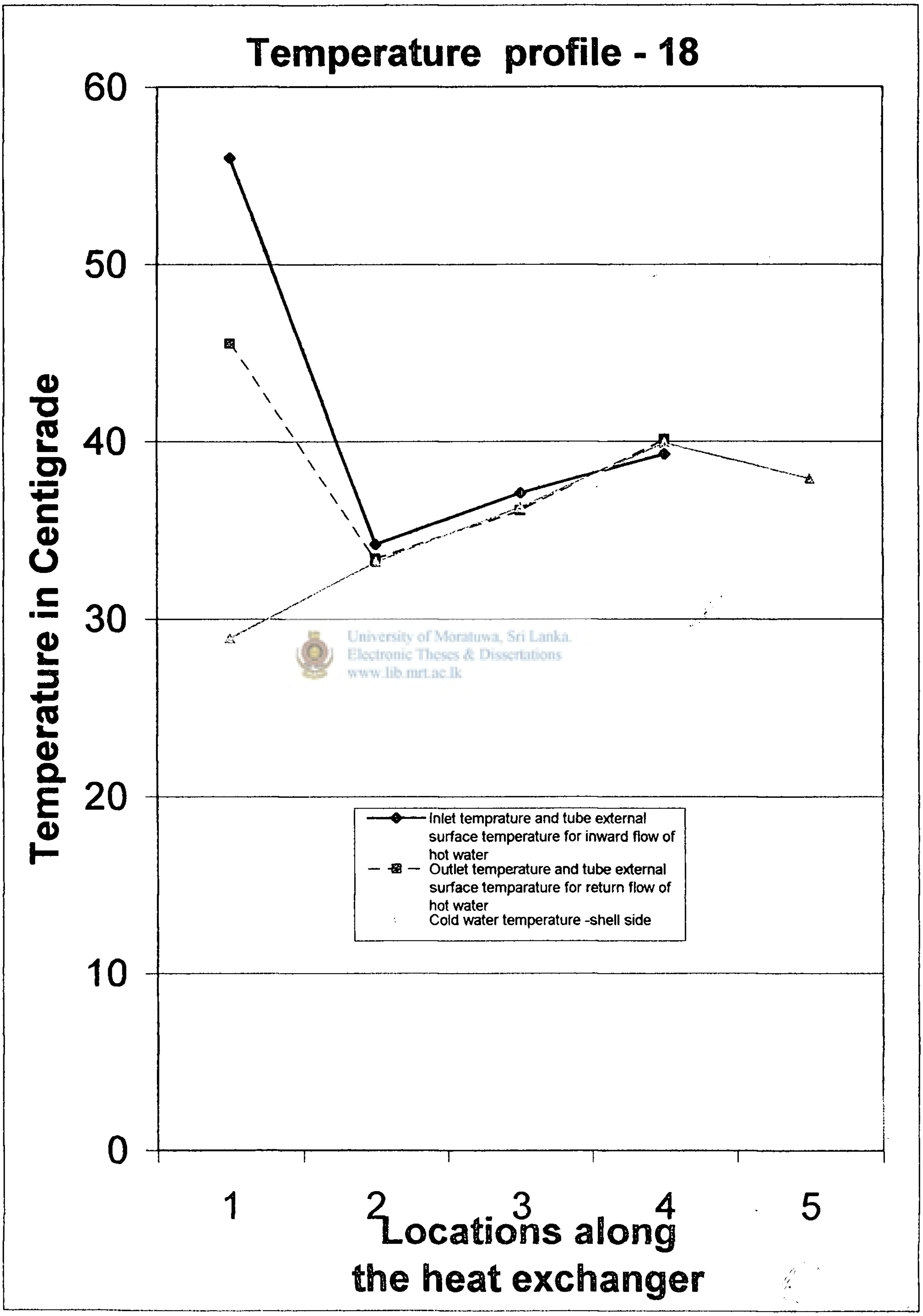


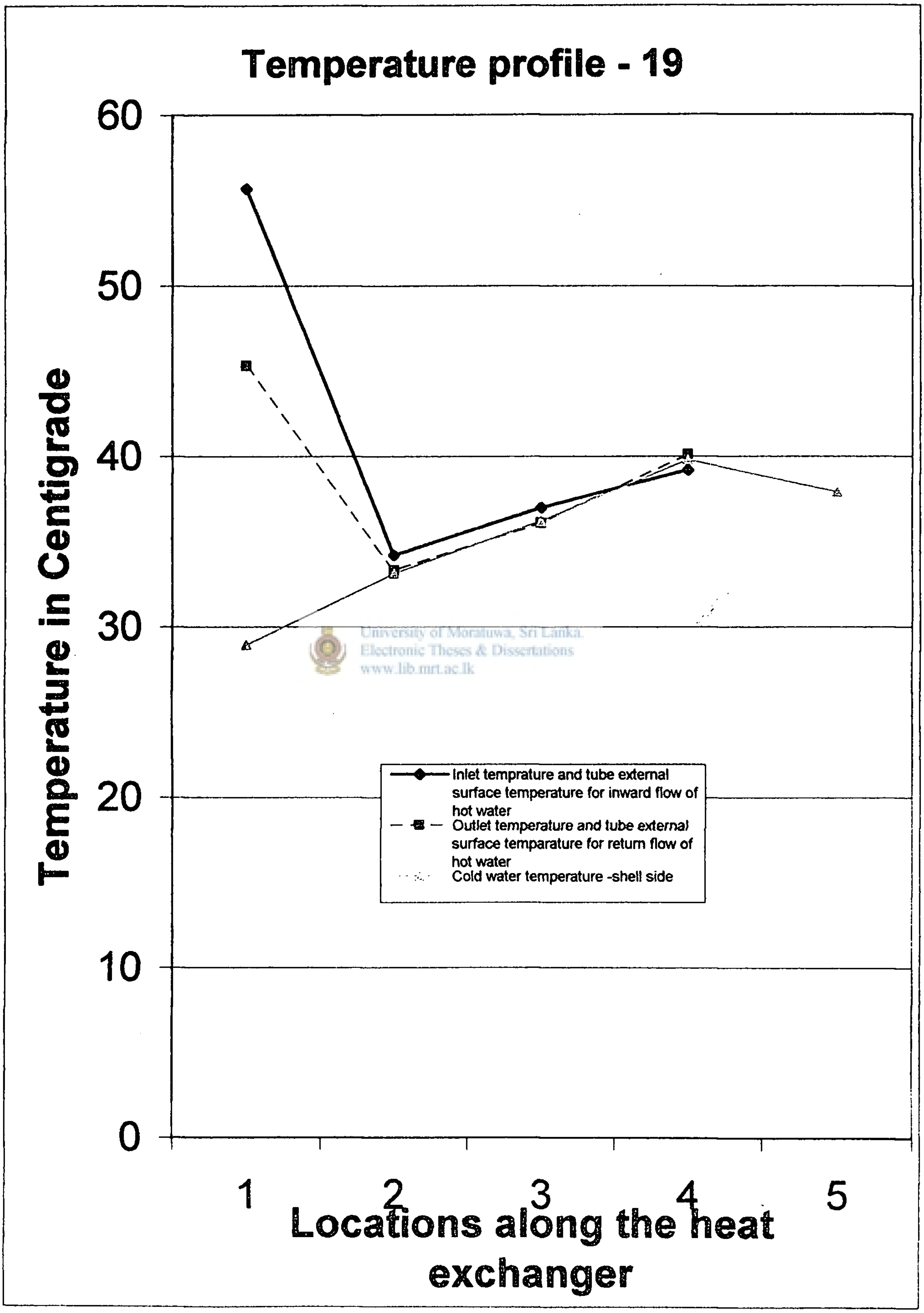
Temperature profile - 15
Temperature in Centigrade
60
50
40
30
20
10
0
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side



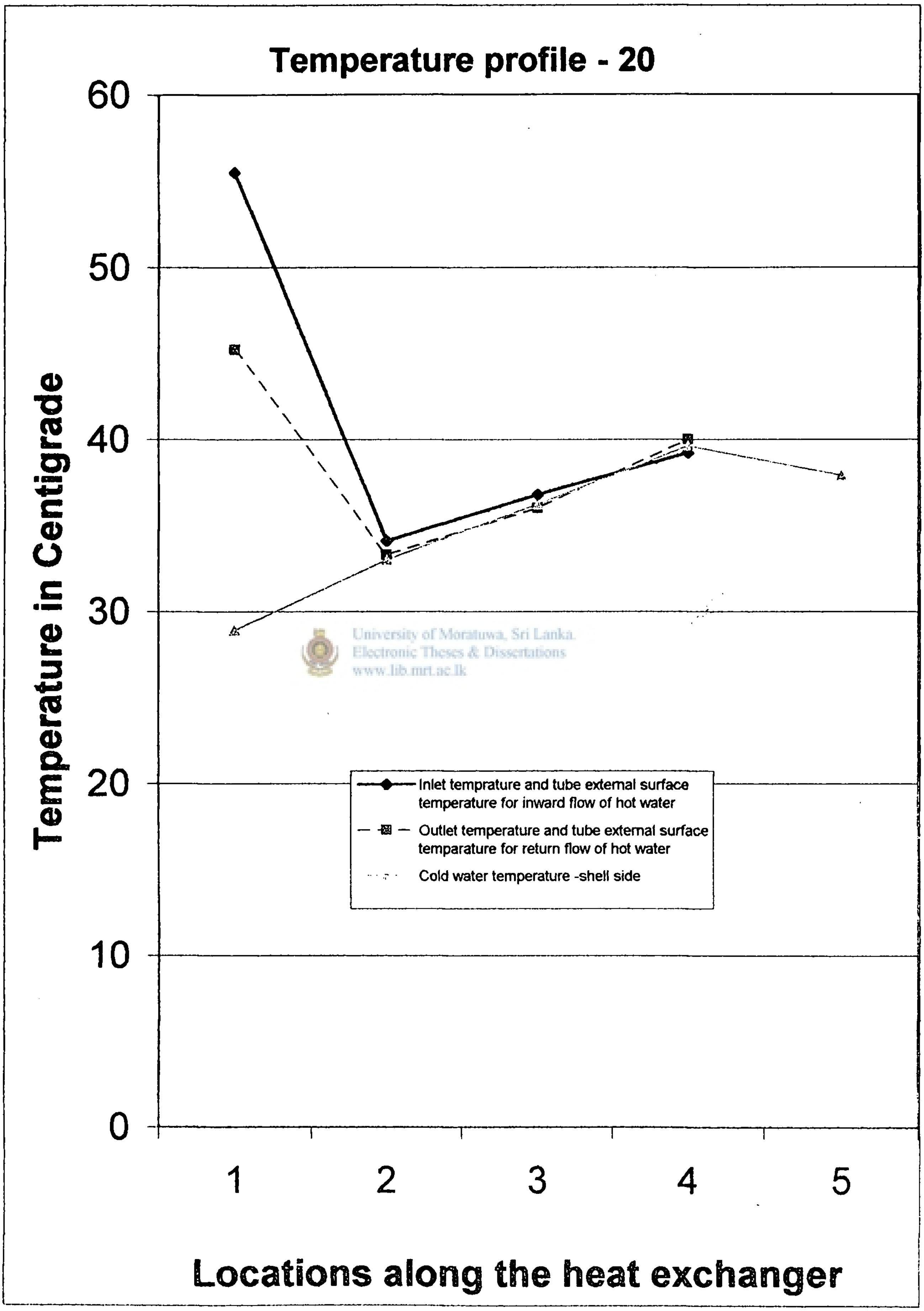
Temperature profile - 16
60
50
40
30
20
10
0
Temperature in Centigrade
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side

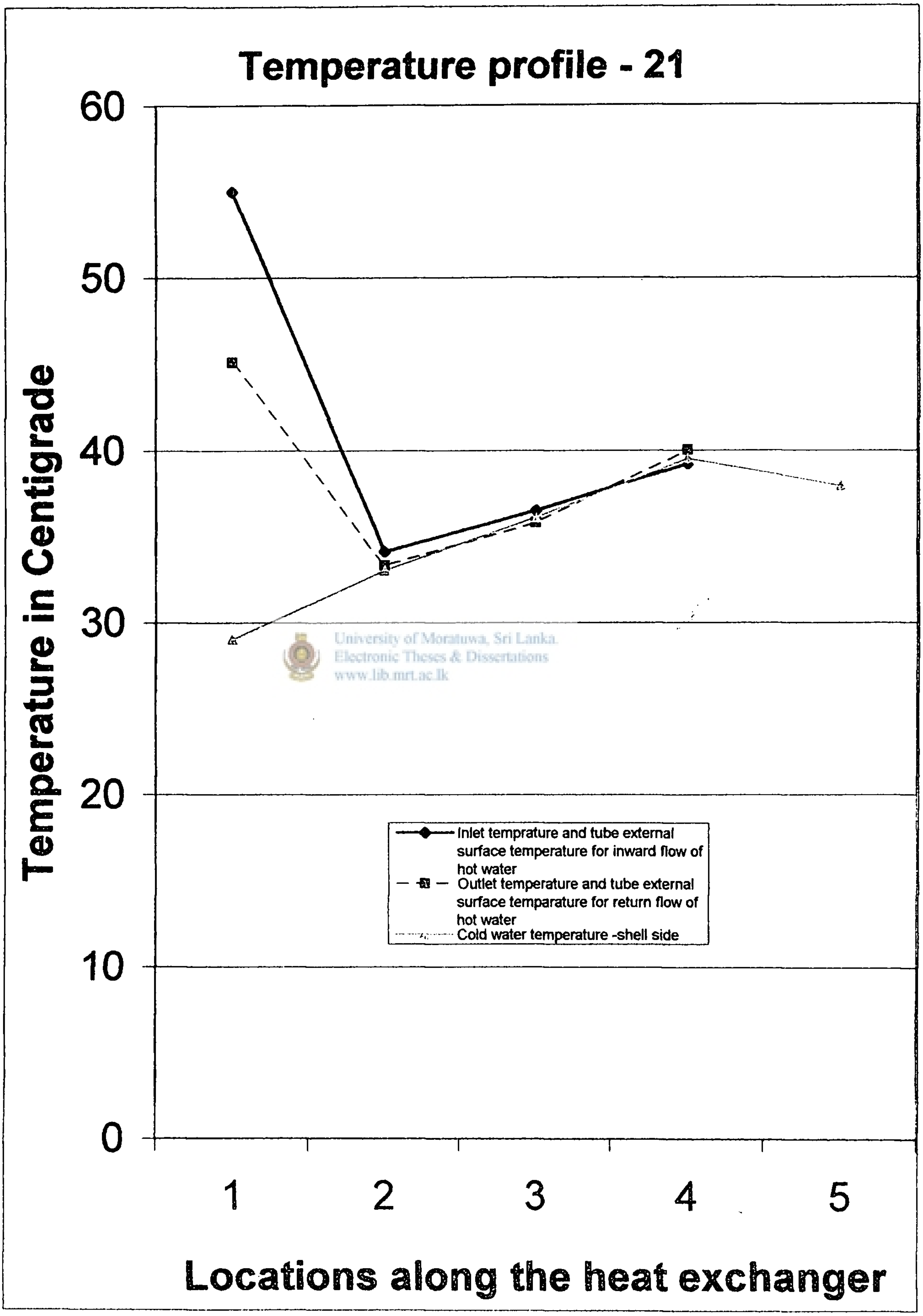

Temperature profile - 17
Temperature in Centigrade
60
50
40
30
20
10
0
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side


Temperature profile - 18
60
50
40
30
20
10
0
Temperature in Centigrade
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface tempatarure for return flow of hot water
Cold water temperature -shell side

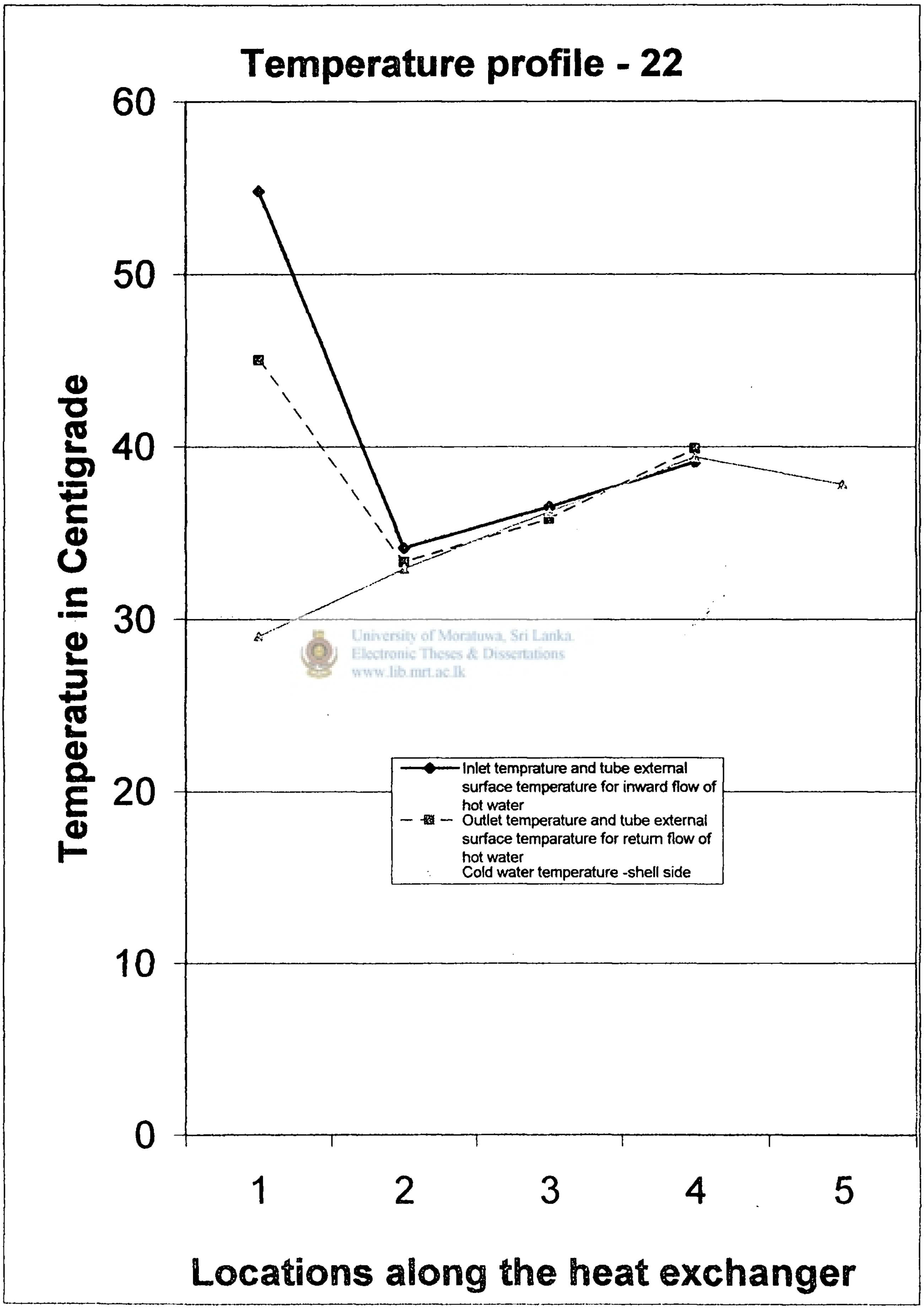


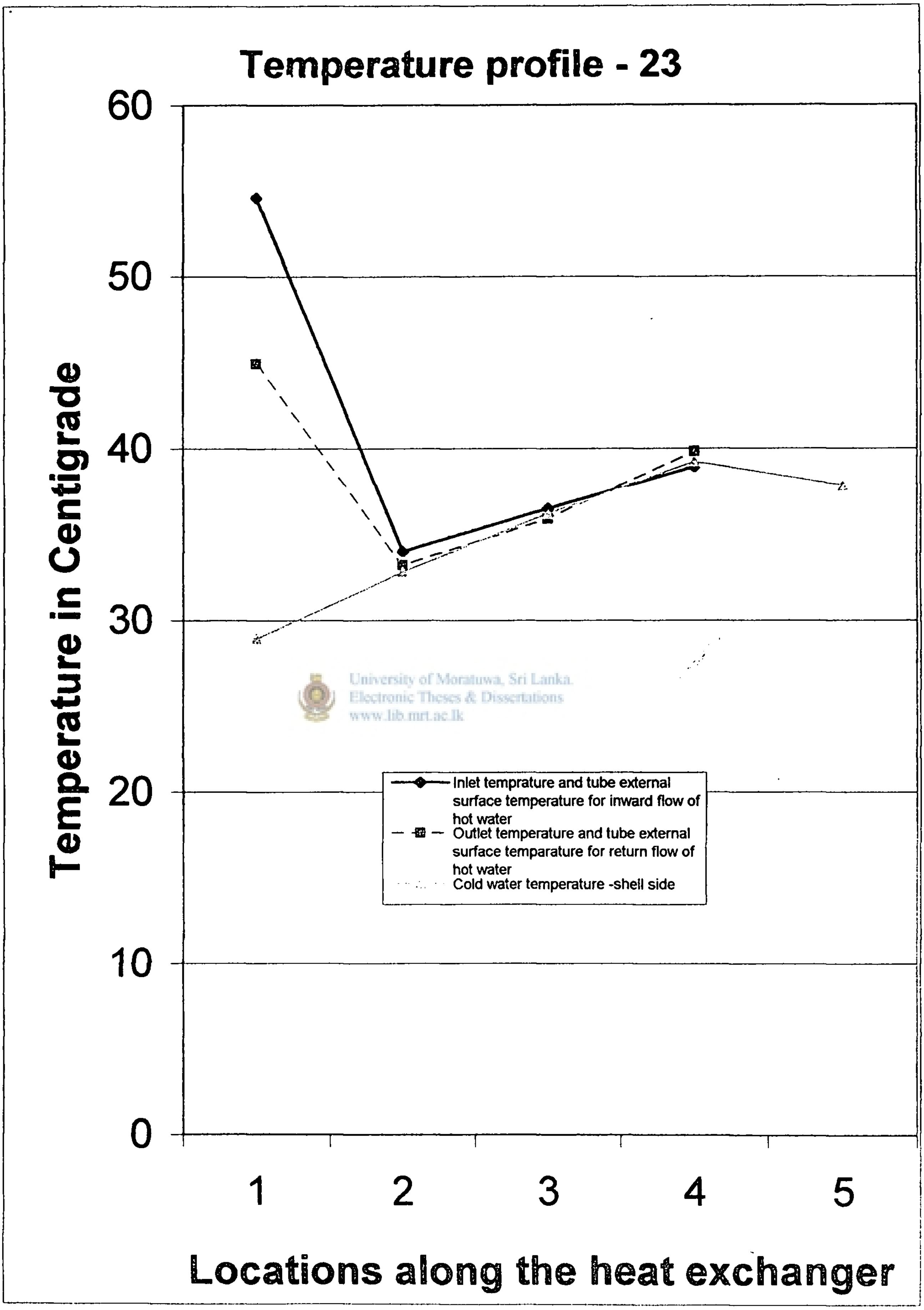
Temperature profile - 19
60
50
40
30
20
10
0
Temperature in Centigrade
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side


Temperature profile - 20
60
50
40
30
20
10
0
Temperature in Centigrade
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side

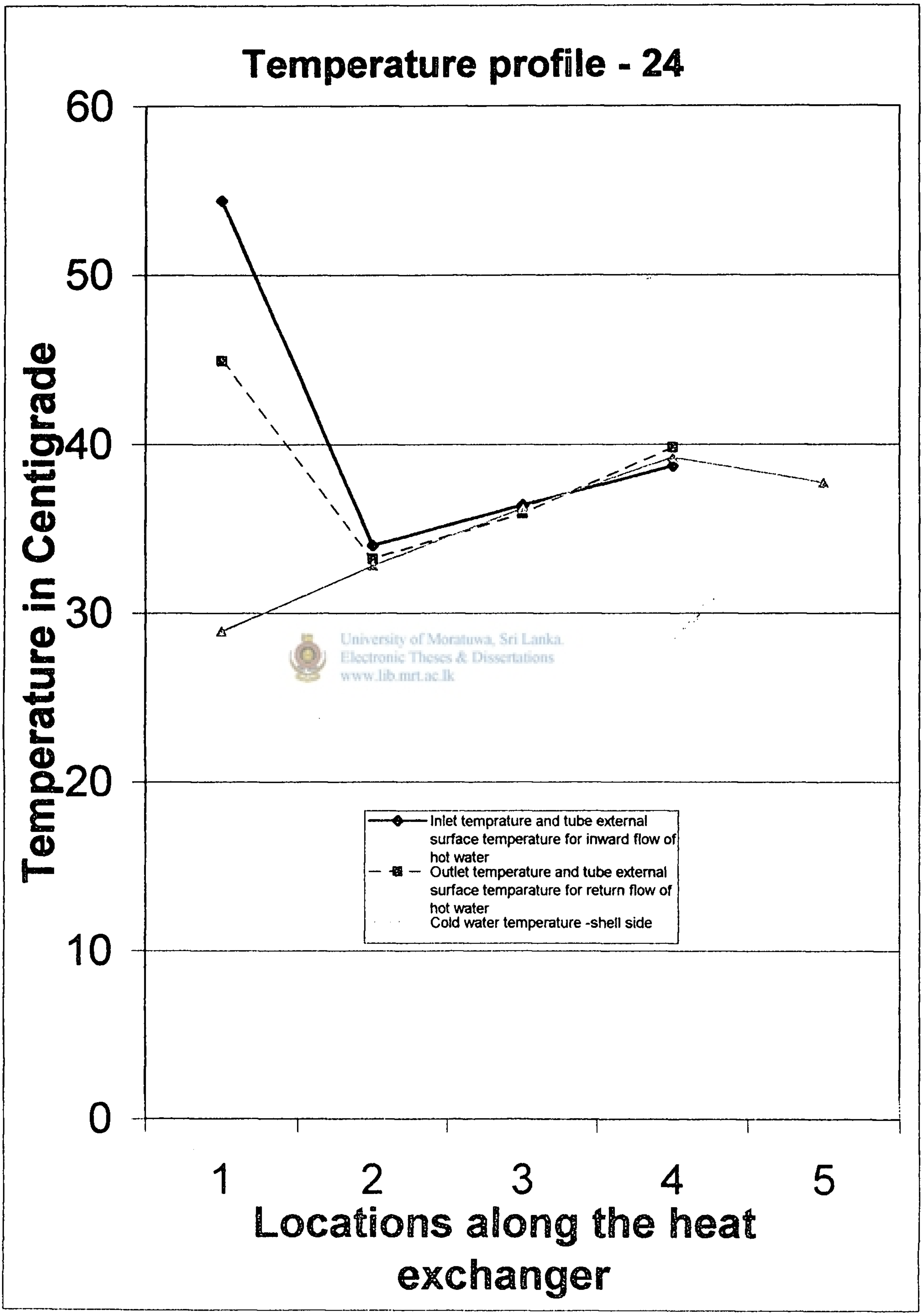


Temperature profile - 21
60
50
40
30
20
10
0
Temperature in Centigrade
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface tempararture for return flow of hot water
Cold water temperature -shell side

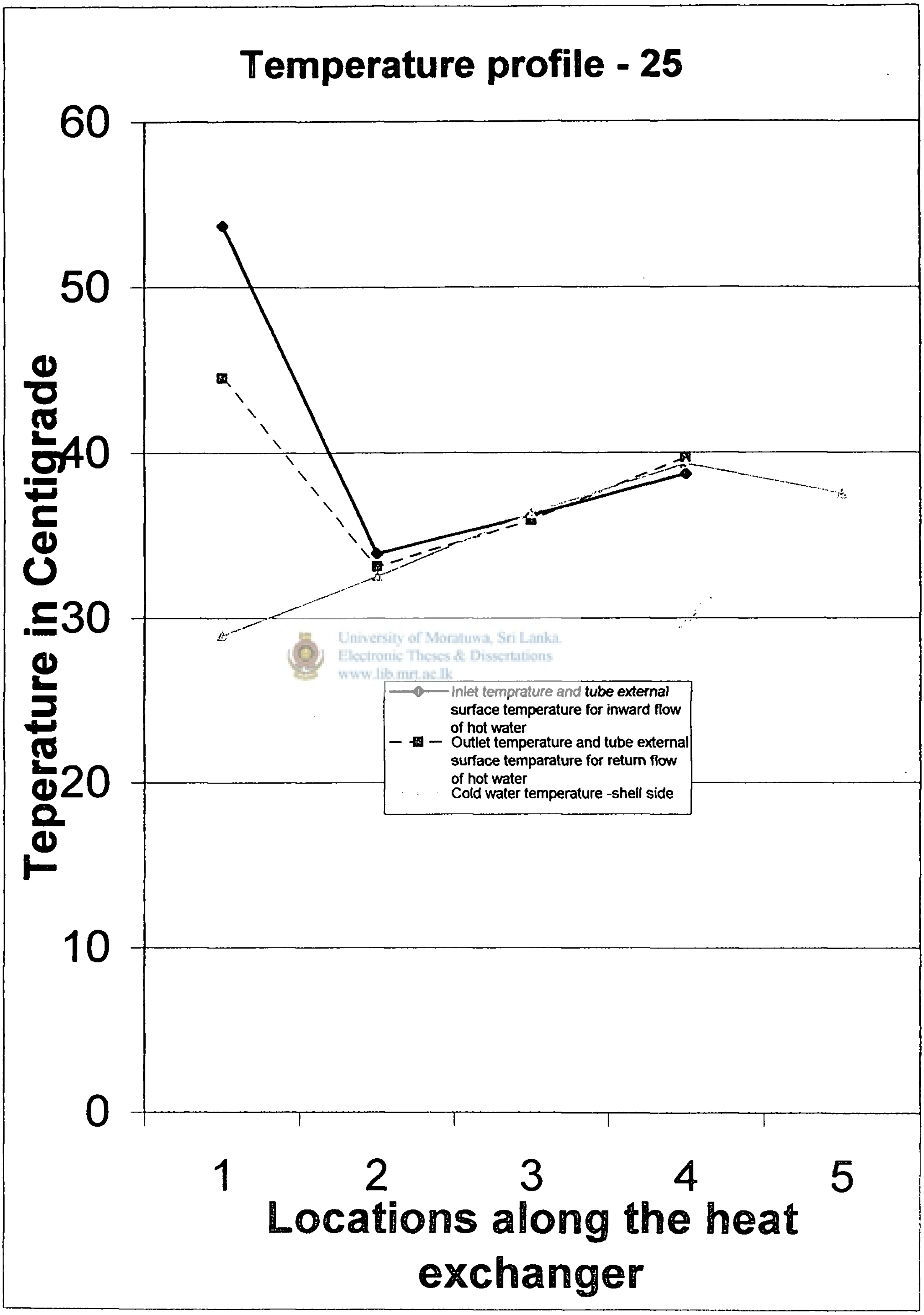

Temperature profile - 22
60
50
40
30
20
10
0
Temperature in Centigrade
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side



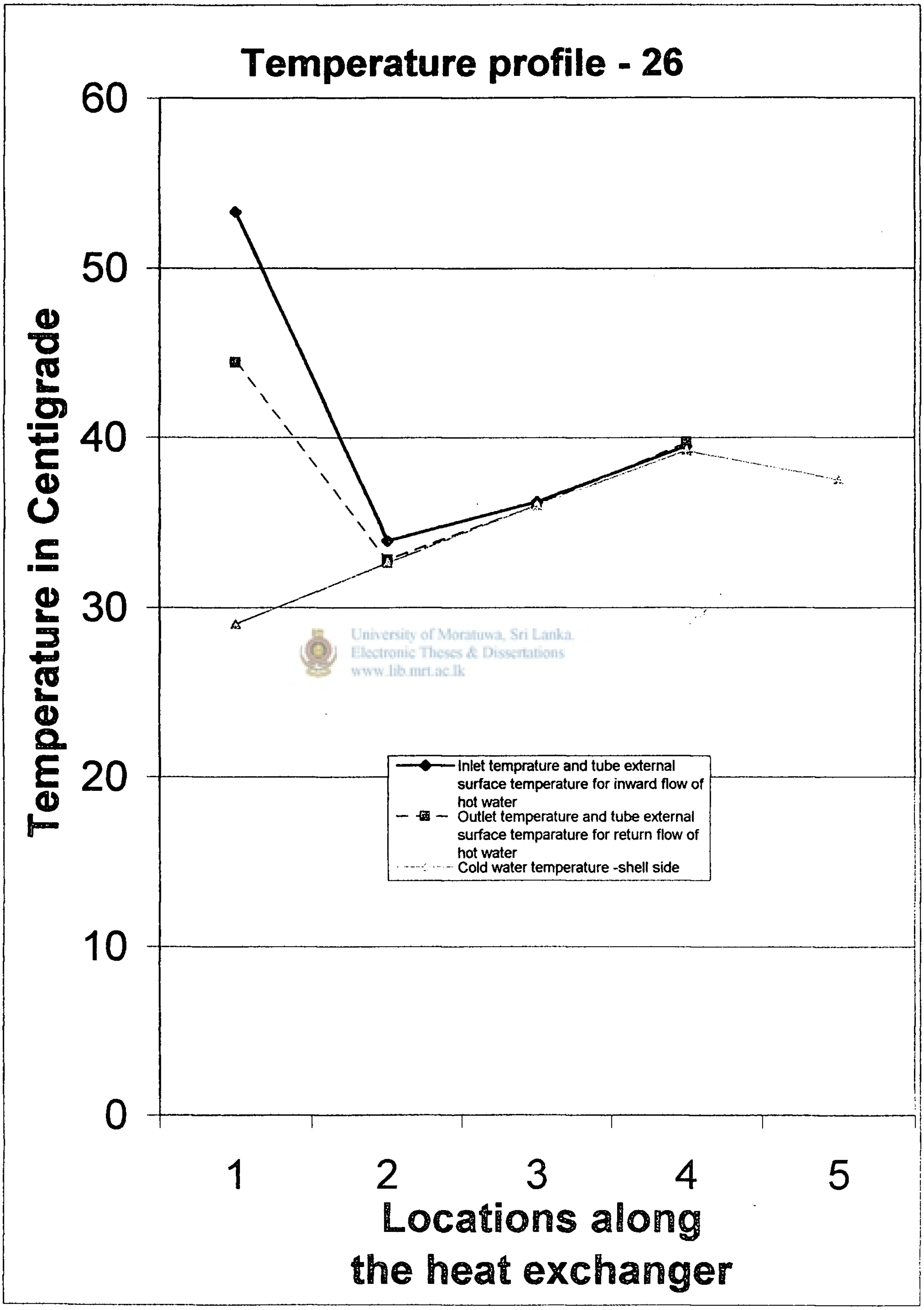
Temperature profile - 23
Temperature in Centigrade
60
50
40
30
20
10
0
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side



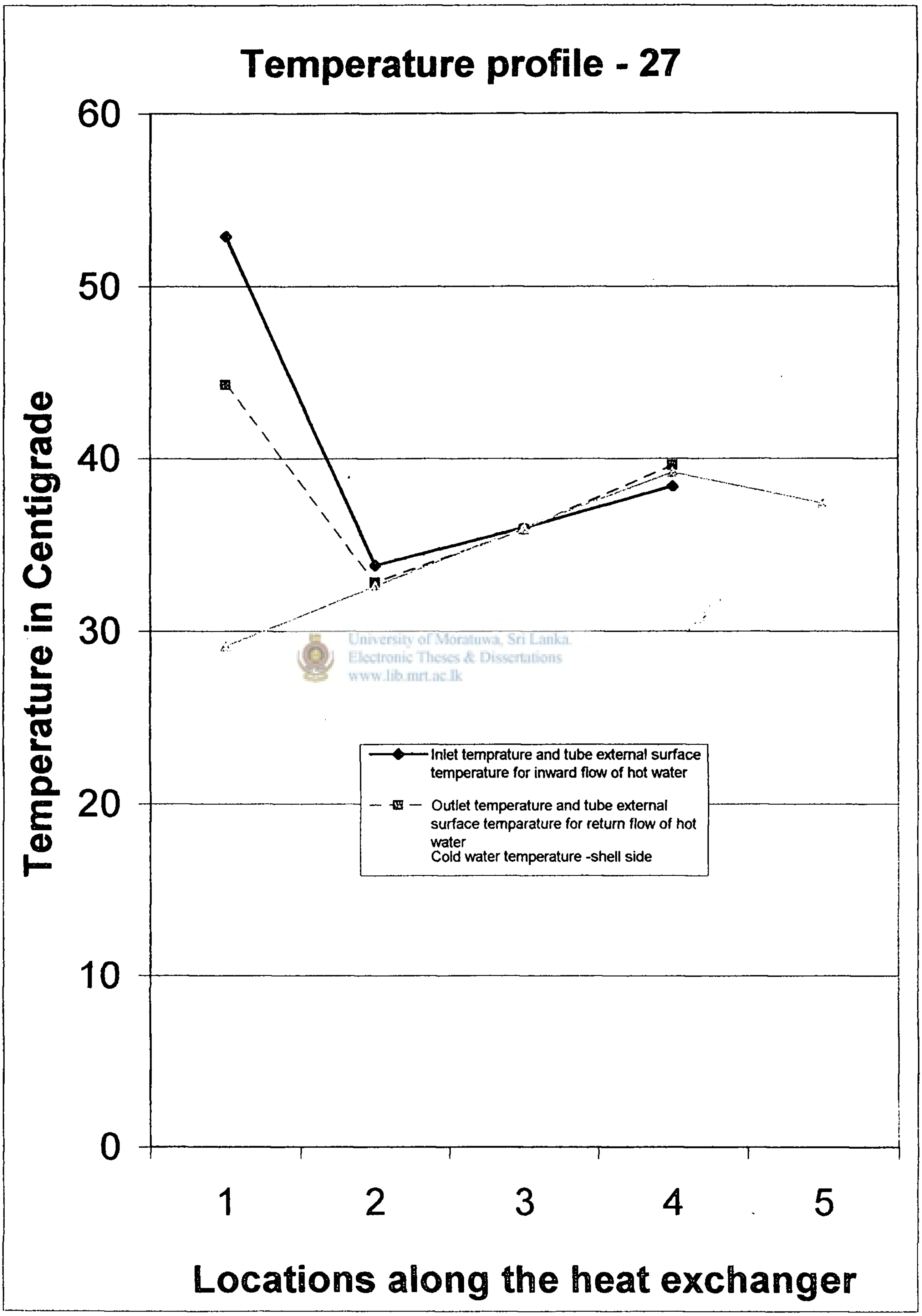
Temperature profile - 24
60
50
40
30
20
10
0
Temperature in Centigrade
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side



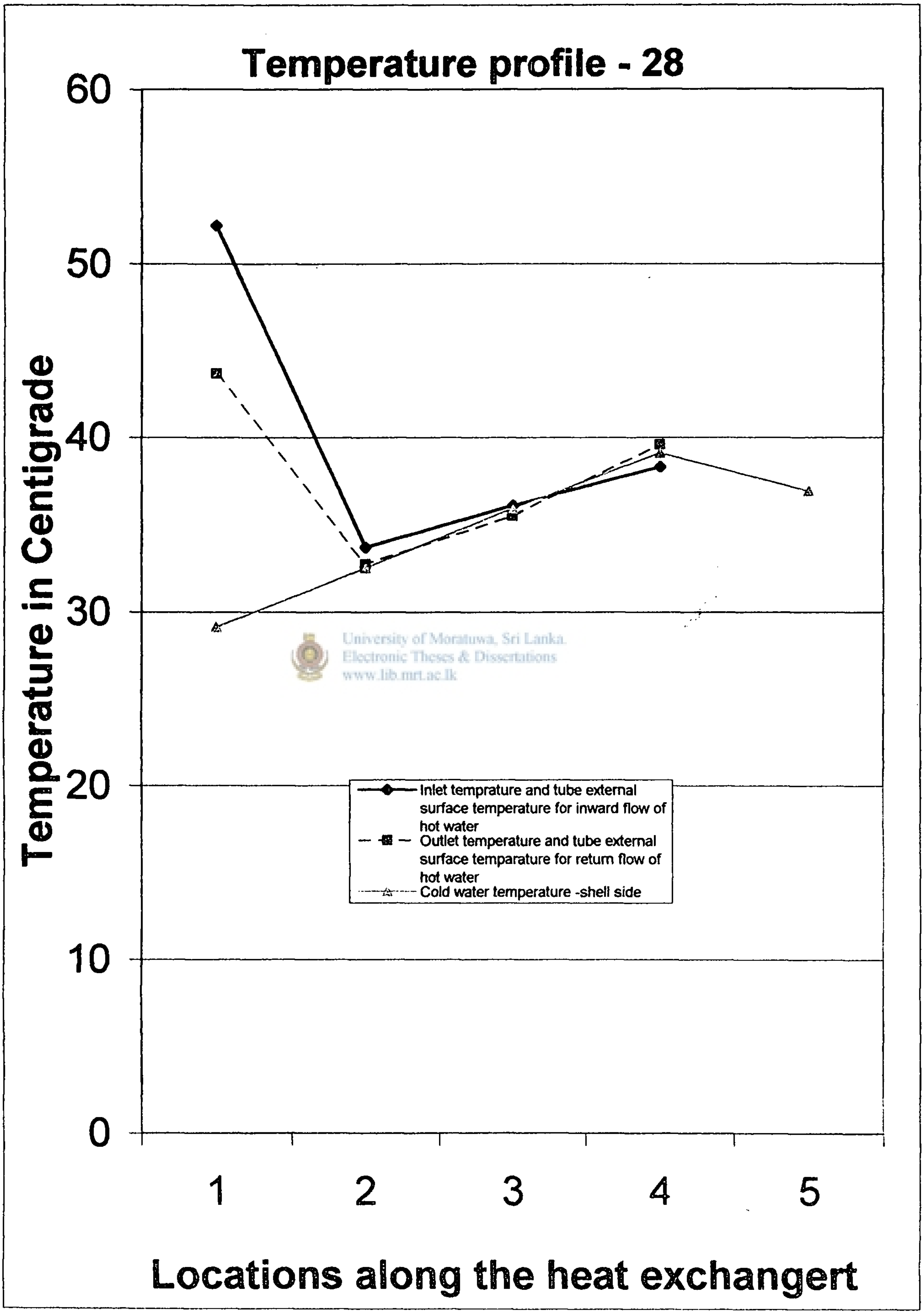
Temperature profile - 25
60
50
40
30
20
10
0
Teperature in Centigrade
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side



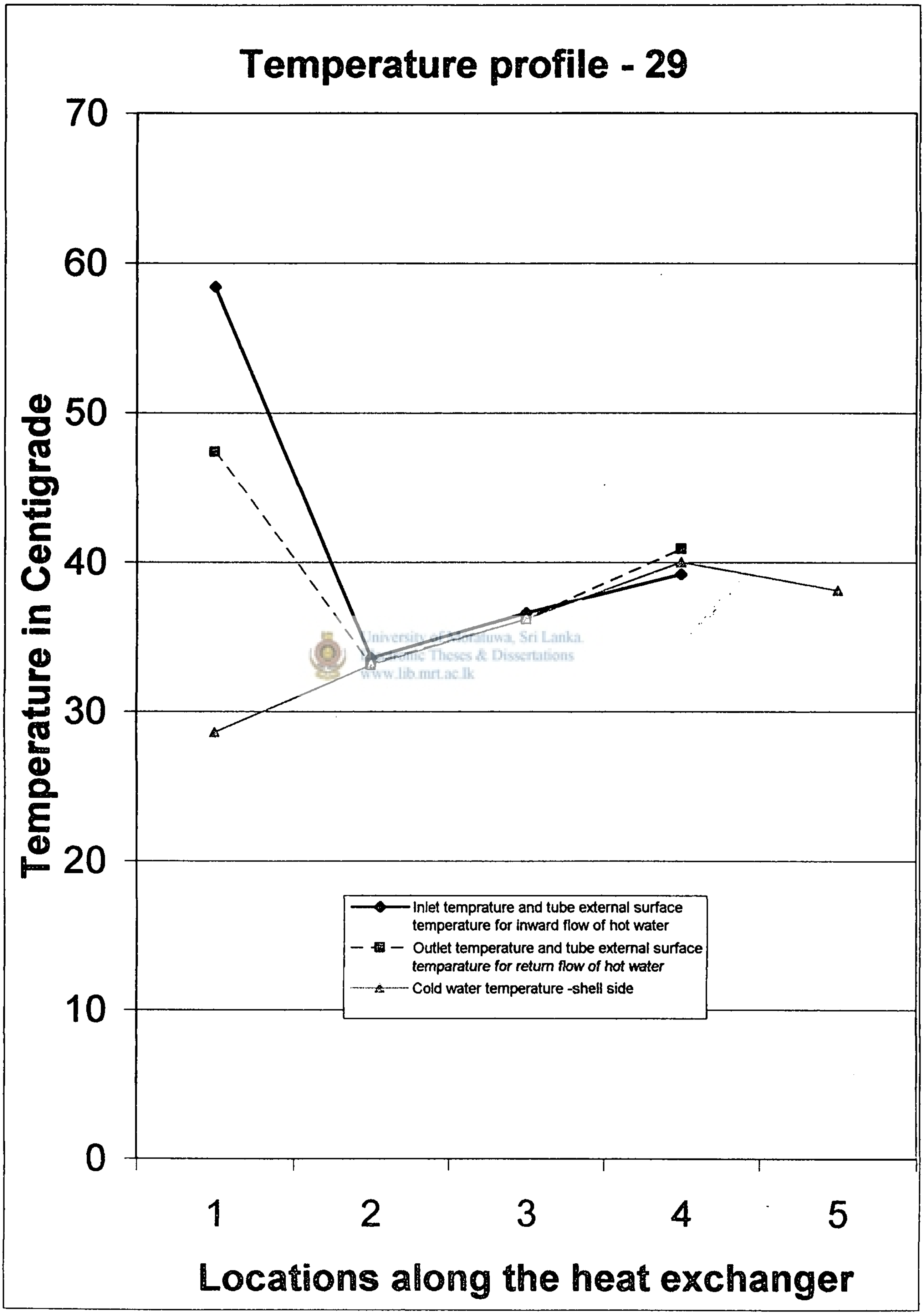
Temperature profile - 26
60
50
40
30
20
10
0
Temperature in Centigrade
1
2
3
4
5
Locations along
the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side

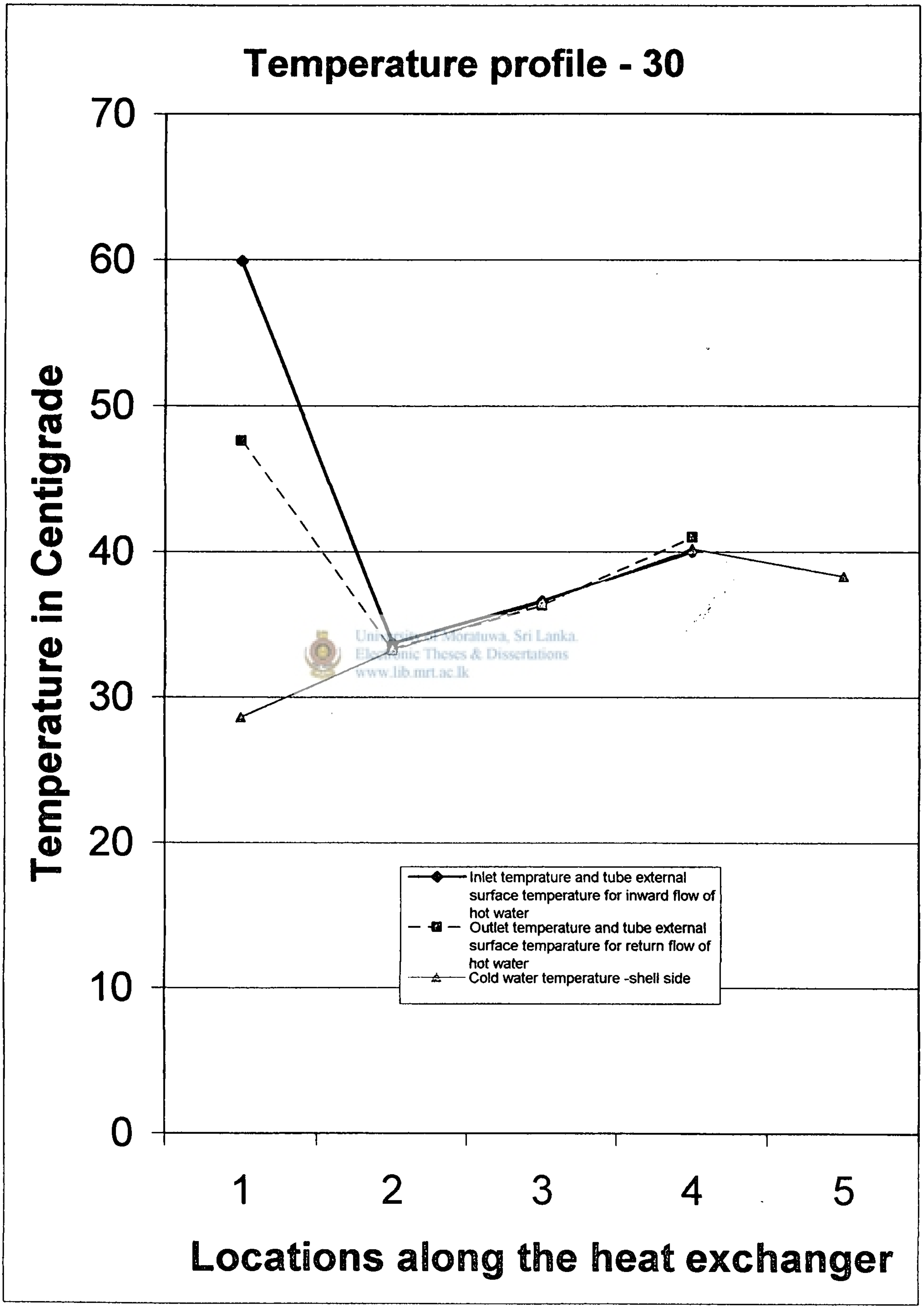


Temperature profile - 27
60
50
40
30
20
10
0
Temperature in Centigrade
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side

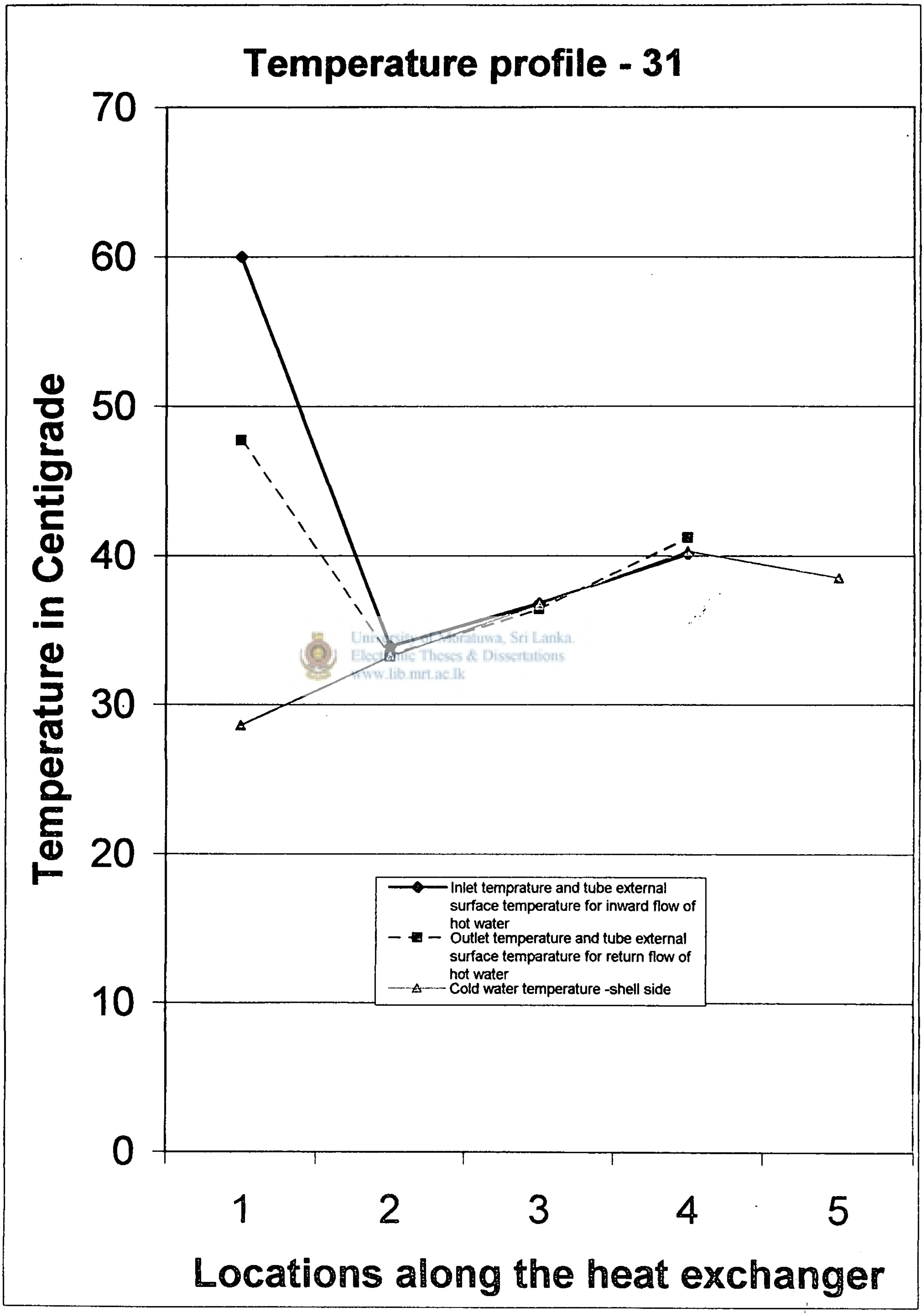


Temperature profile - 28
60
50
40
30
20
10
0
Temperature in Centigrade
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side
1
2
3
4
5
Locations along the heat exchangert


Temperature profile - 29
70
60
50
40
30
20
10
0
Temperature in Centigrade
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side



Temperature profile - 30
70
60
50
40
30
20
10
0
Temperature in Centigrade
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side



Temperature profile - 31
Temperature in Centigrade
70
60
50
40
30
20
10
0
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side
University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
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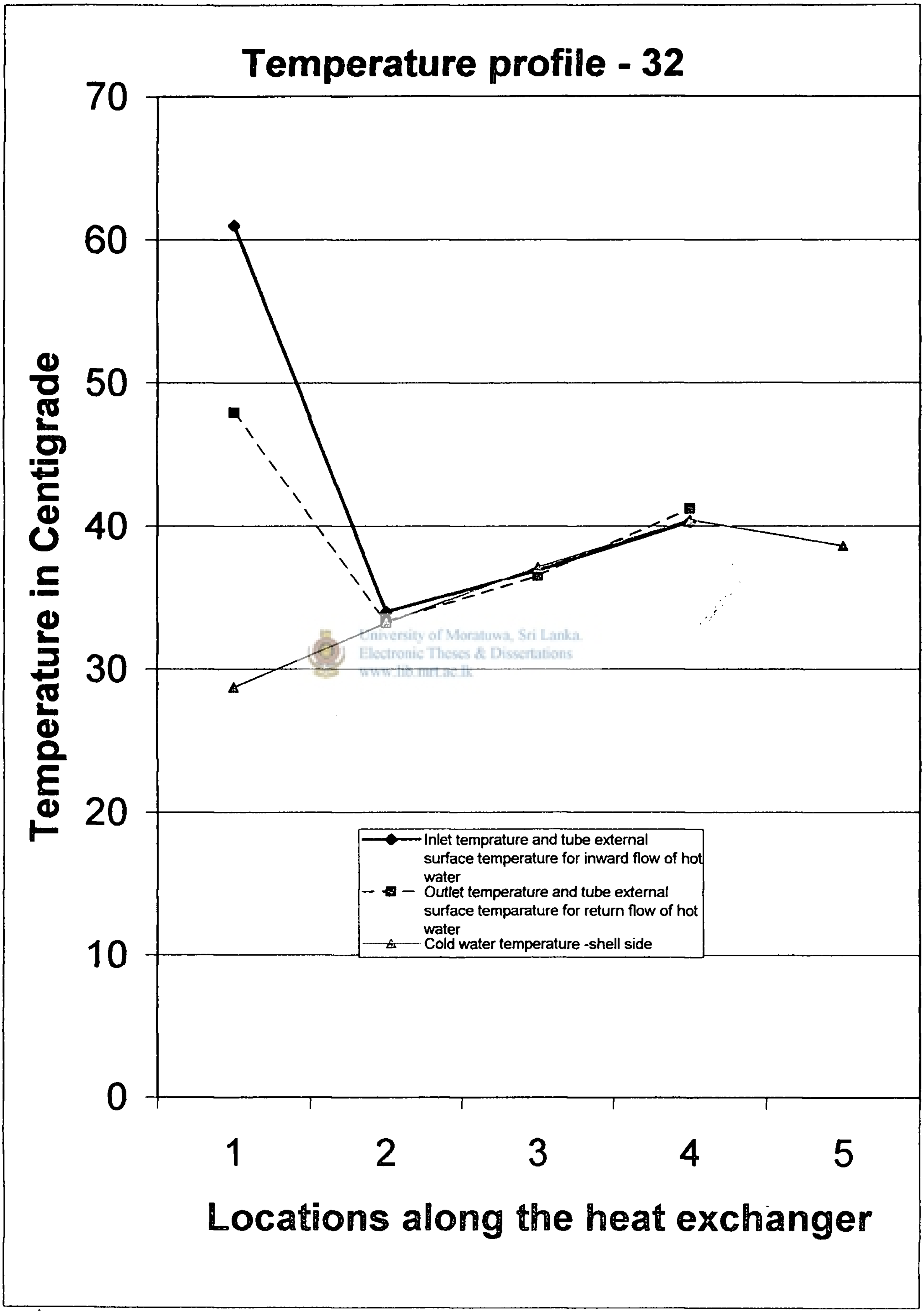
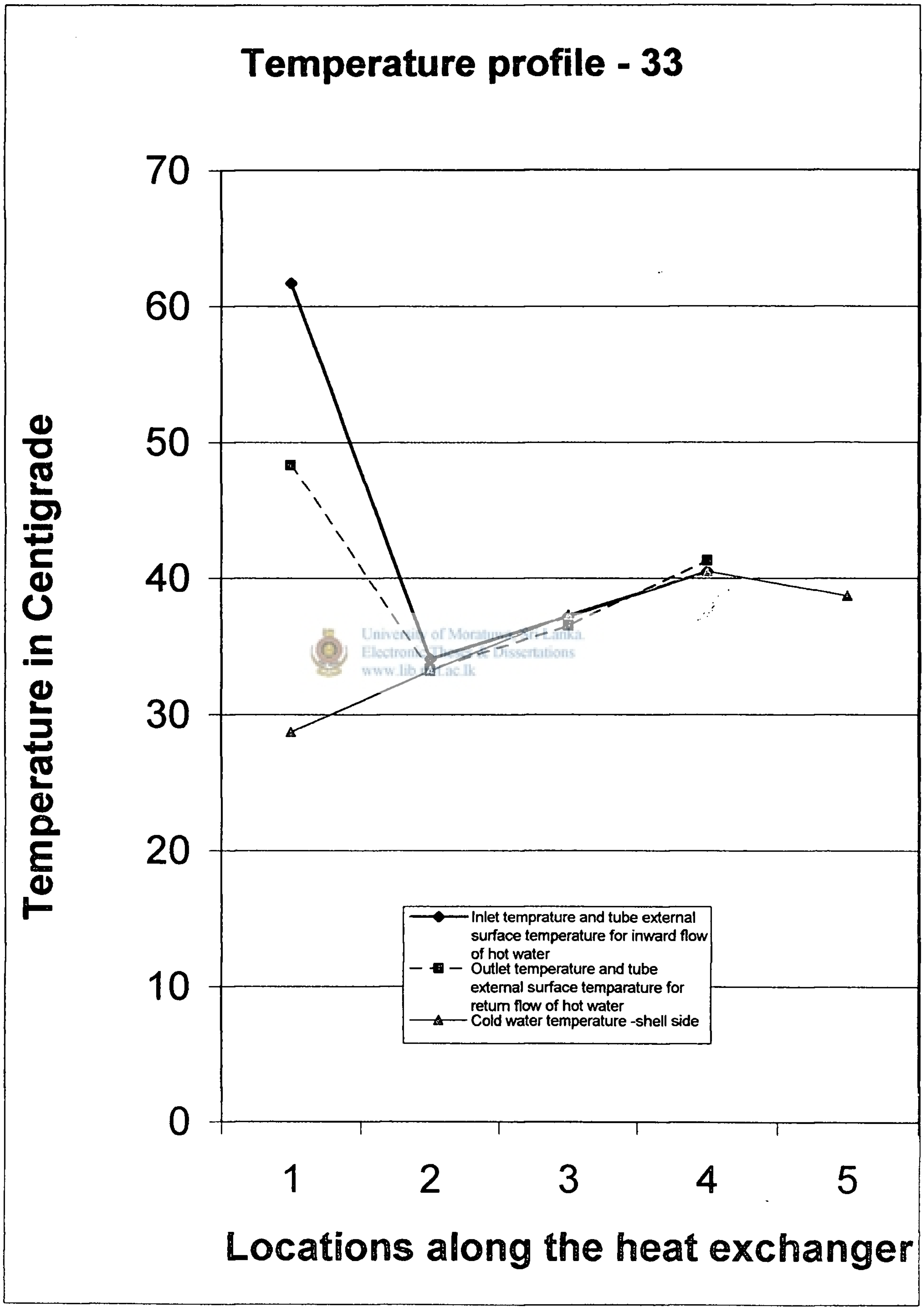
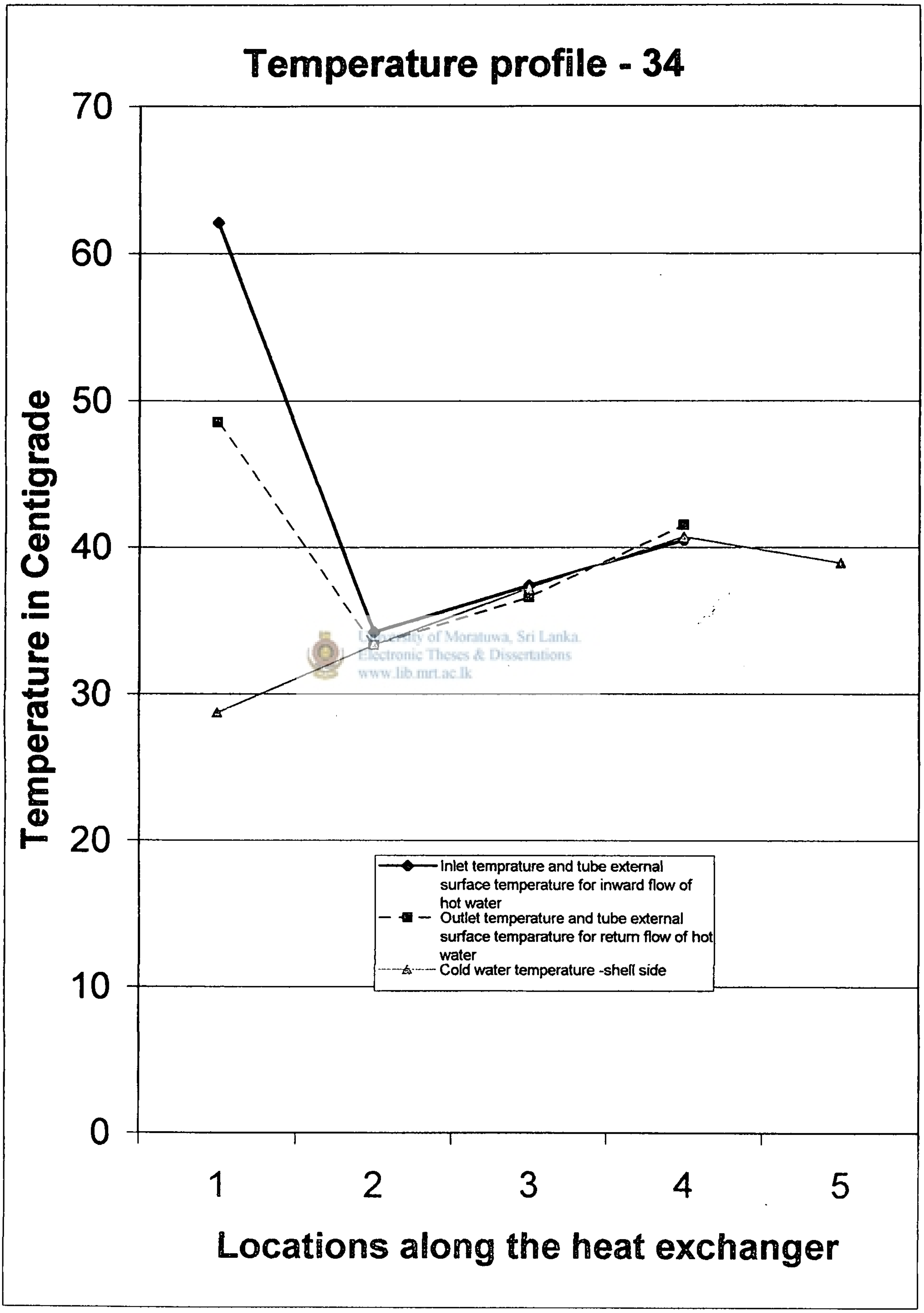


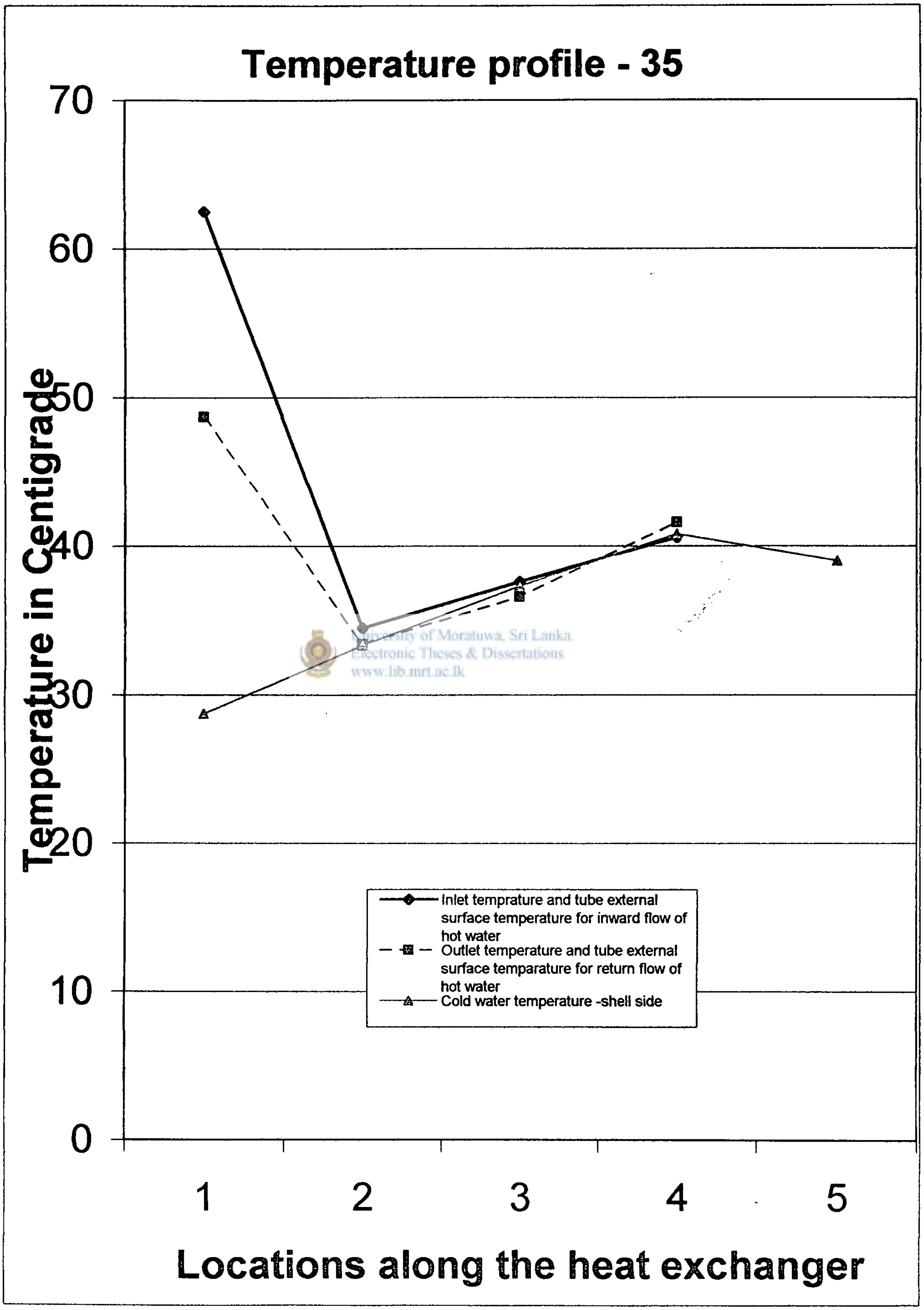
Temperature profile - 32
70
60
50
40
30
20
10
0
Temperature in Centigrade
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side
University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk



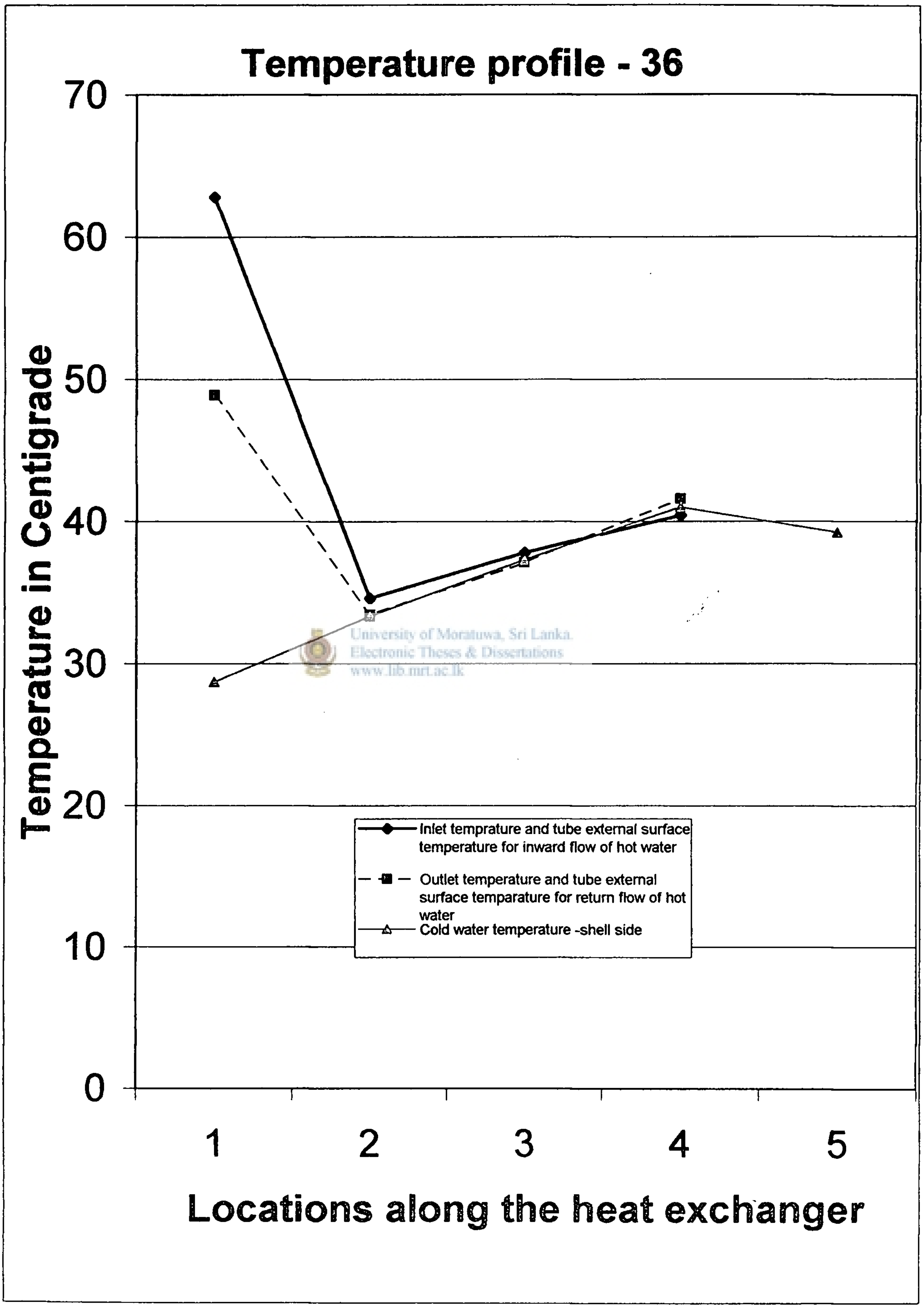
Temperature profile - 33
70
60
50
40
30
20
10
0
Temperature in Centigrade
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side

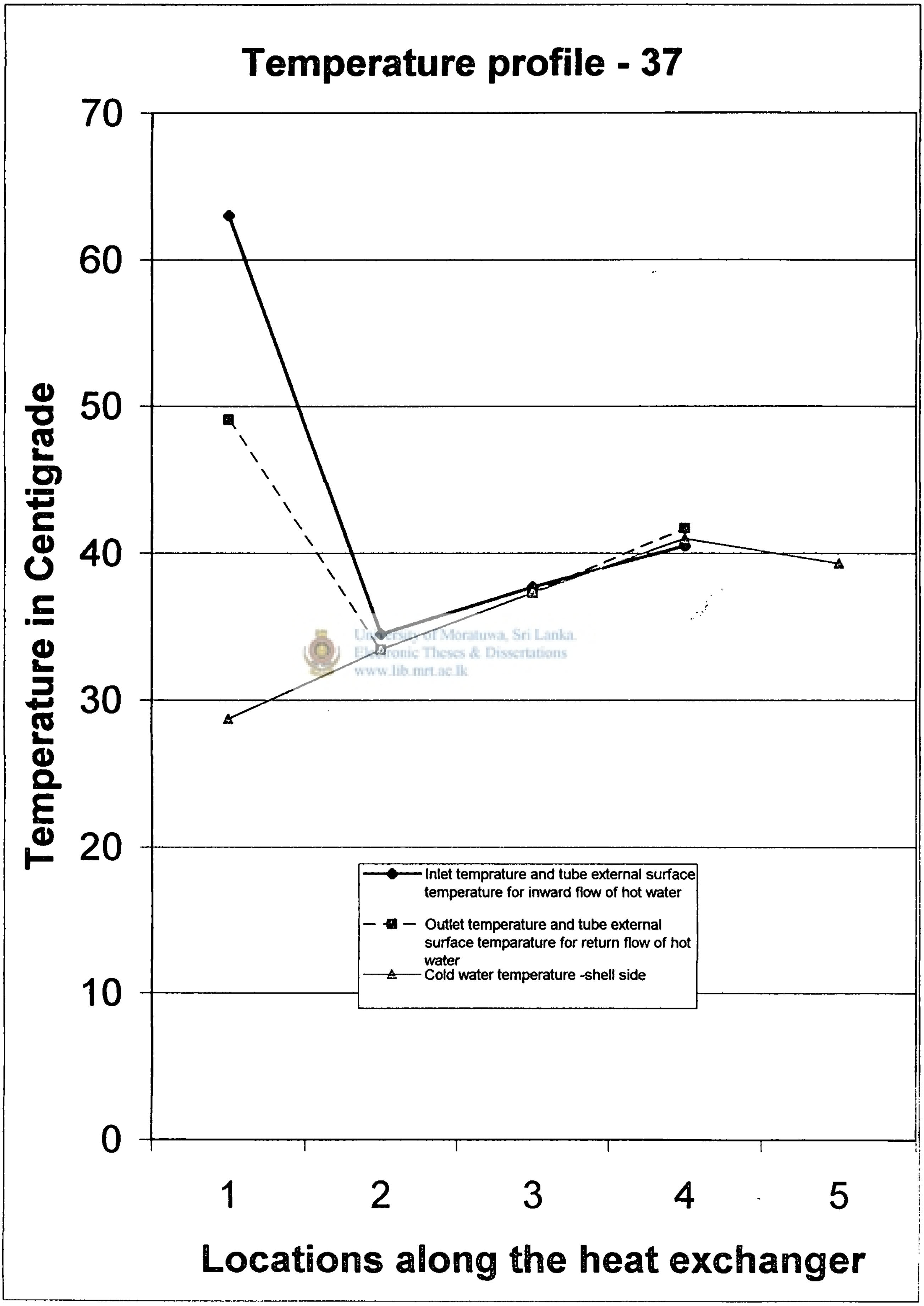


Temperature profile - 34
70
60
50
40
30
20
10
0
Temperature in Centigrade
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side

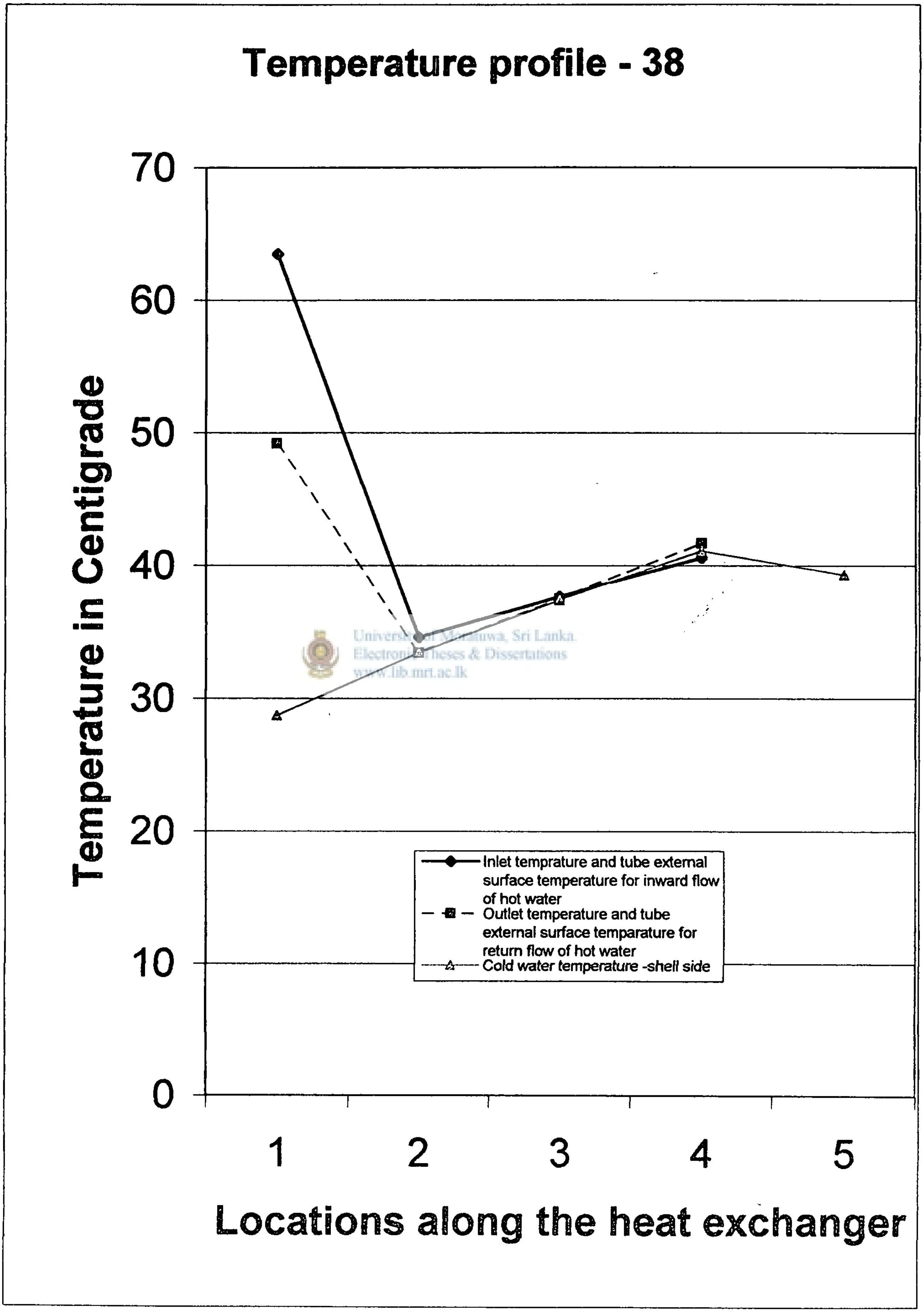


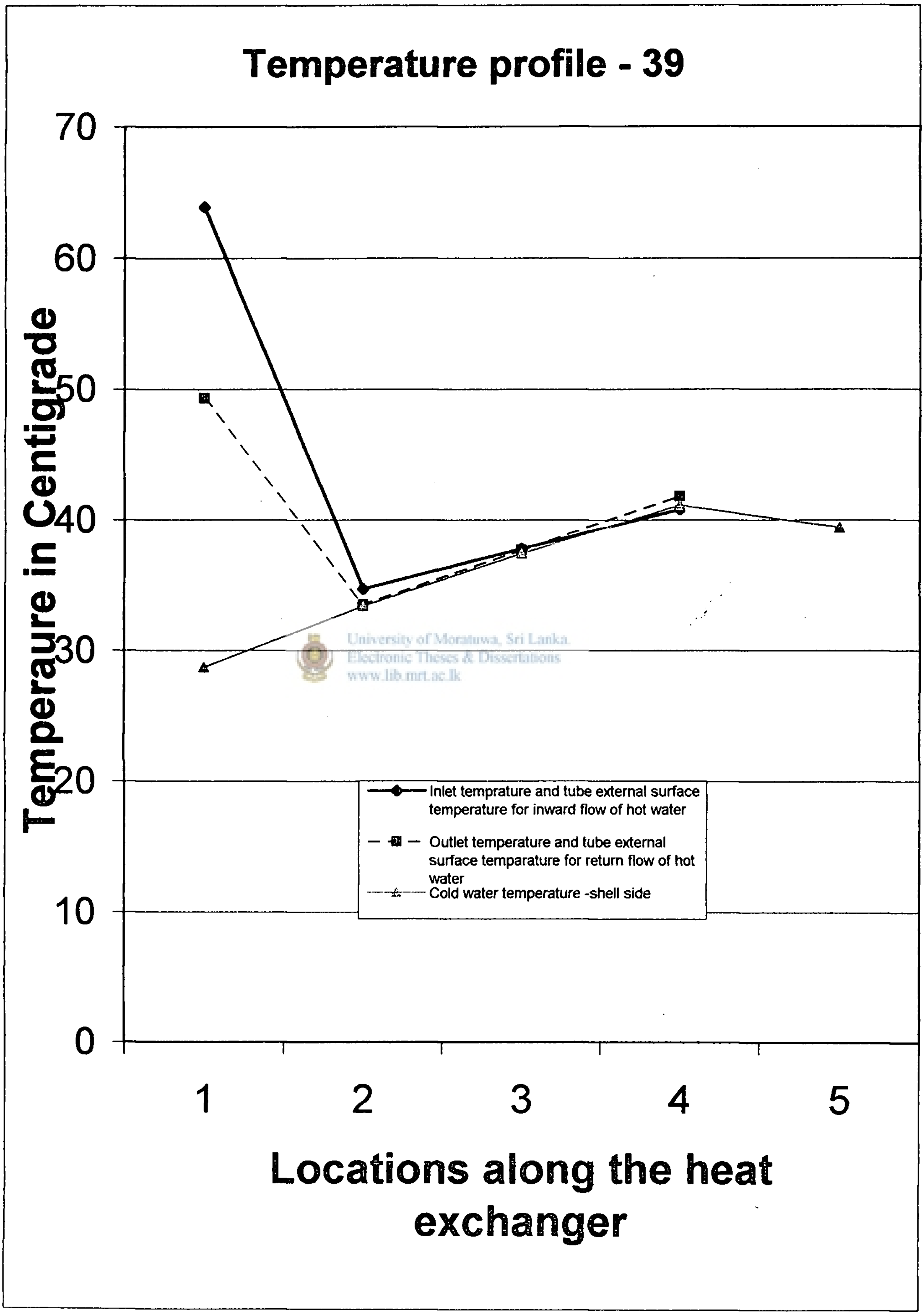
Temperature profile - 35
70
60
50
40
30
20
10
0
Temperature in Centigrade
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side
1
2
3
4
5
Locations along the heat exchanger


Temperature profile - 36
Temperature in Centigrade
70
60
50
40
30
20
10
0
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side

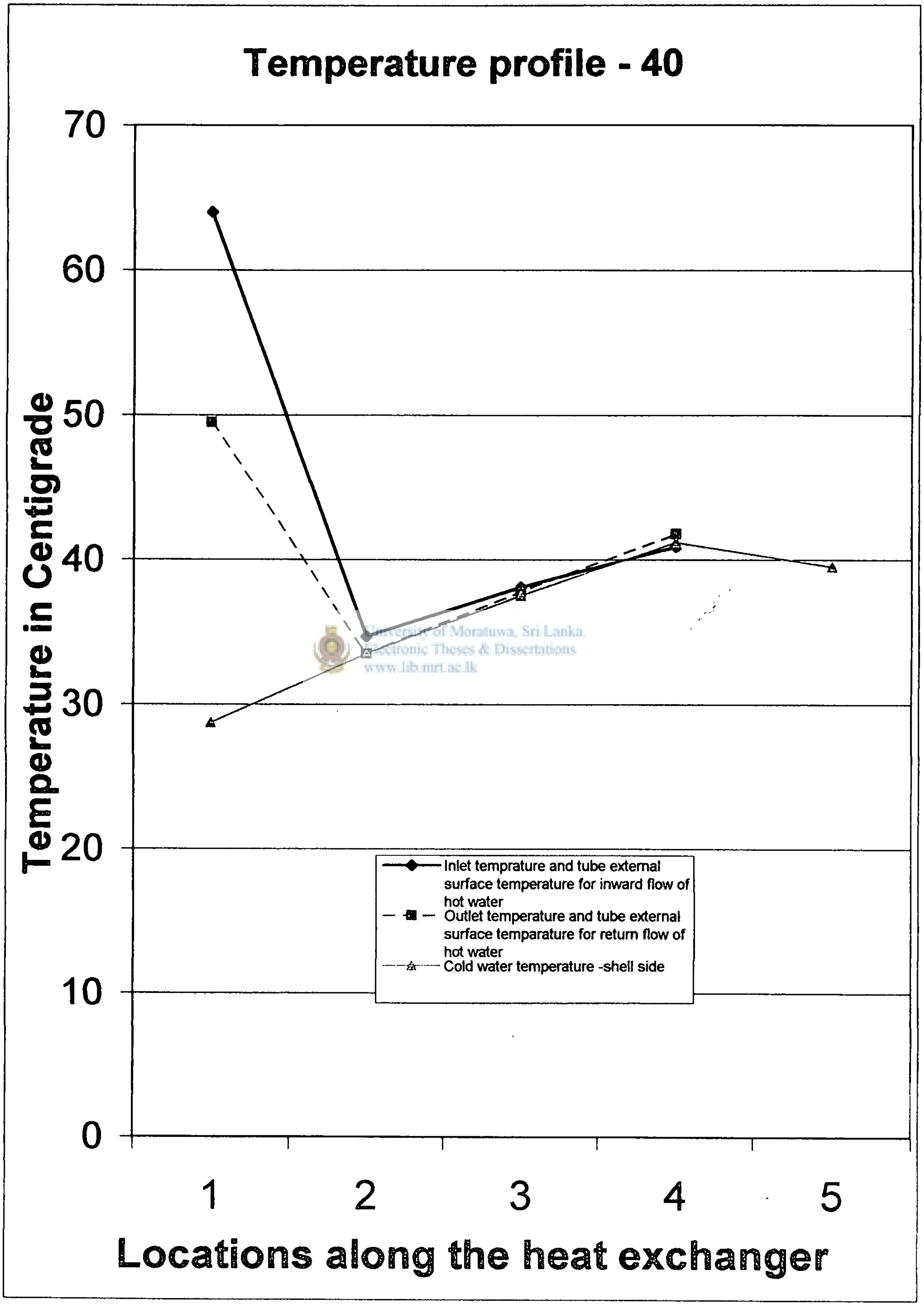


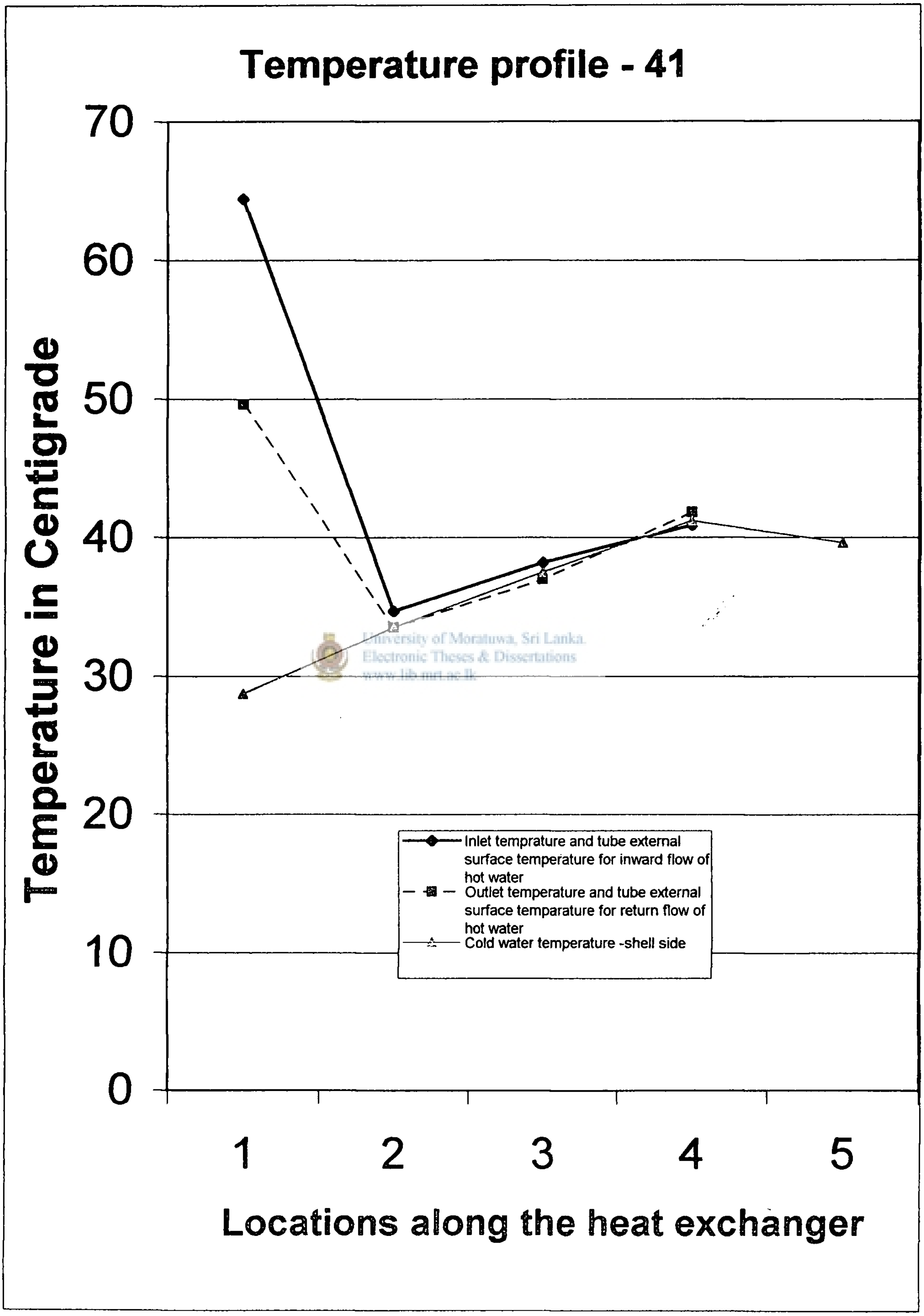
Temperature profile - 37
70
60
50
40
30
20
10
0
Temperature in Centigrade
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side

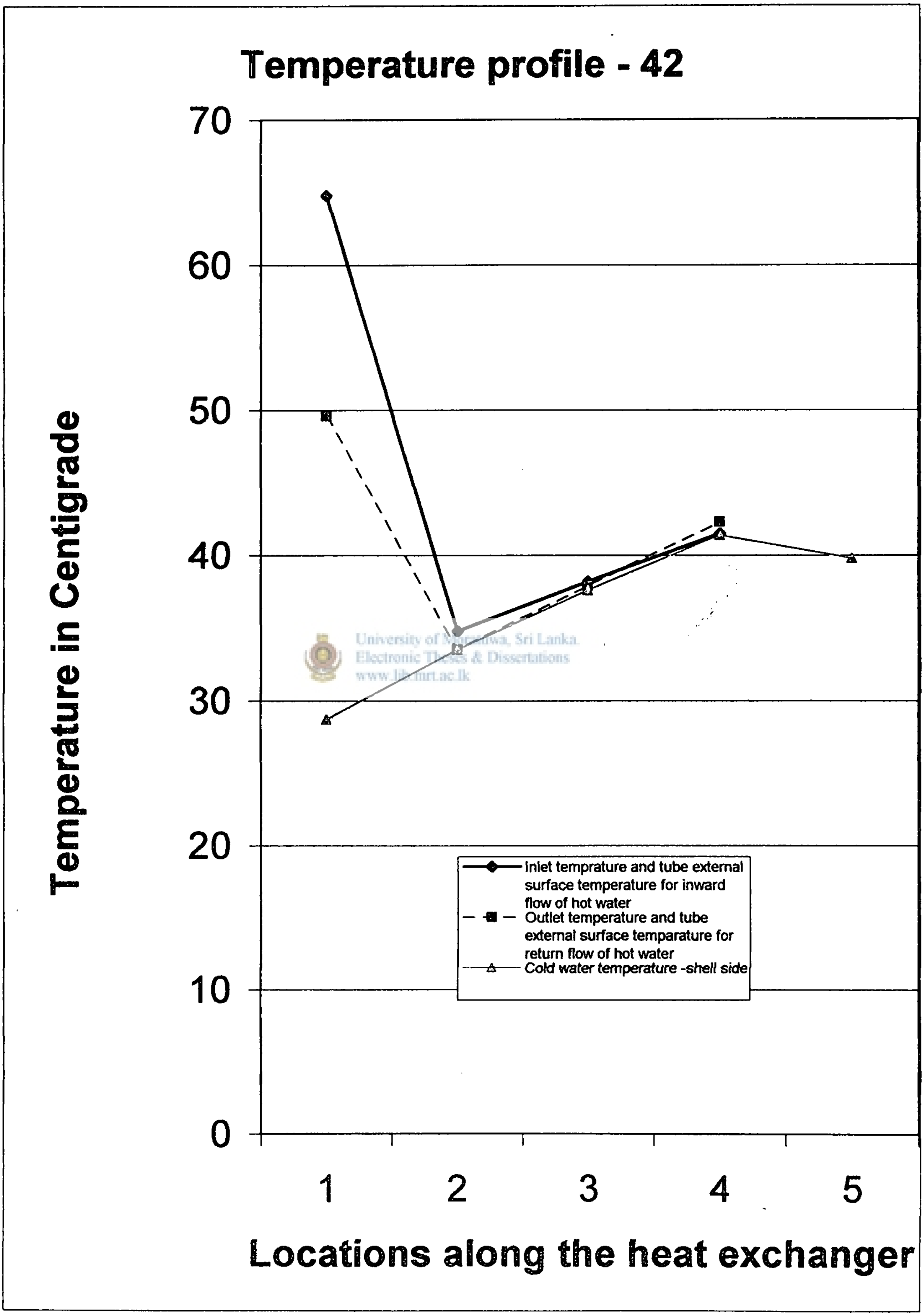

Temperature profile - 38
70
60
50
40
30
20
10
0
Temperature in Centigrade
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side



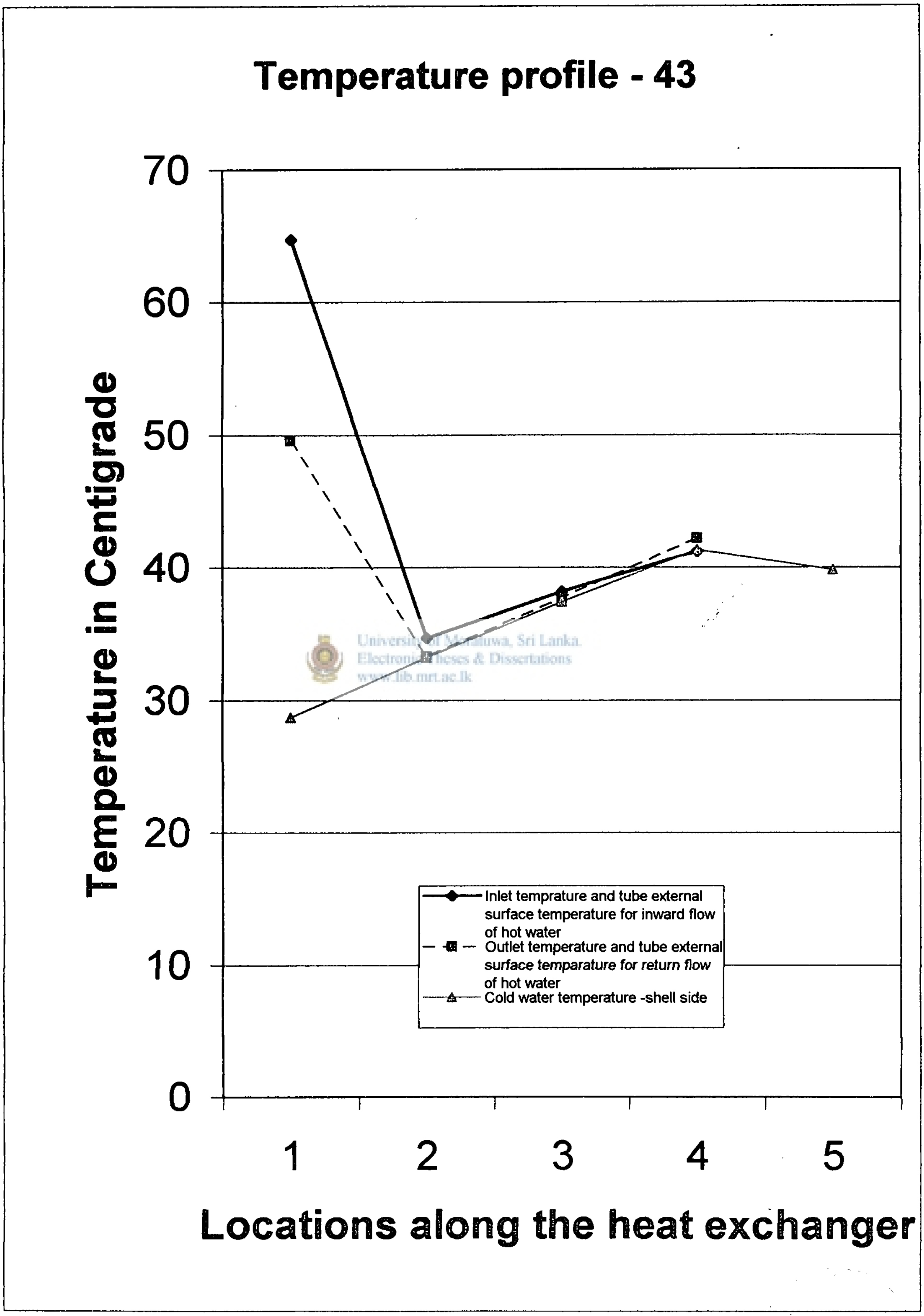
Temperature profile - 39
70
60
50
40
30
20
10
0
Temperaure in Centigrade
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side
1
2
3
4
5
Locations along the heat exchanger


Temperature profile - 40
Temperature in Centigrade
70
60
50
40
30
20
10
0
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side

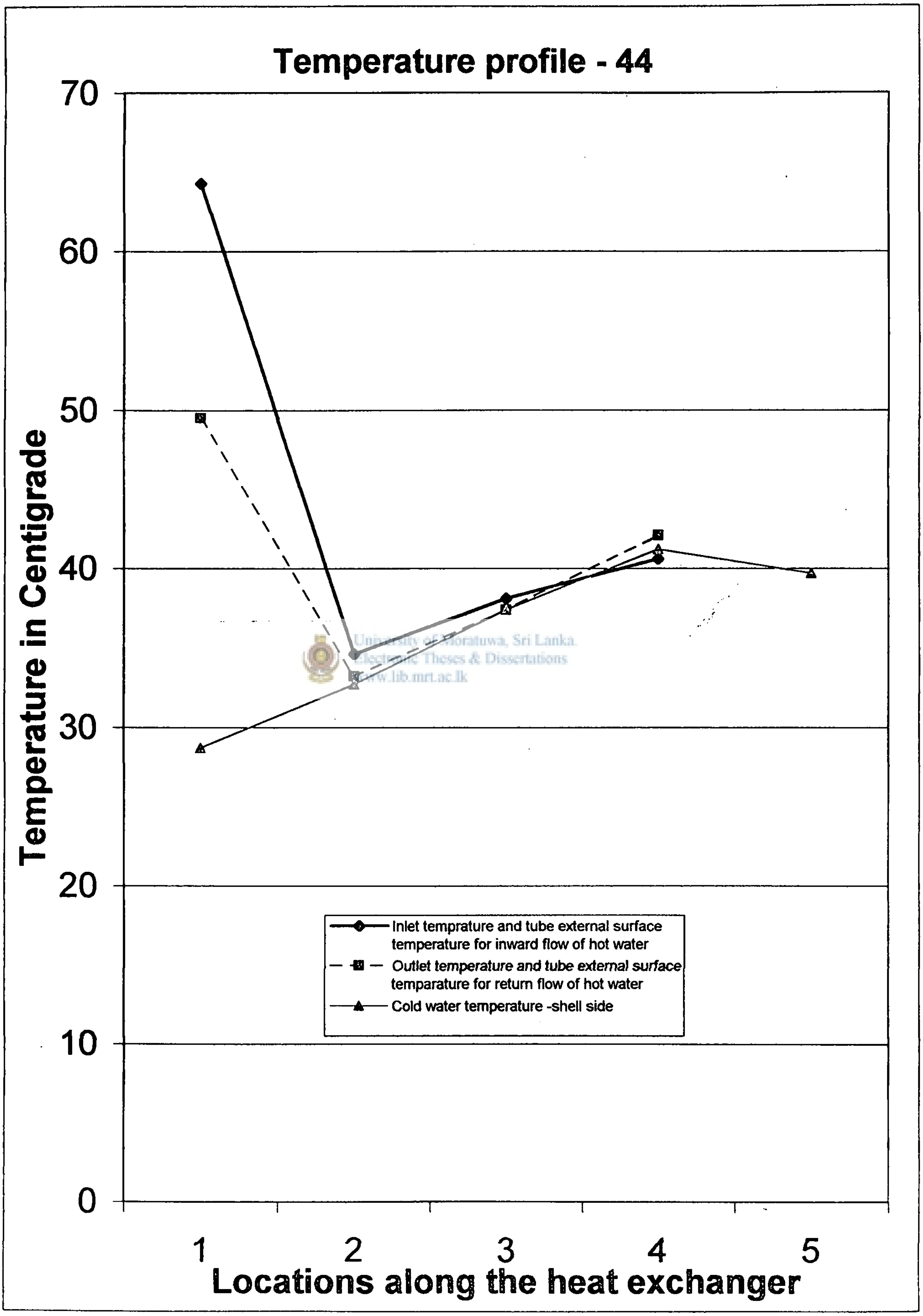

Temperature profile - 41
Temperature in Centigrade
70
60
50
40
30
20
10
0
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side

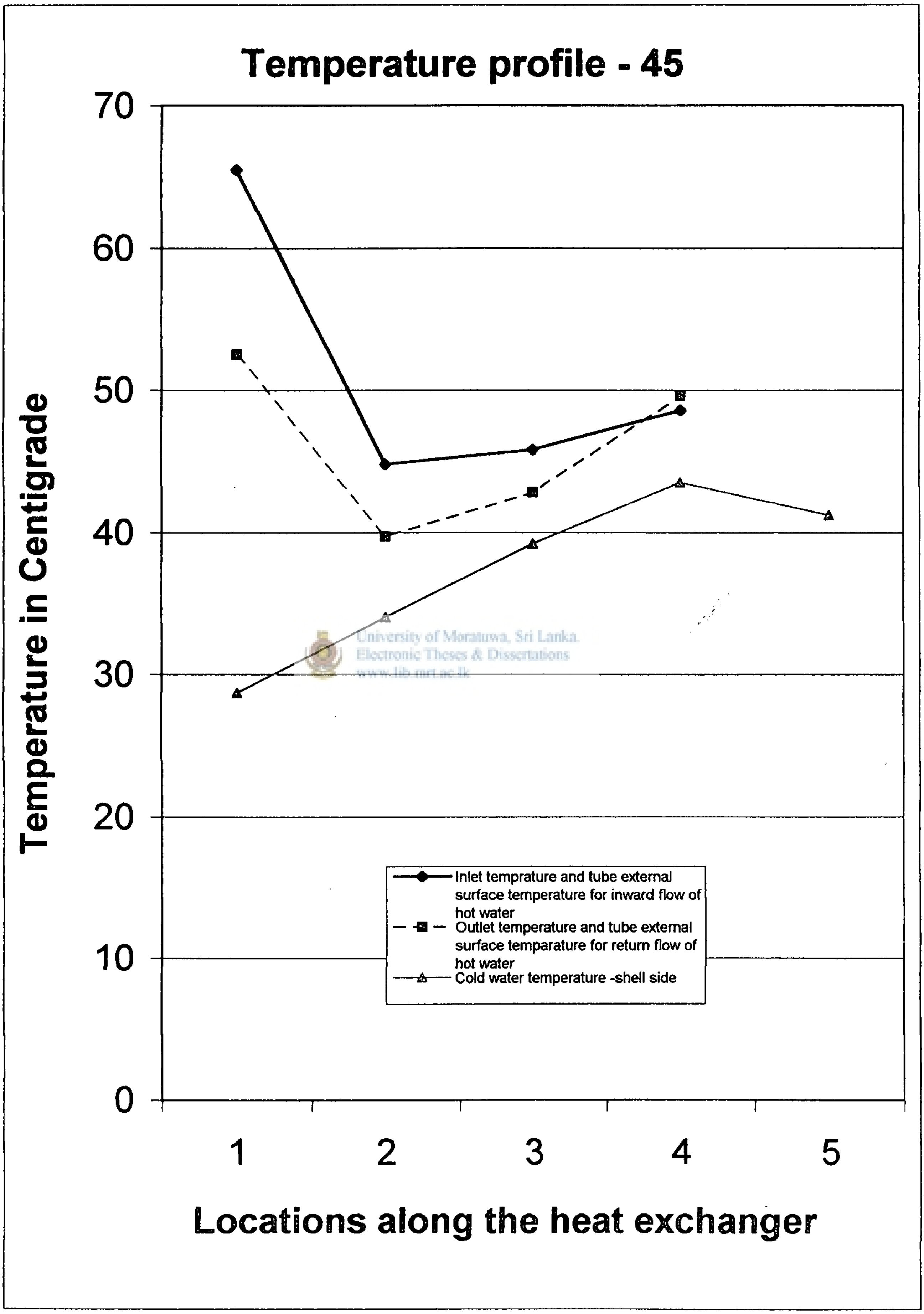


Temperature profile - 42
70
60
50
40
30
20
10
0
Temperature in Centigrade
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side

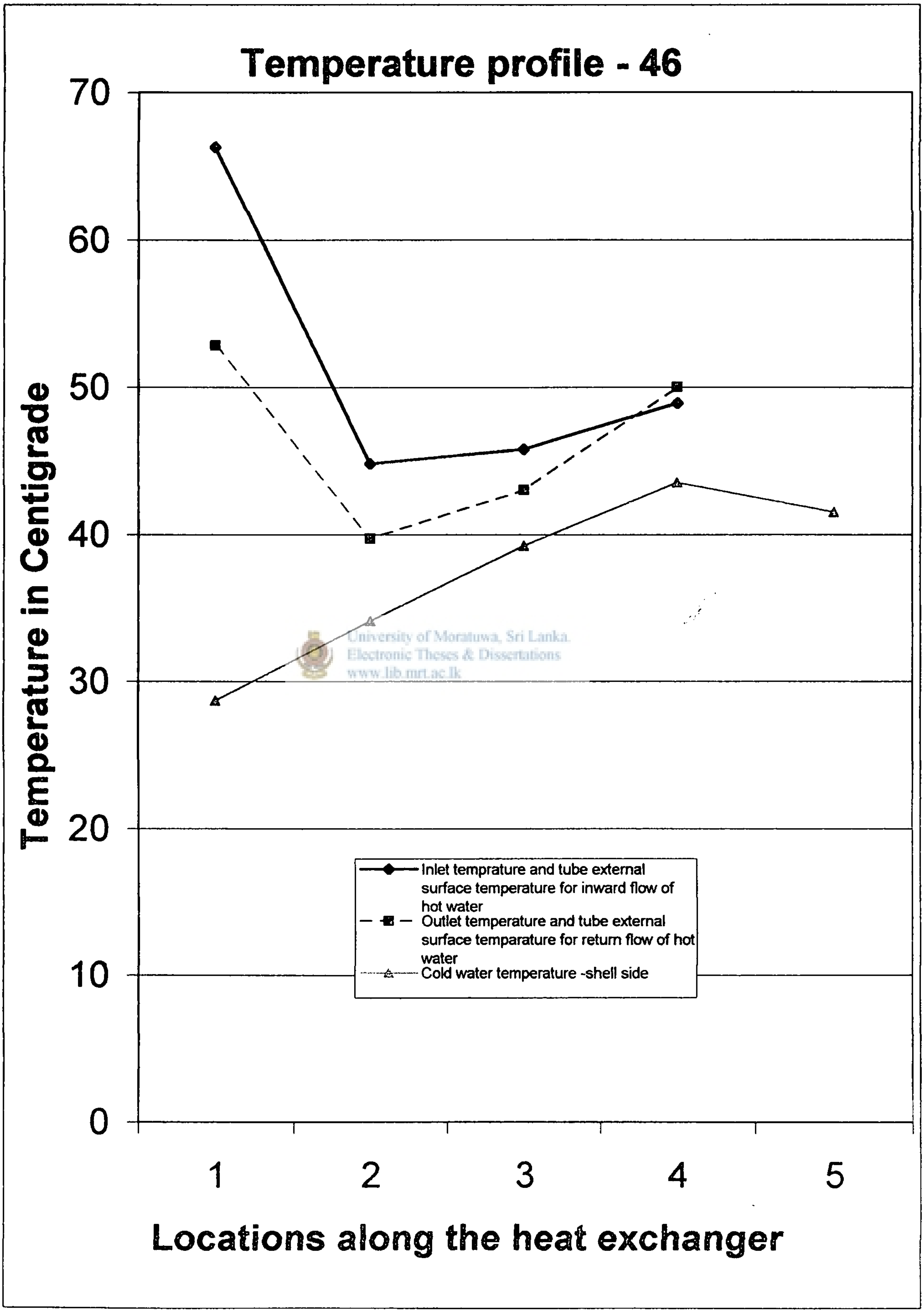


Temperature profile - 43
70
60
50
40
30
20
10
0
Temperature in Centigrade
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side

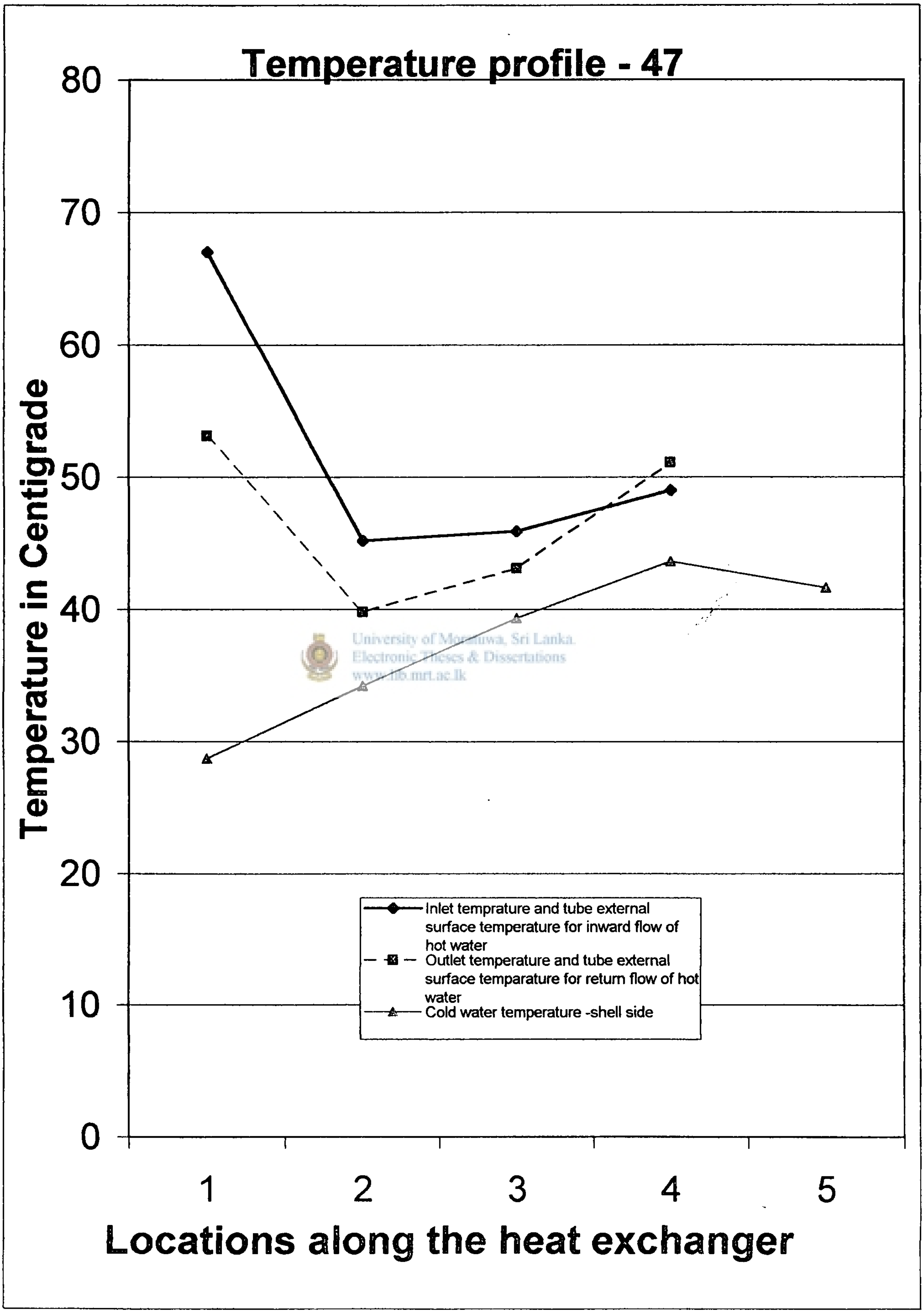

Temperature profile - 44
70
60
50
40
30
20
10
0
Temperature in Centigrade
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side



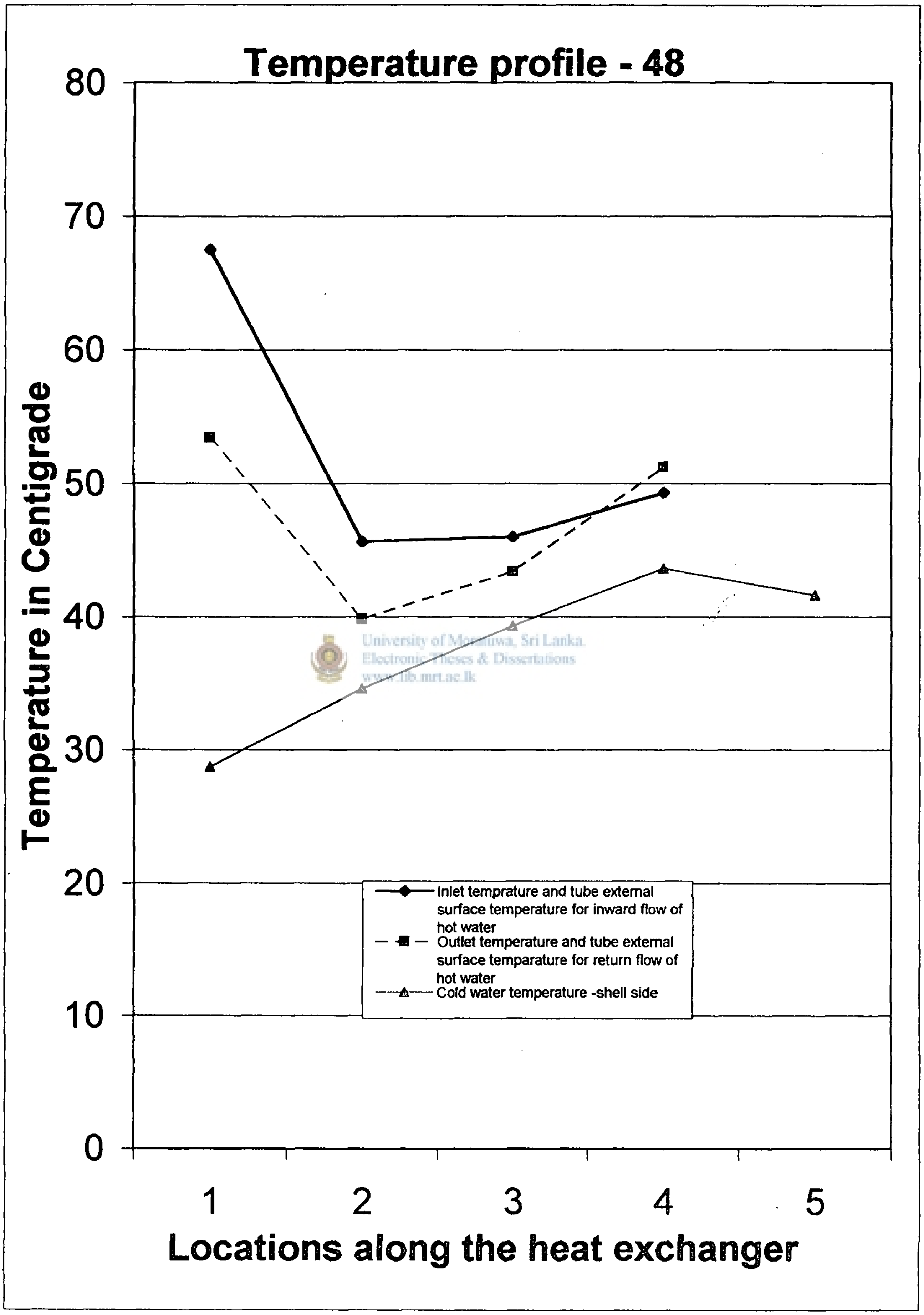
Temperature profile - 45
Temperature in Centigrade
70
60
50
40
30
20
10
0
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side



Temperature profile - 46
Temperature in Centigrade
70
60
50
40
30
20
10
0
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side



Temperature profile - 47
80
70
60
50
40
30
20
10
0
Temperature in Centigrade
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side
1
2
3
4
5
Locations along the heat exchanger


Temperature profile - 48
Temperature in Centigrade
80
70
60
50
40
30
20
10
0
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side
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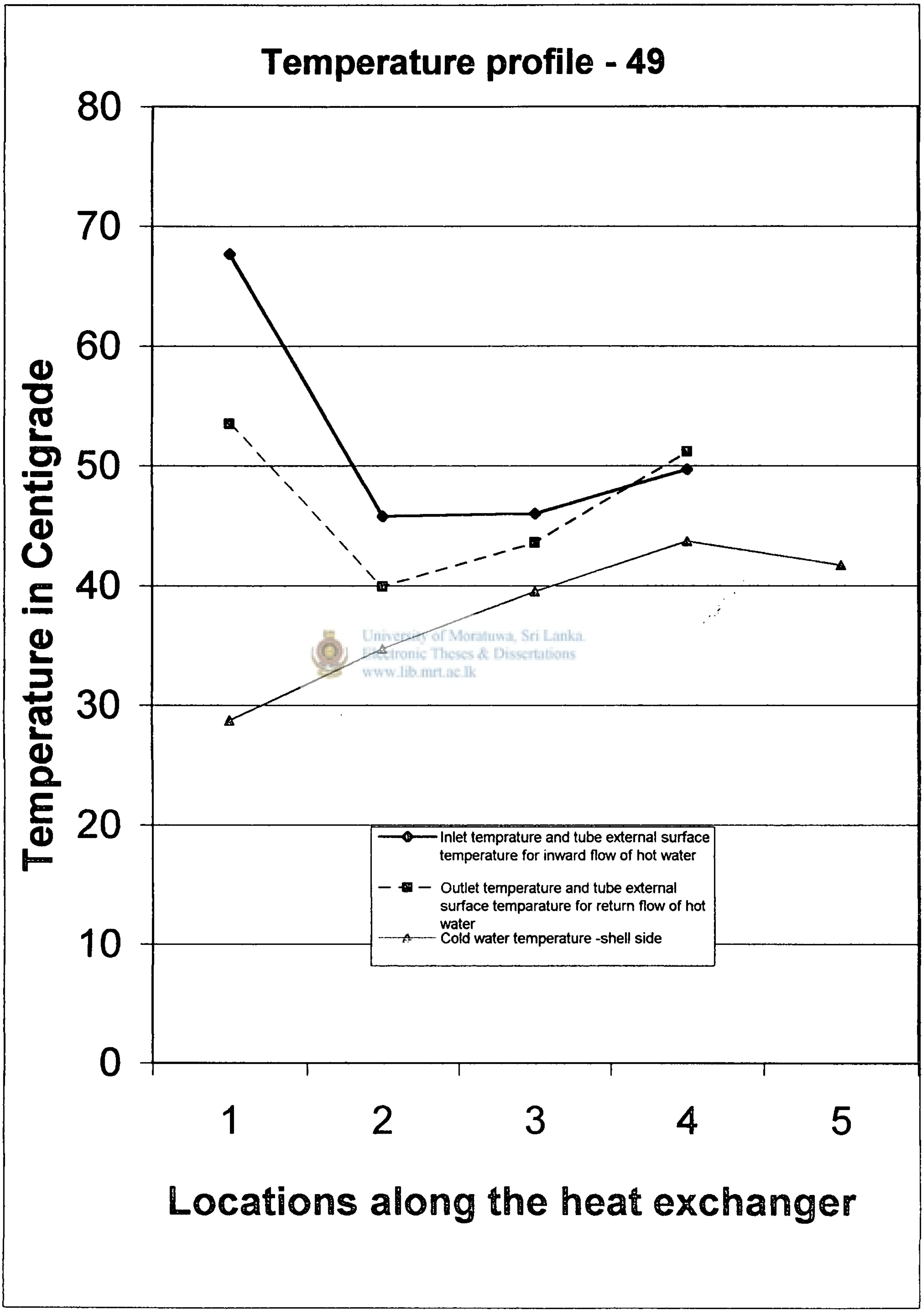
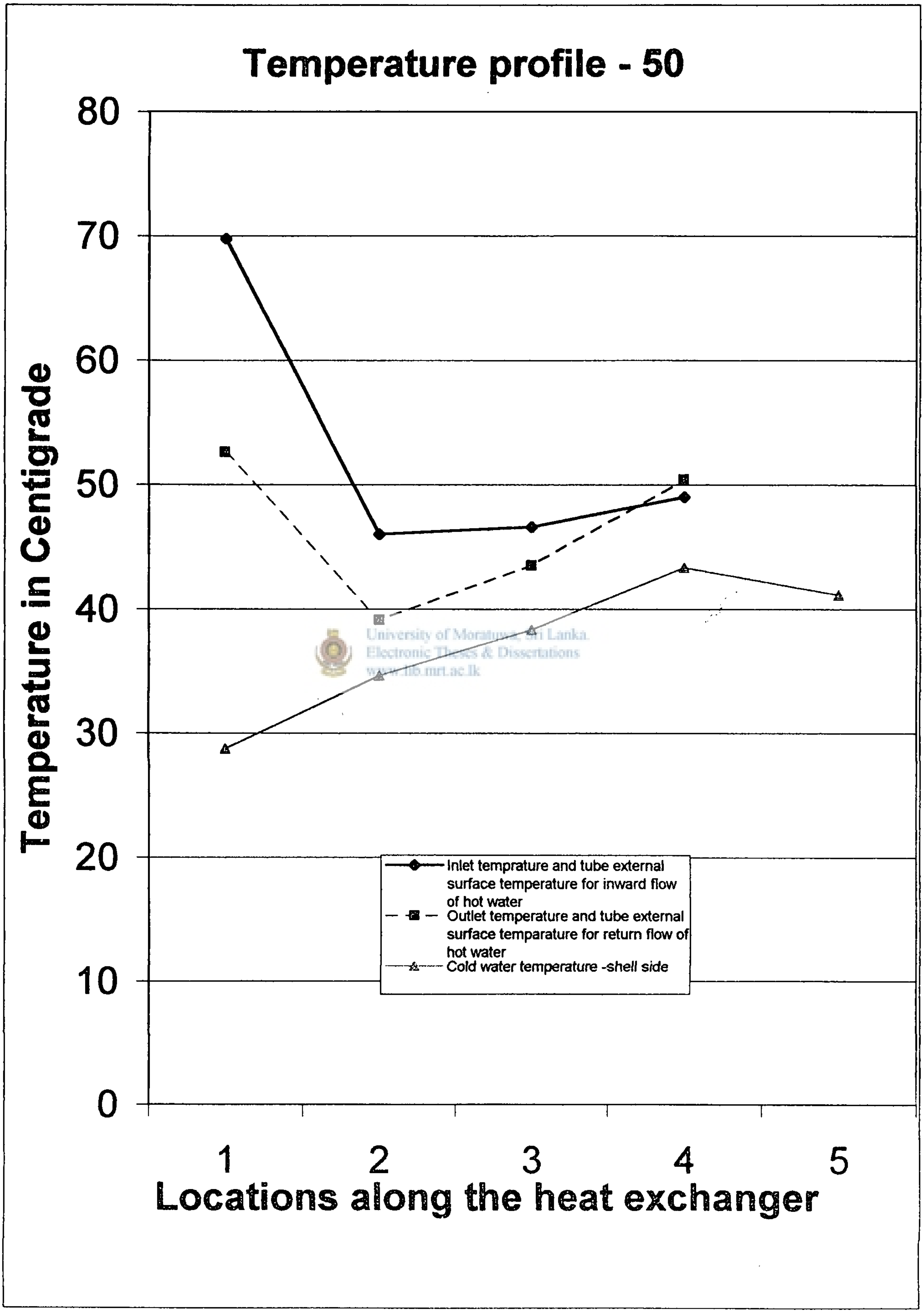
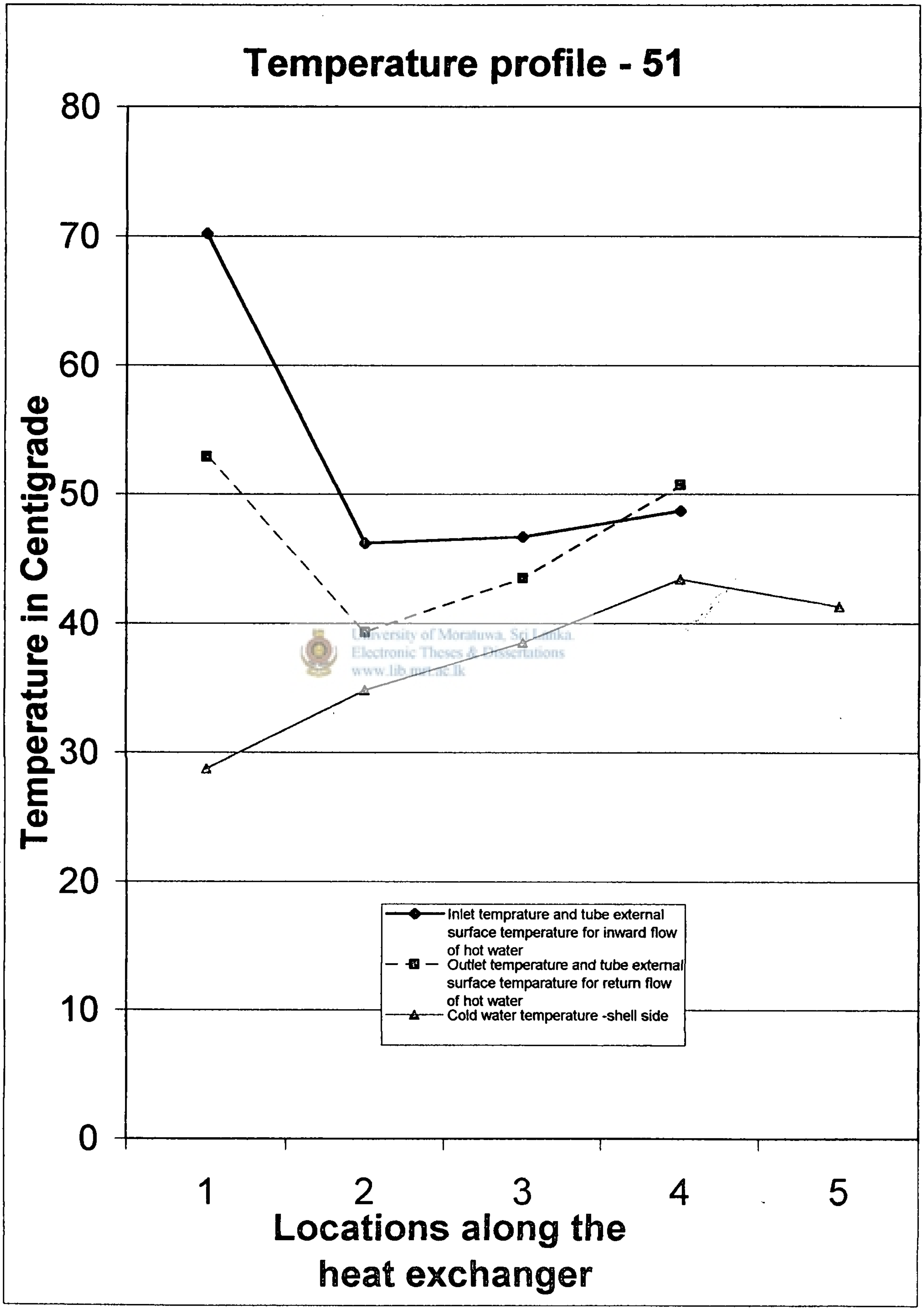


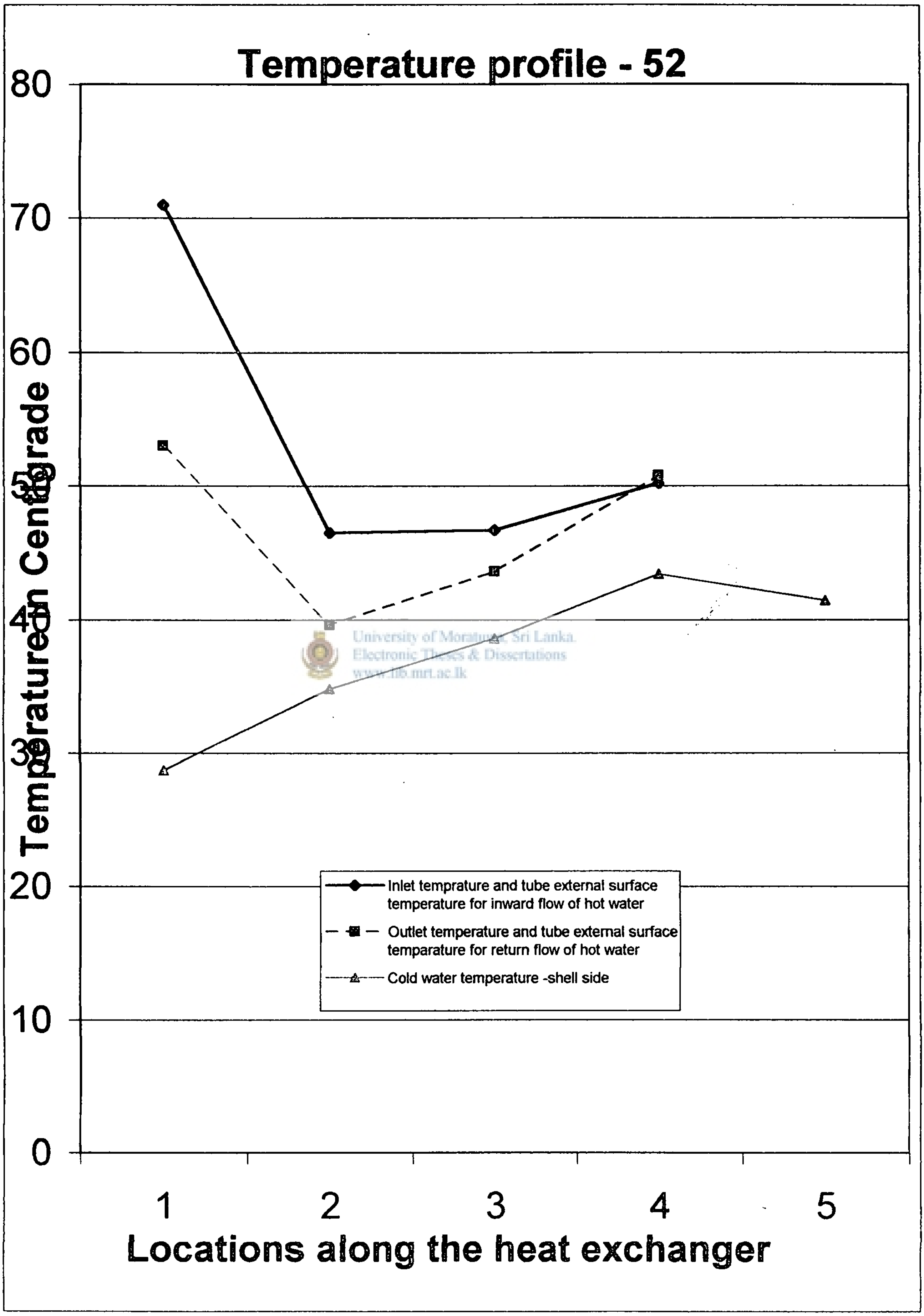
Temperature profile - 49
80
70
60
50
40
30
20
10
0
Temperature in Centigrade
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side



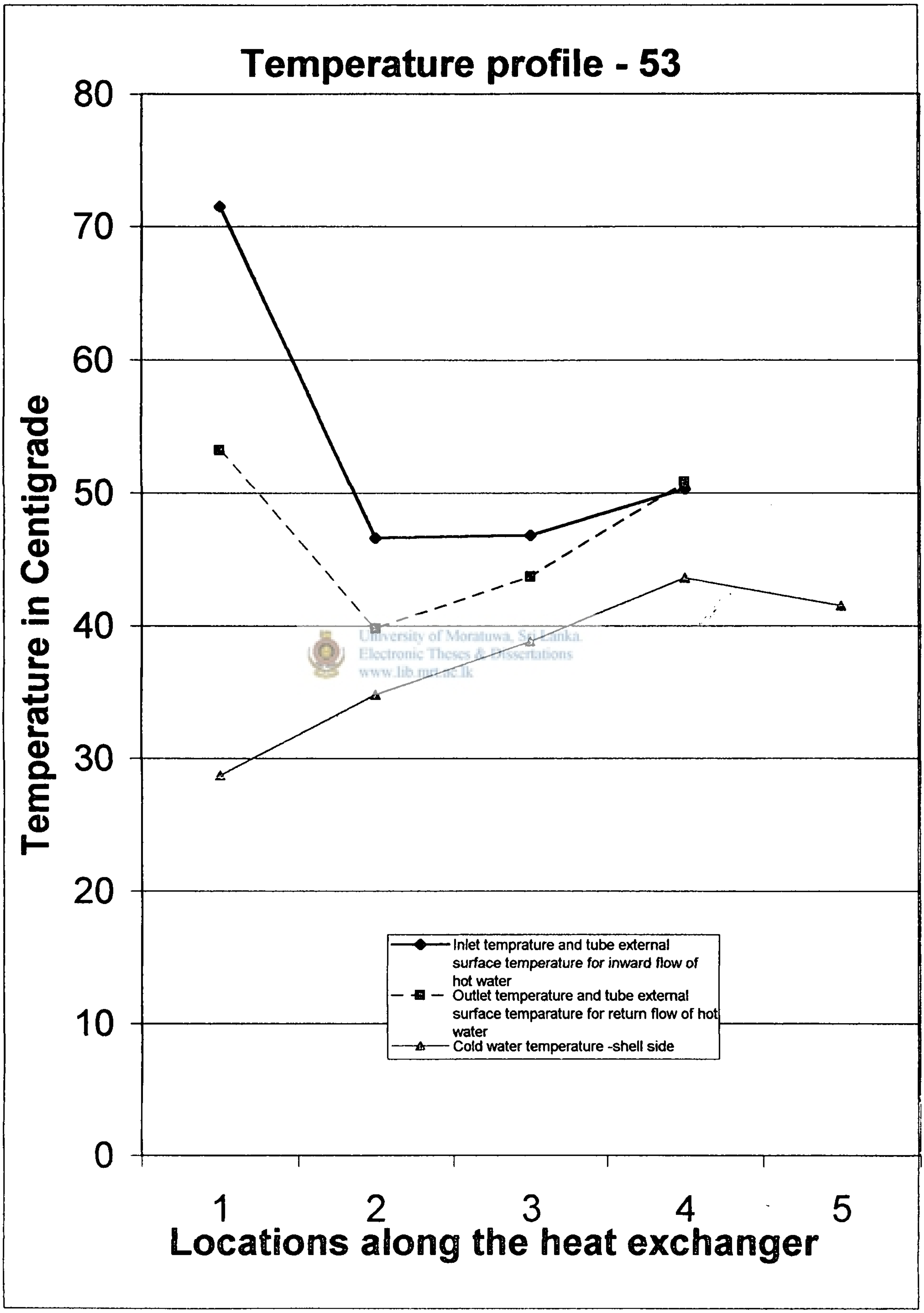
Temperature profile - 50
80
70
60
50
40
30
20
10
0
Temperature in Centigrade
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side



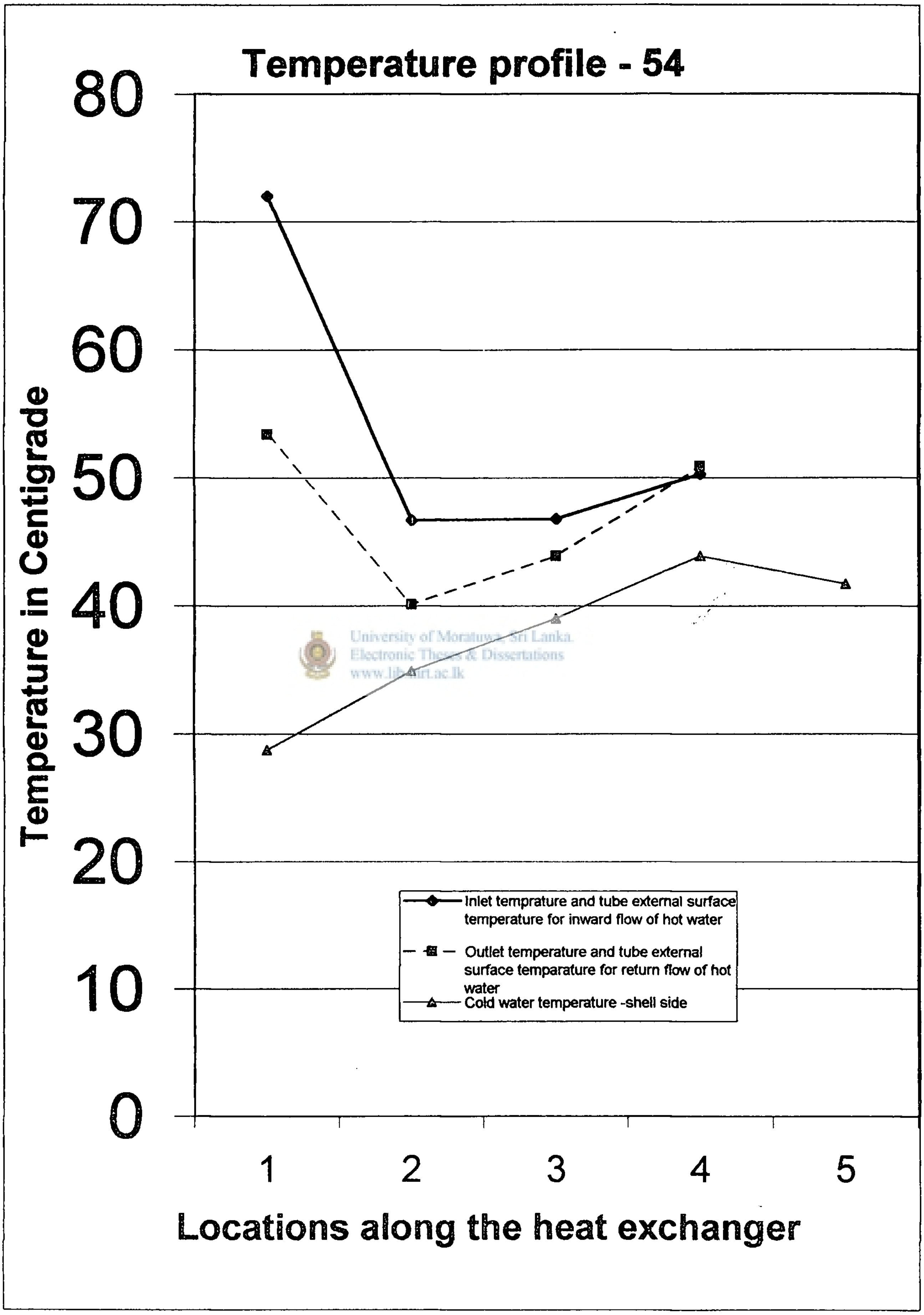
Temperature profile - 51
Temperature in Centigrade
80
70
60
50
40
30
20
10
0
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side



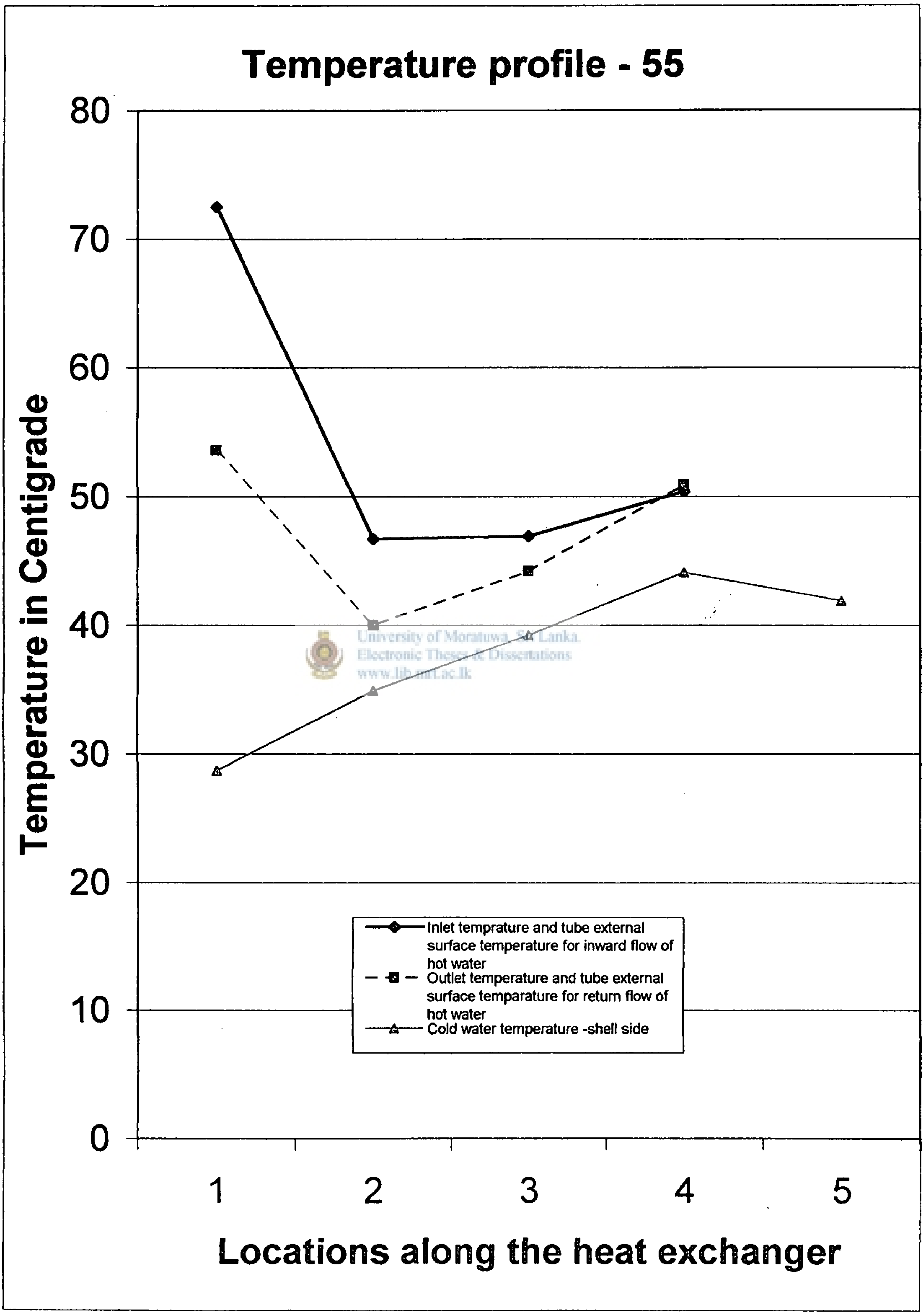
Temperature profile - 52
80
70
60
50
40
30
20
10
0
Temperature in Centigrade
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side



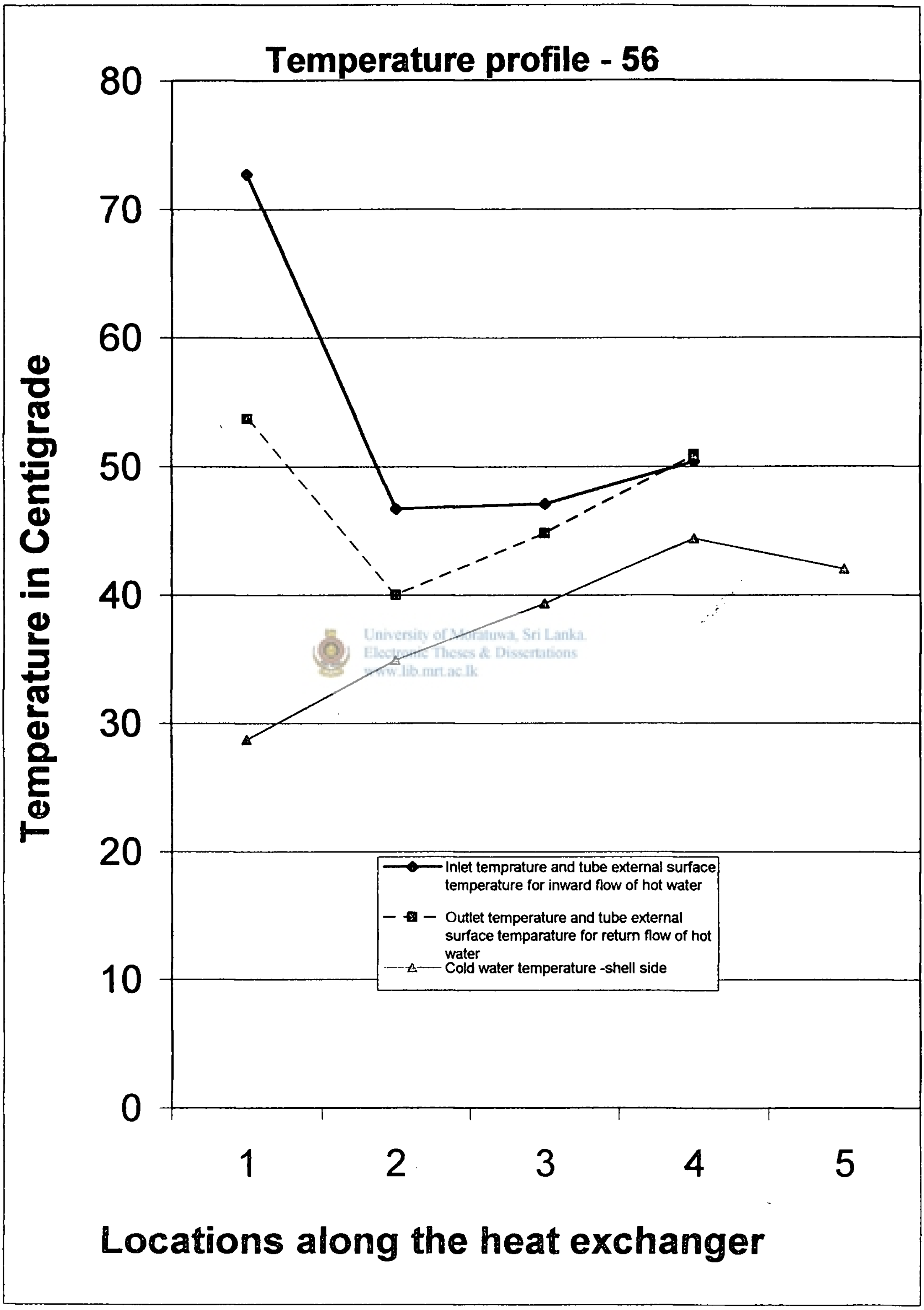
Temperature profile - 53
80
70
60
50
40
30
20
10
0
Temperature in Centigrade
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side



Temperature profile - 54
80
70
60
50
40
30
20
10
0
Temperature in Centigrade
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side
1
2
3
4
5
Locations along the heat exchanger



Temperature profile - 55
80
70
60
50
40
30
20
10
0
Temperature in Centigrade
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side


Temperature profile - 56
Temperature in Centigrade
80
70
60
50
40
30
20
10
0
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side
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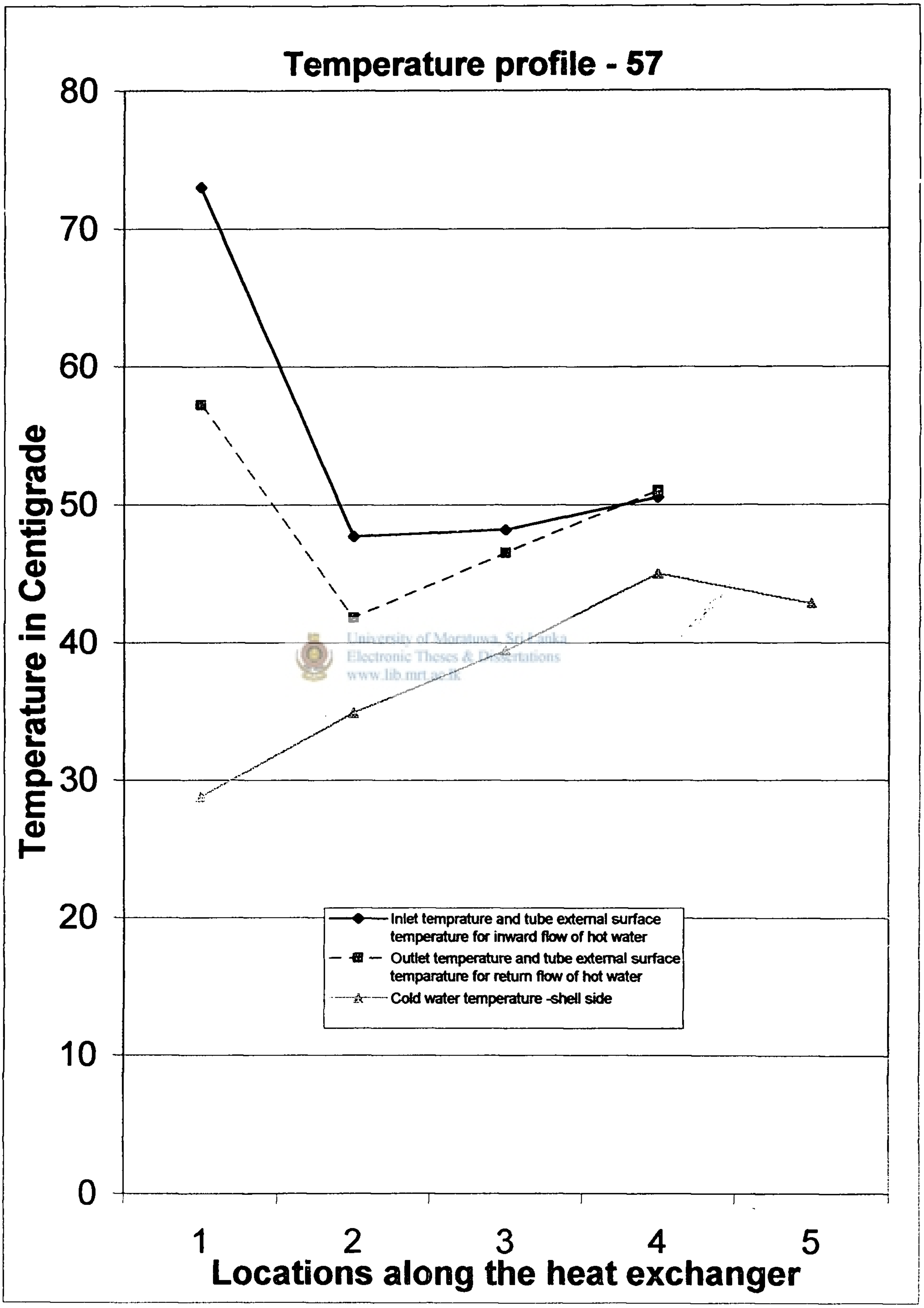
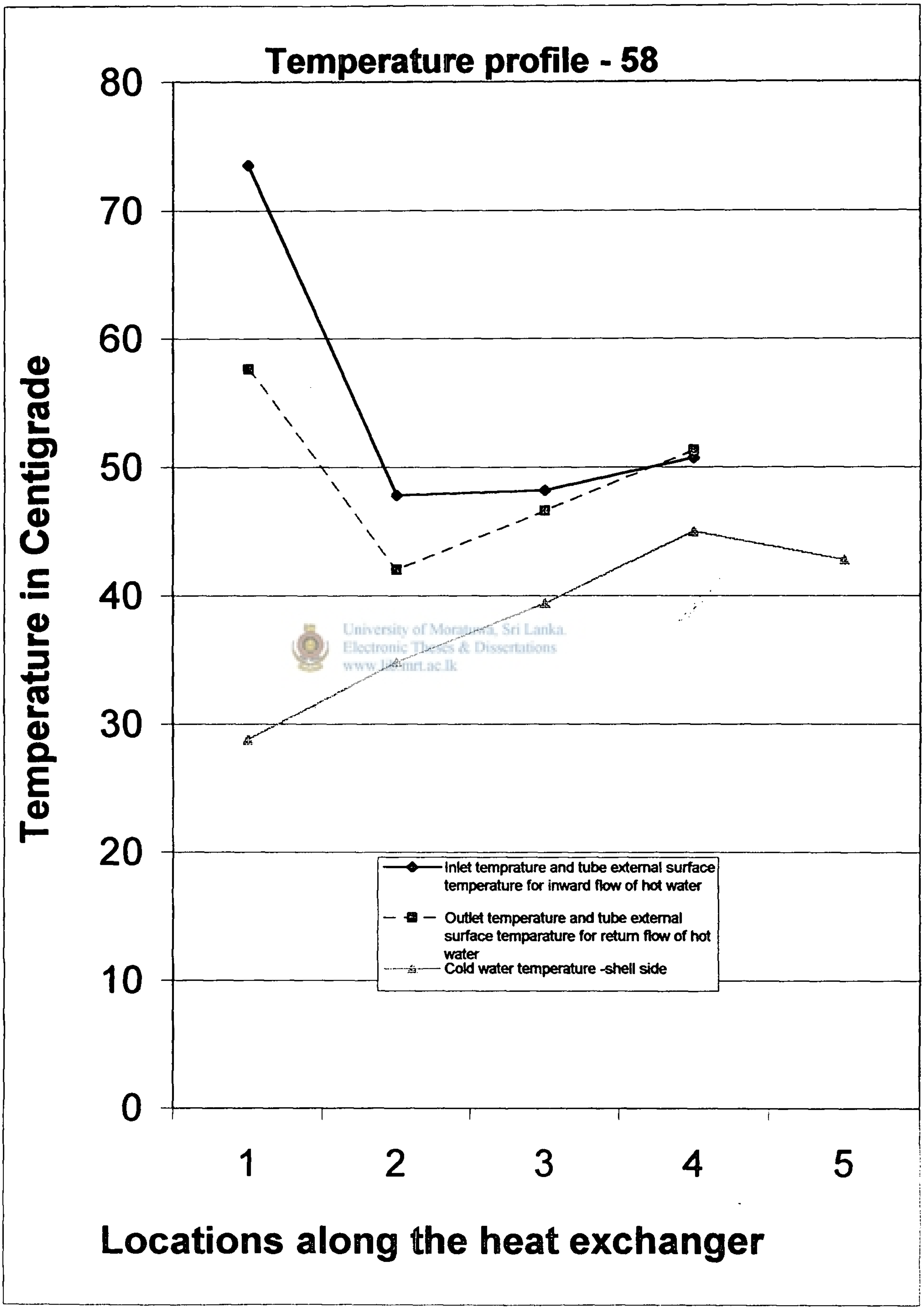
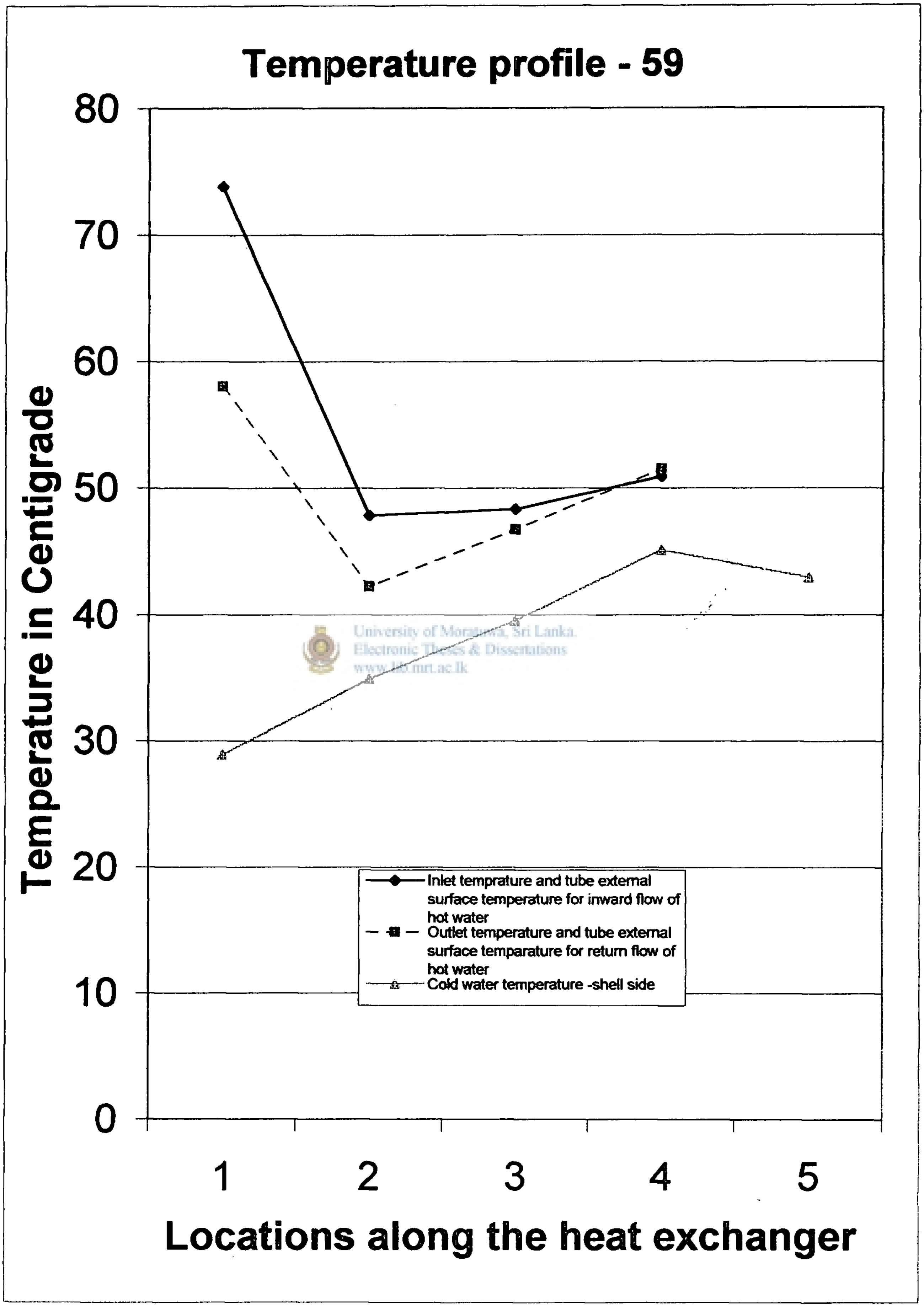
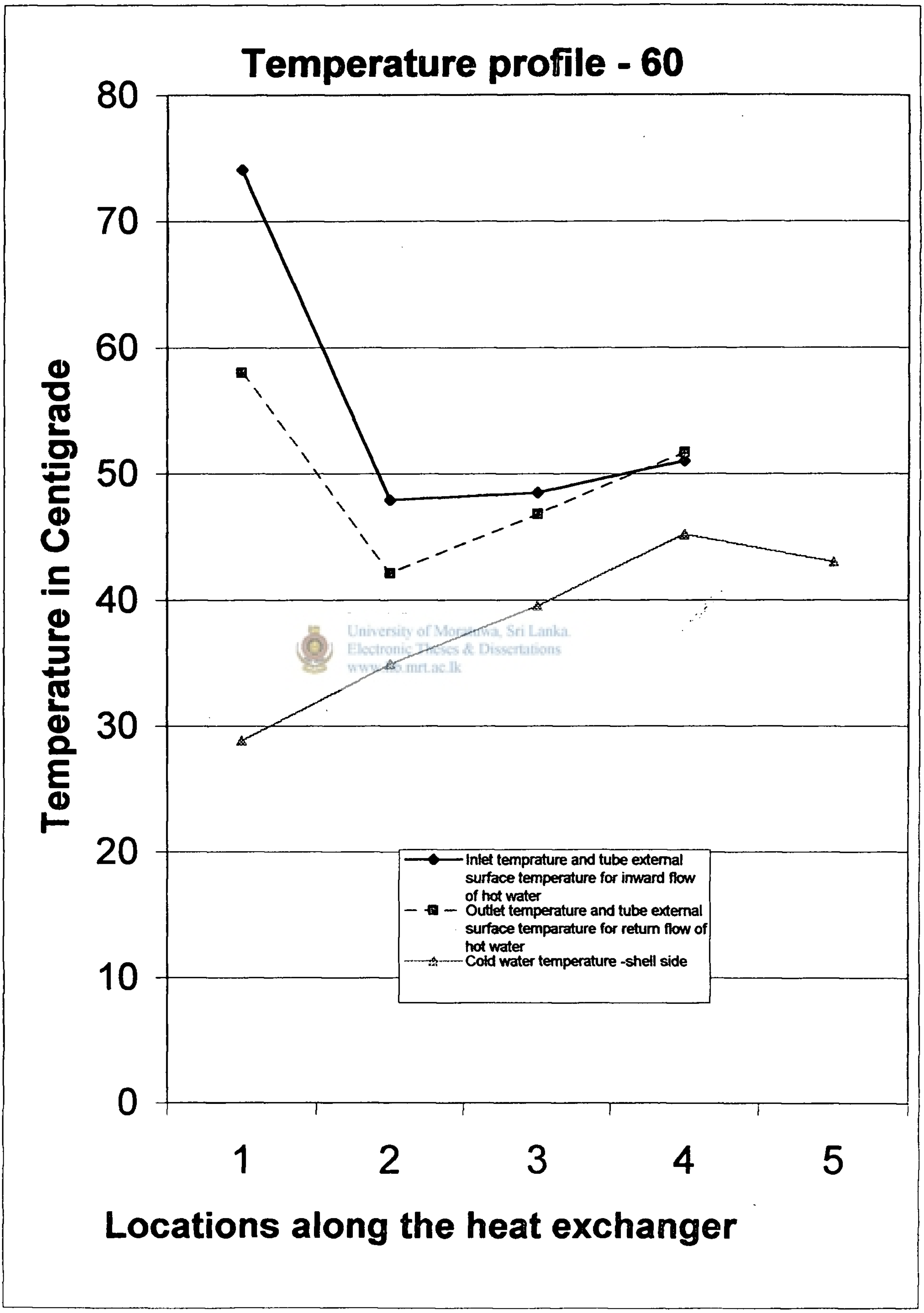


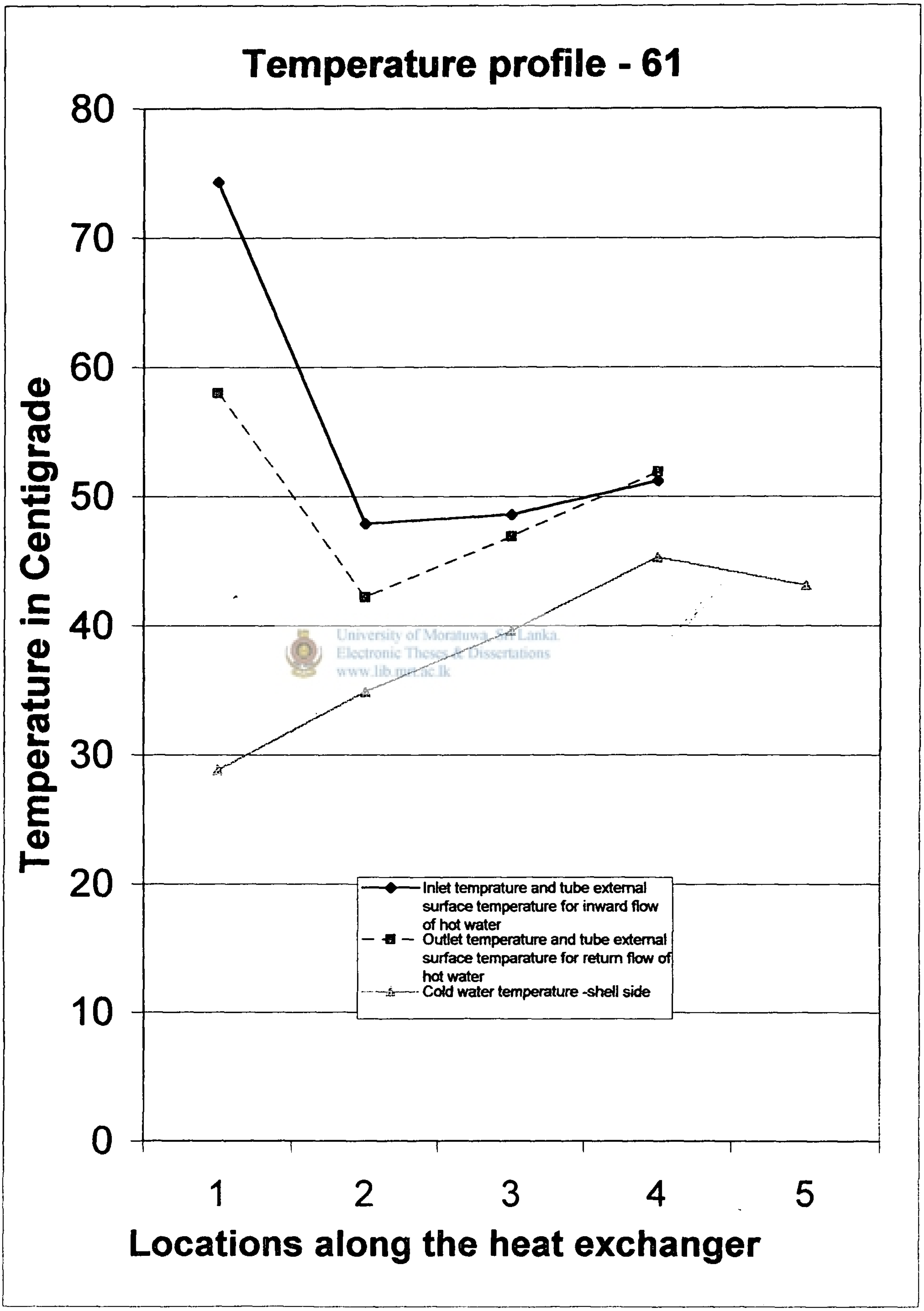
Temperature profile - 57
80
70
60
50
40
30
20
10
0
Temperature in Centigrade
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side
1
2
3
4
5
Locations along the heat exchanger



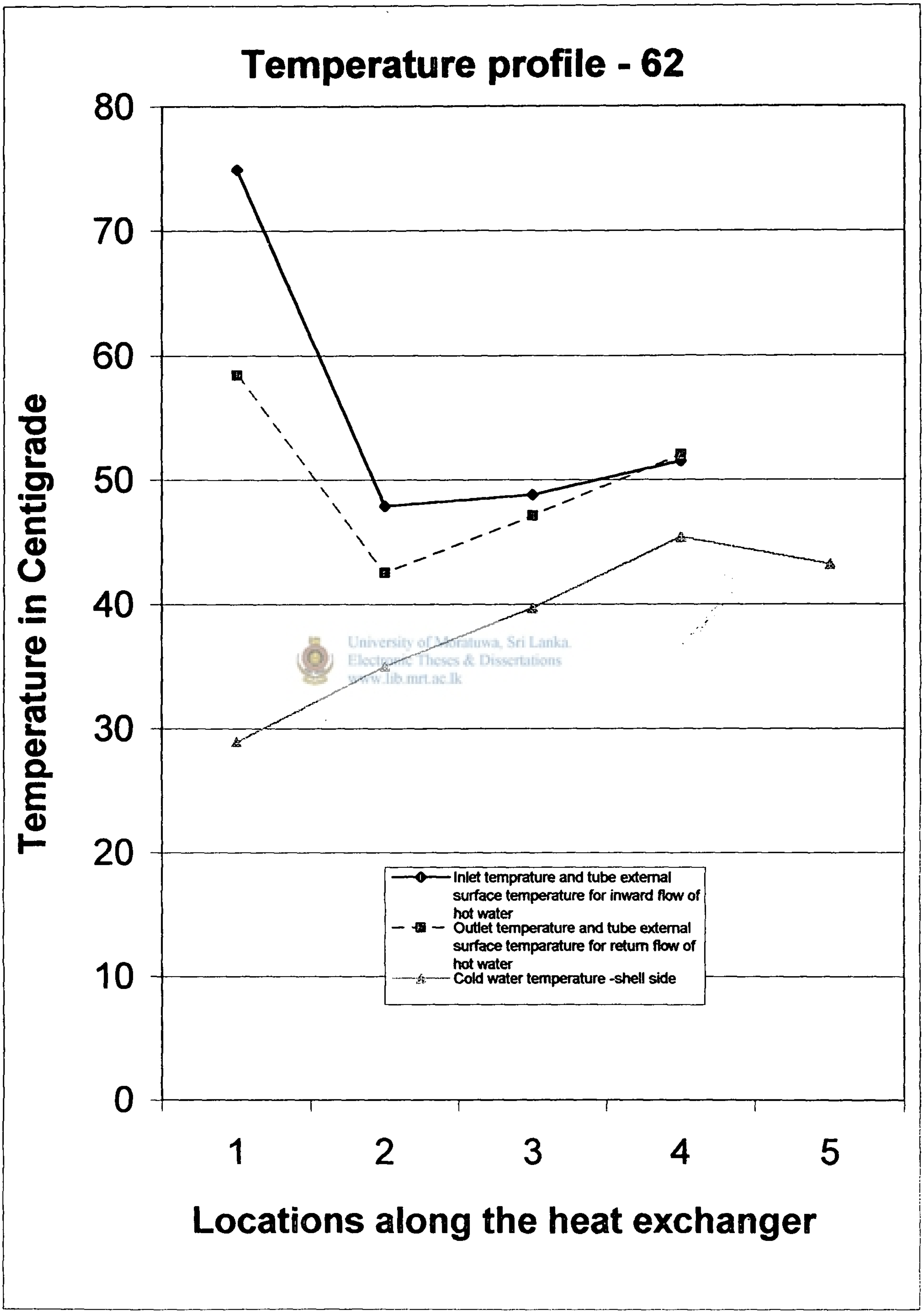
Temperature profile - 58
Temperature in Centigrade
80
70
60
50
40
30
20
10
0
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side


Temperature profile - 59
80
70
60
50
40
30
20
10
0
Temperature in Centigrade
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side


Temperature profile - 60
Temperature in Centigrade
0
10
20
30
40
50
60
70
80
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side



Temperature profile - 61
Temperature in Centigrade
80
70
60
50
40
30
20
10
0
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side



Temperature profile - 62
80
70
60
50
40
30
20
10
0
Temperature in Centigrade
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side
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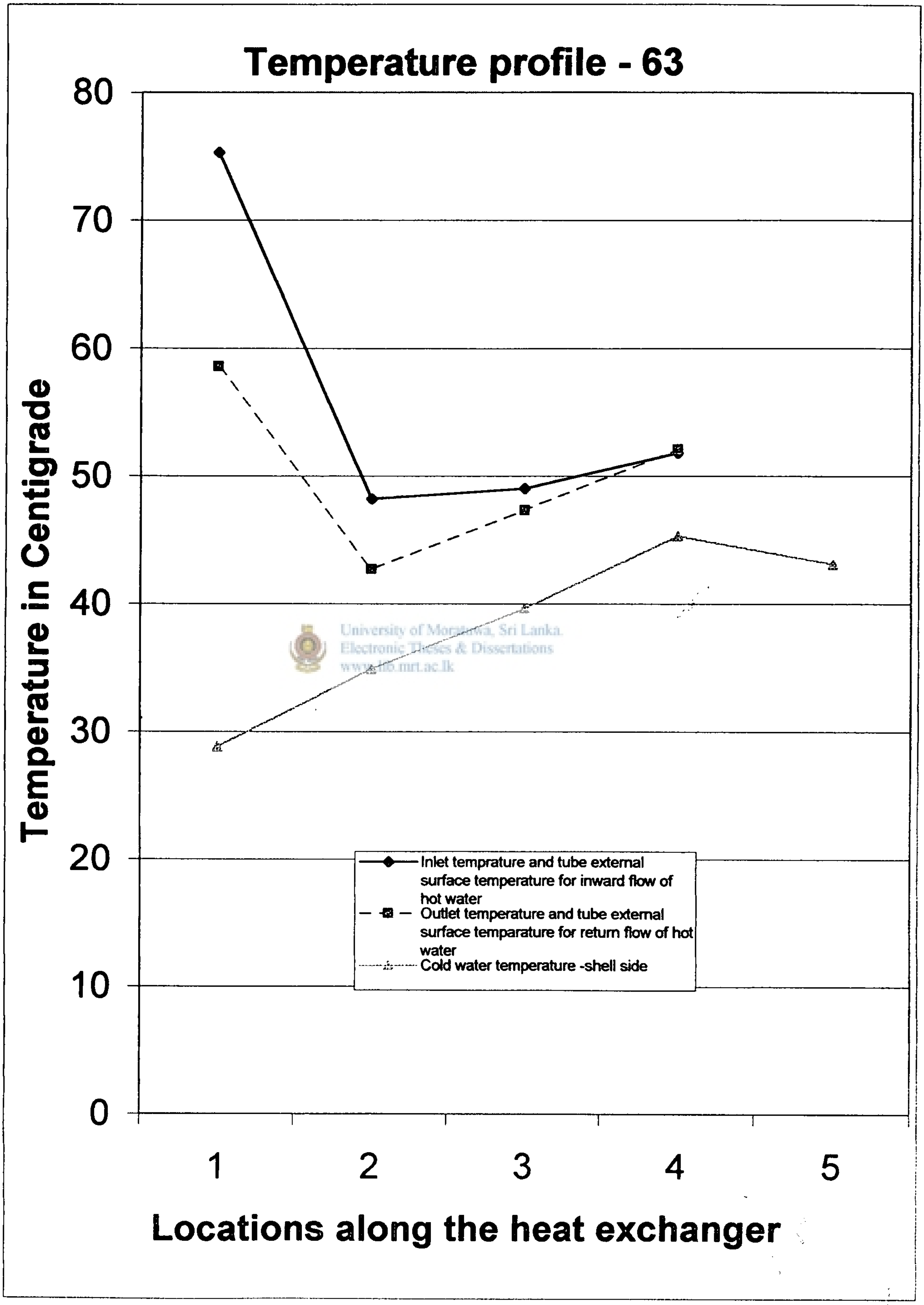
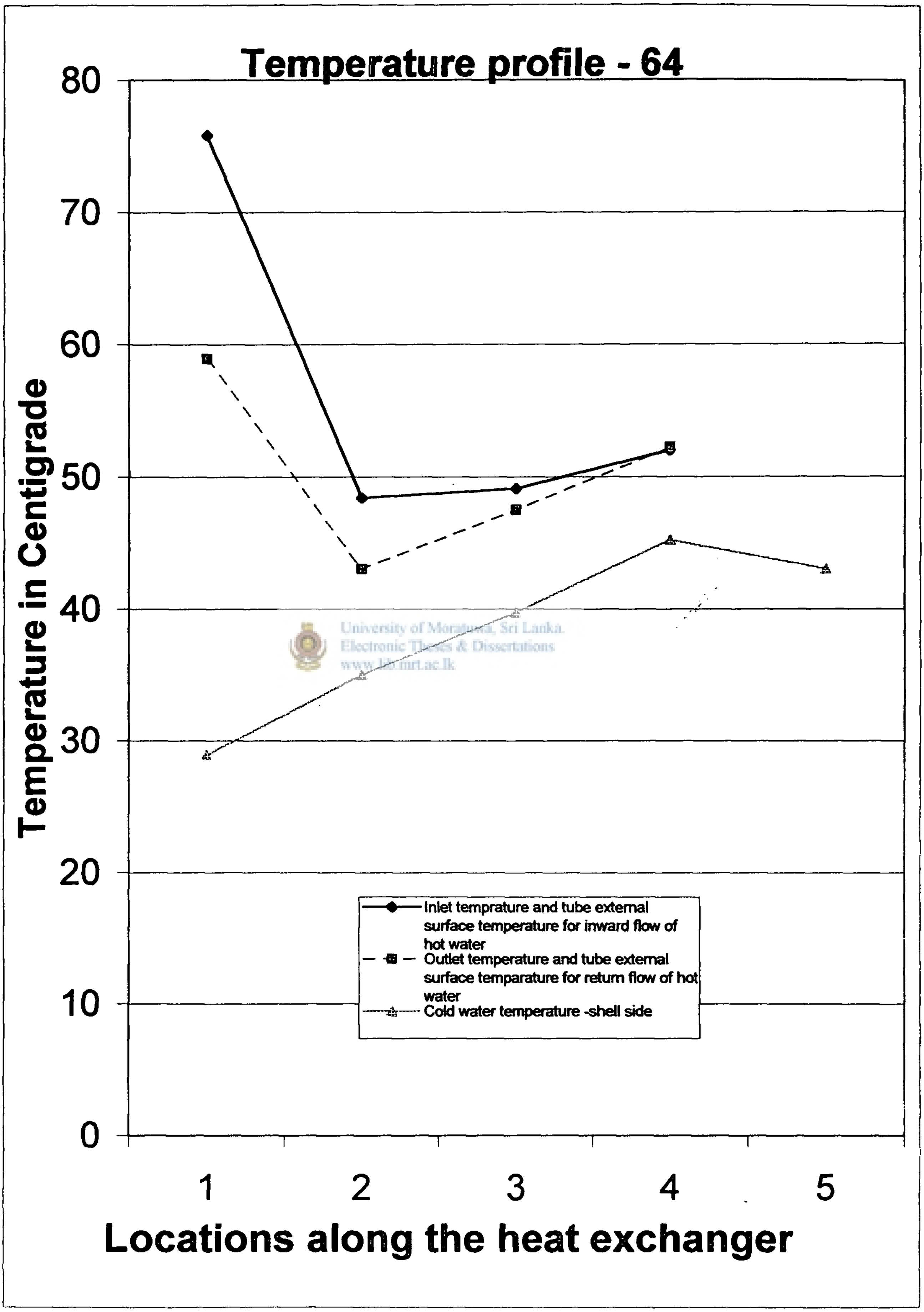
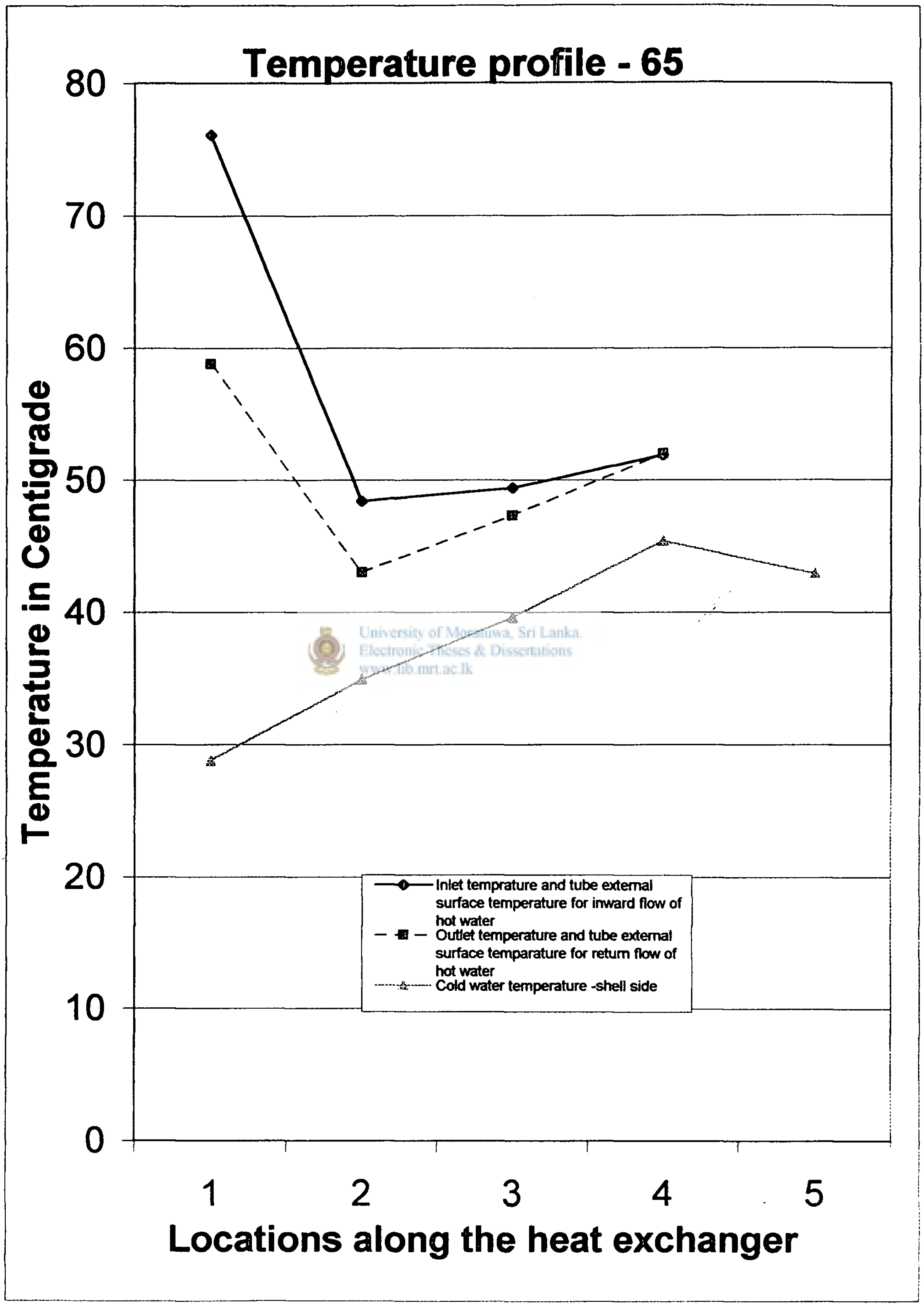


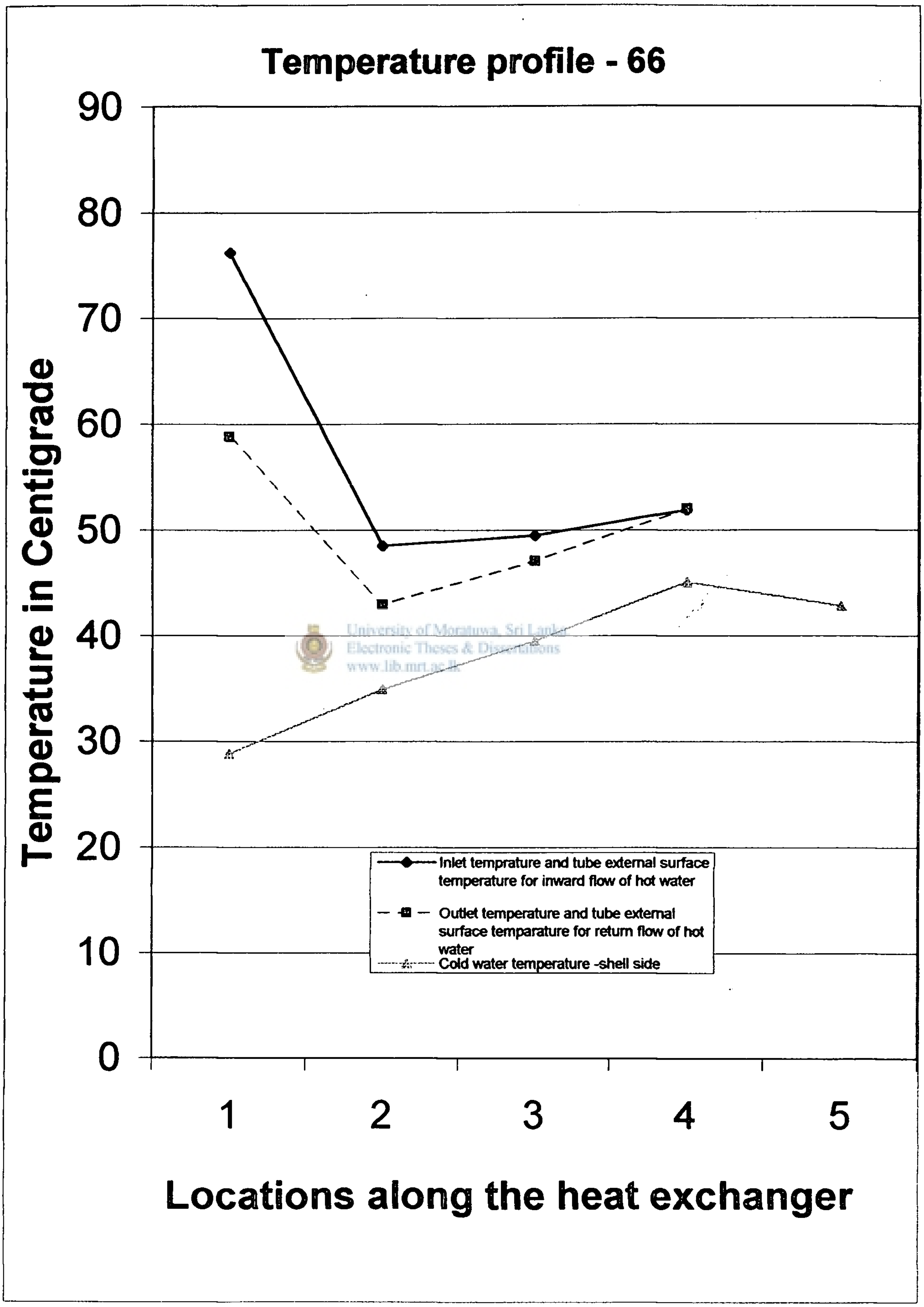
Temperature profile - 63
80
70
60
50
40
30
20
10
0
Temperature in Centigrade
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side

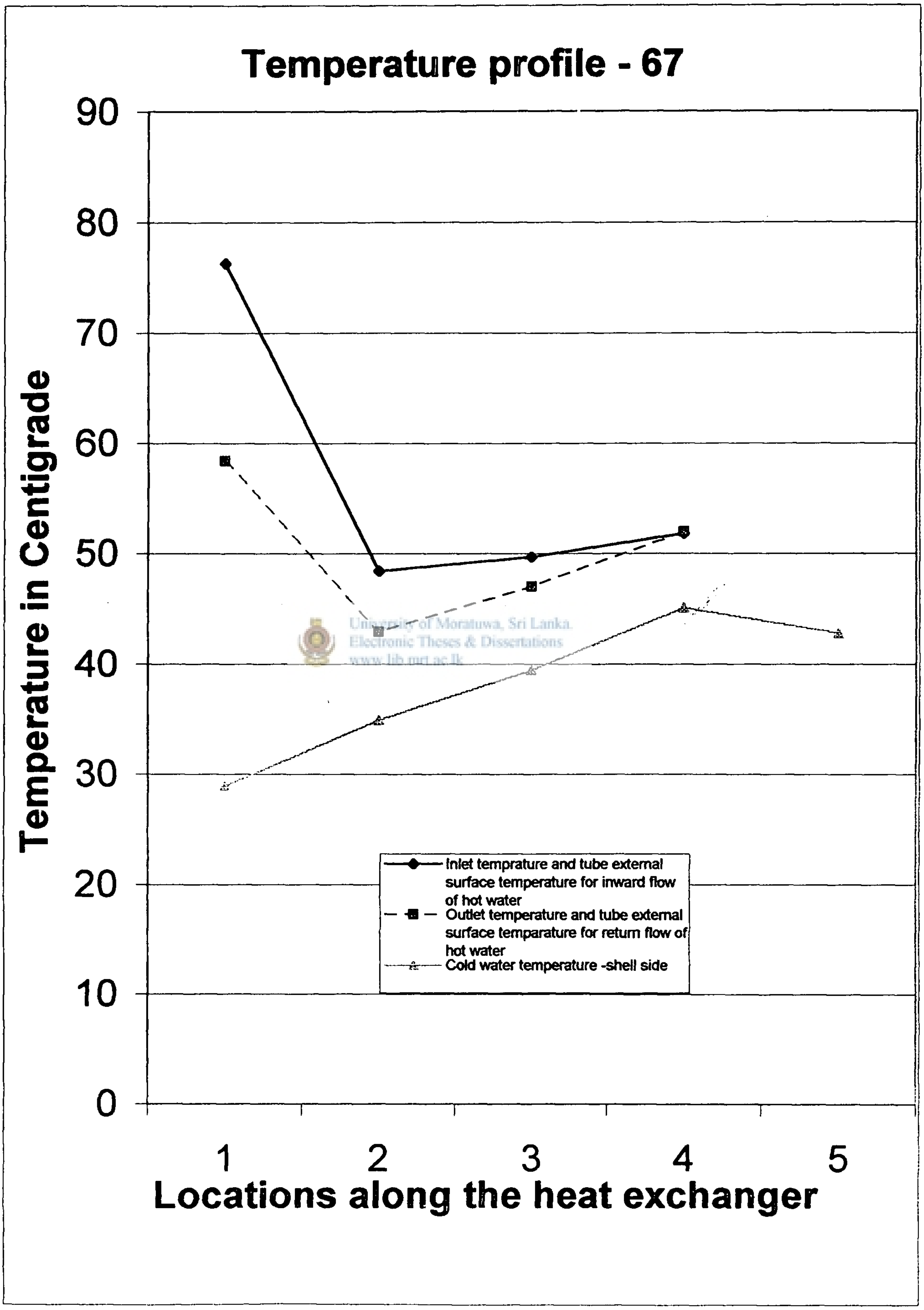


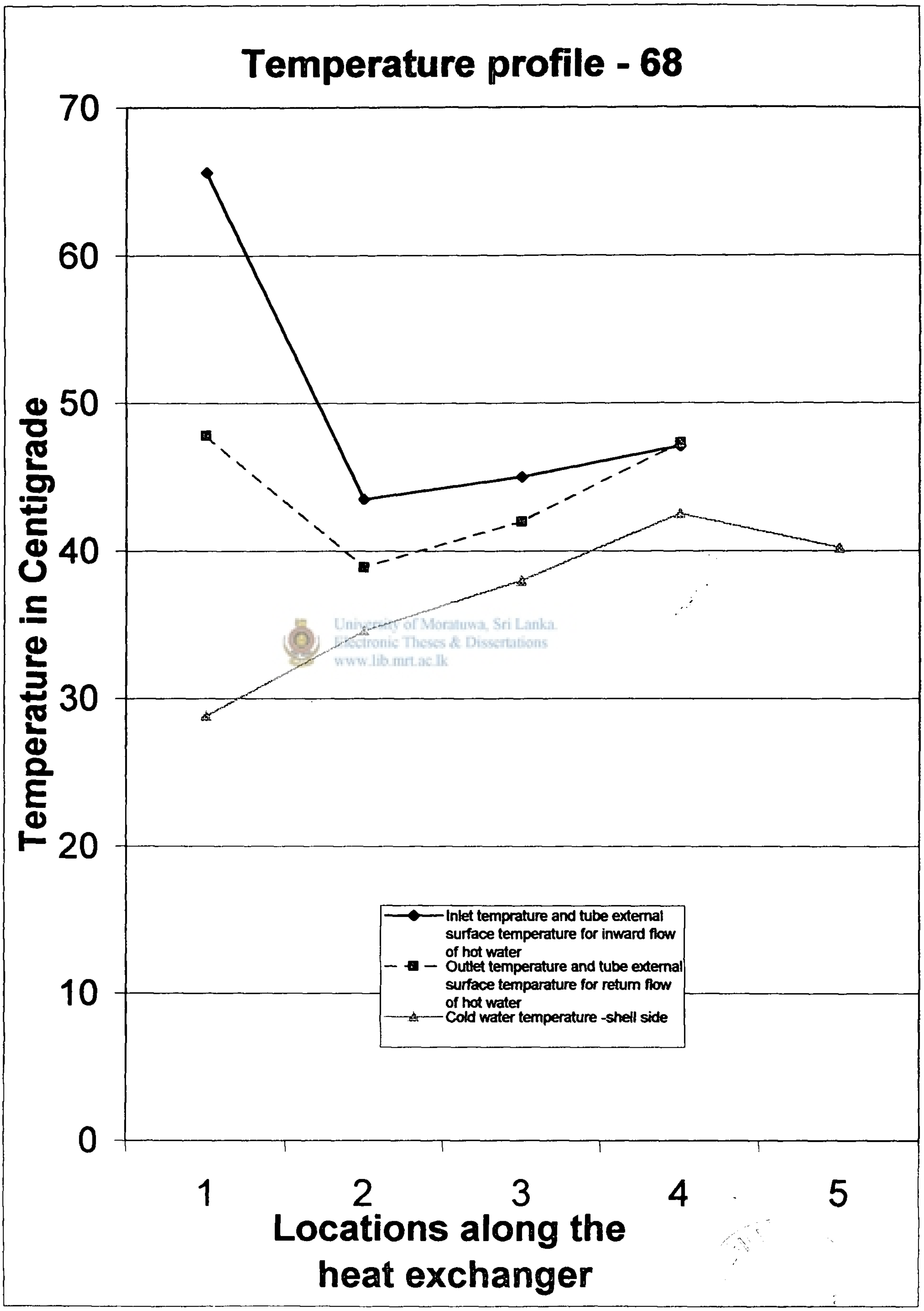
Temperature profile - 64
Temperature in Centigrade
80
70
60
50
40
30
20
10
0
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side



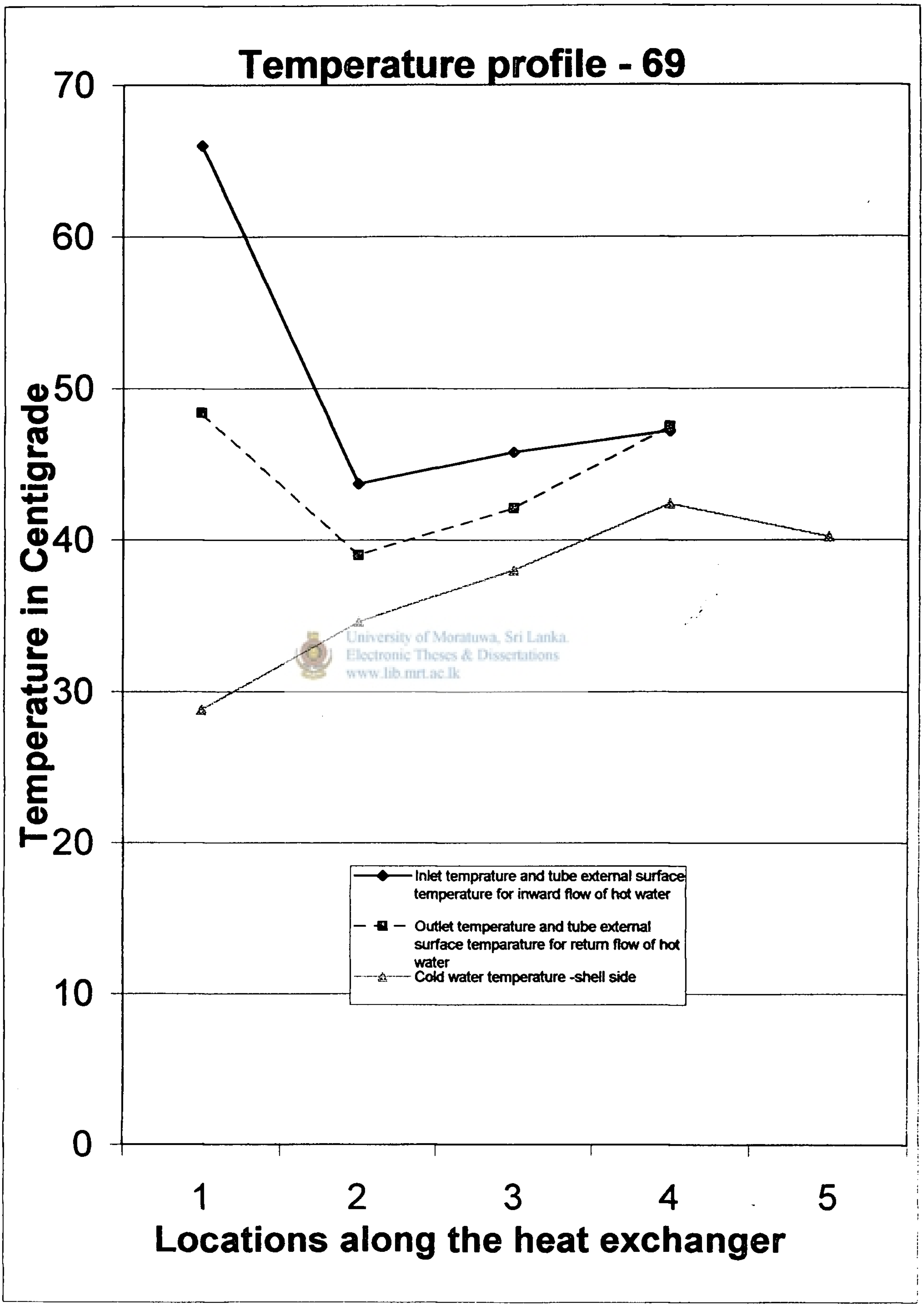
Temperature profile - 65
80
70
60
50
40
30
20
10
0
Temperature in Centigrade
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side


Temperature profile - 66
Temperature in Centigrade
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side

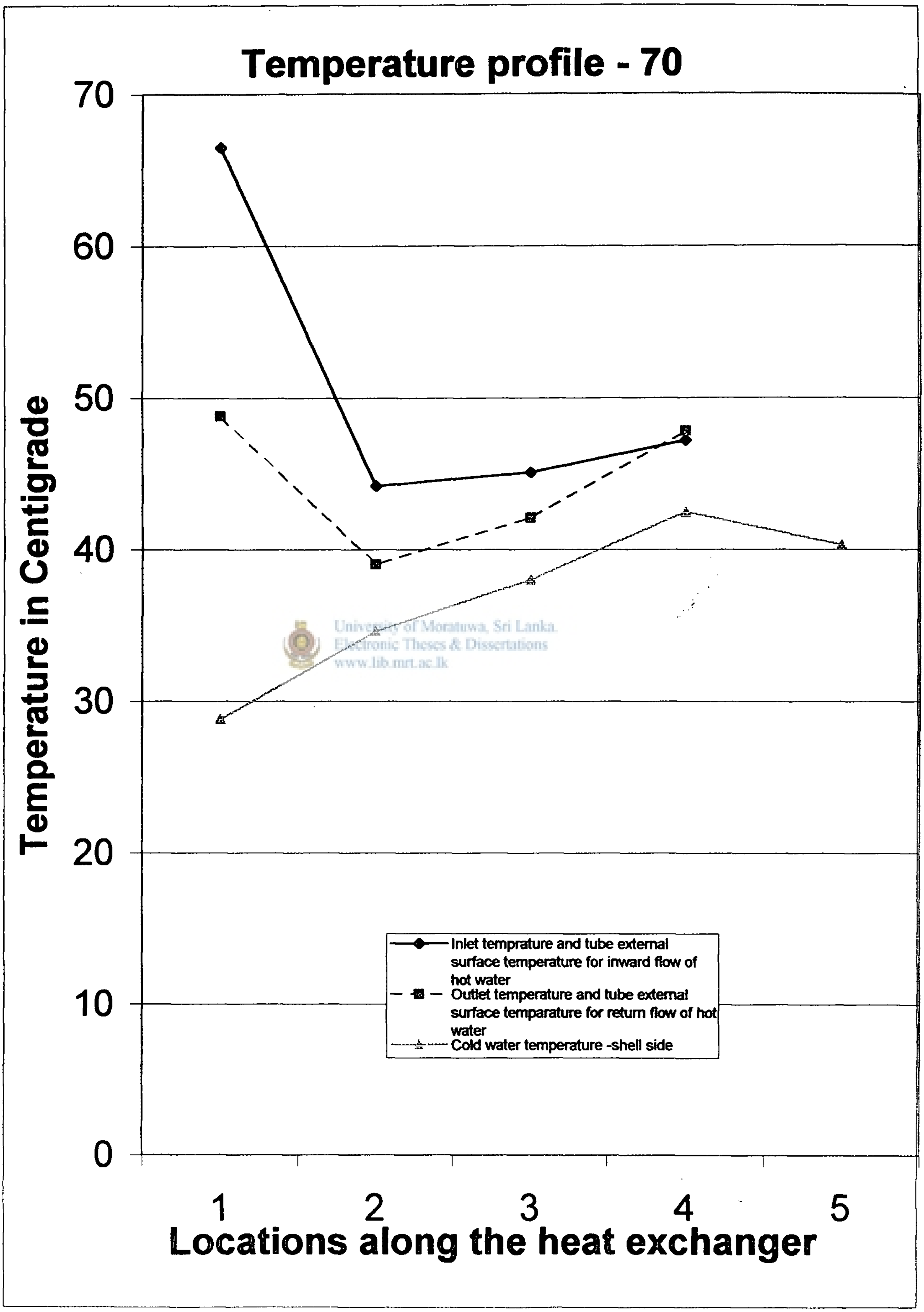

Temperature profile - 67
90
80
70
60
50
40
30
20
10
0
Temperature in Centigrade
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side



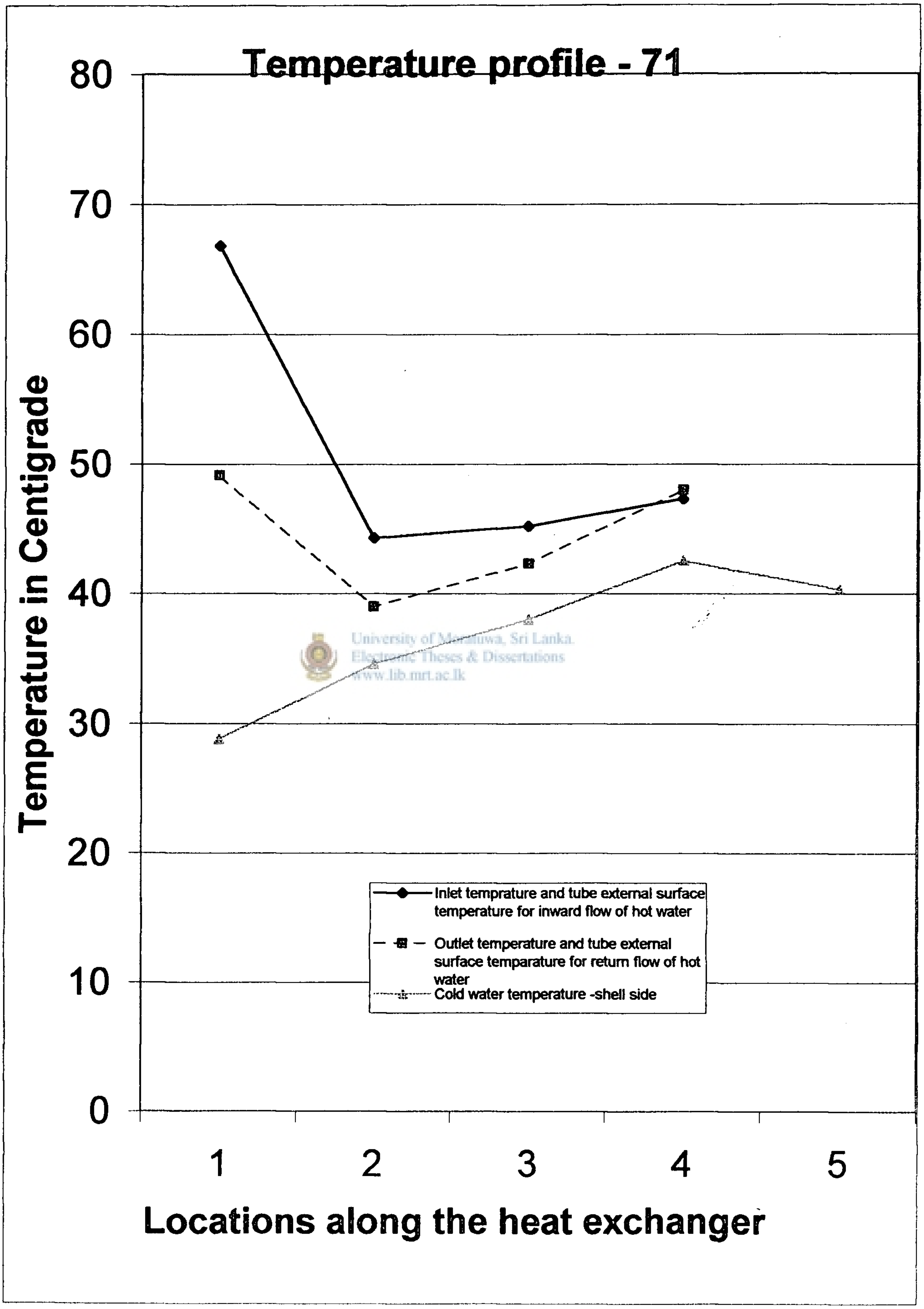
Temperature profile - 68
70
60
50
40
30
20
10
0
Temperature in Centigrade
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side
1
2
3
4
5
Locations along the heat exchanger

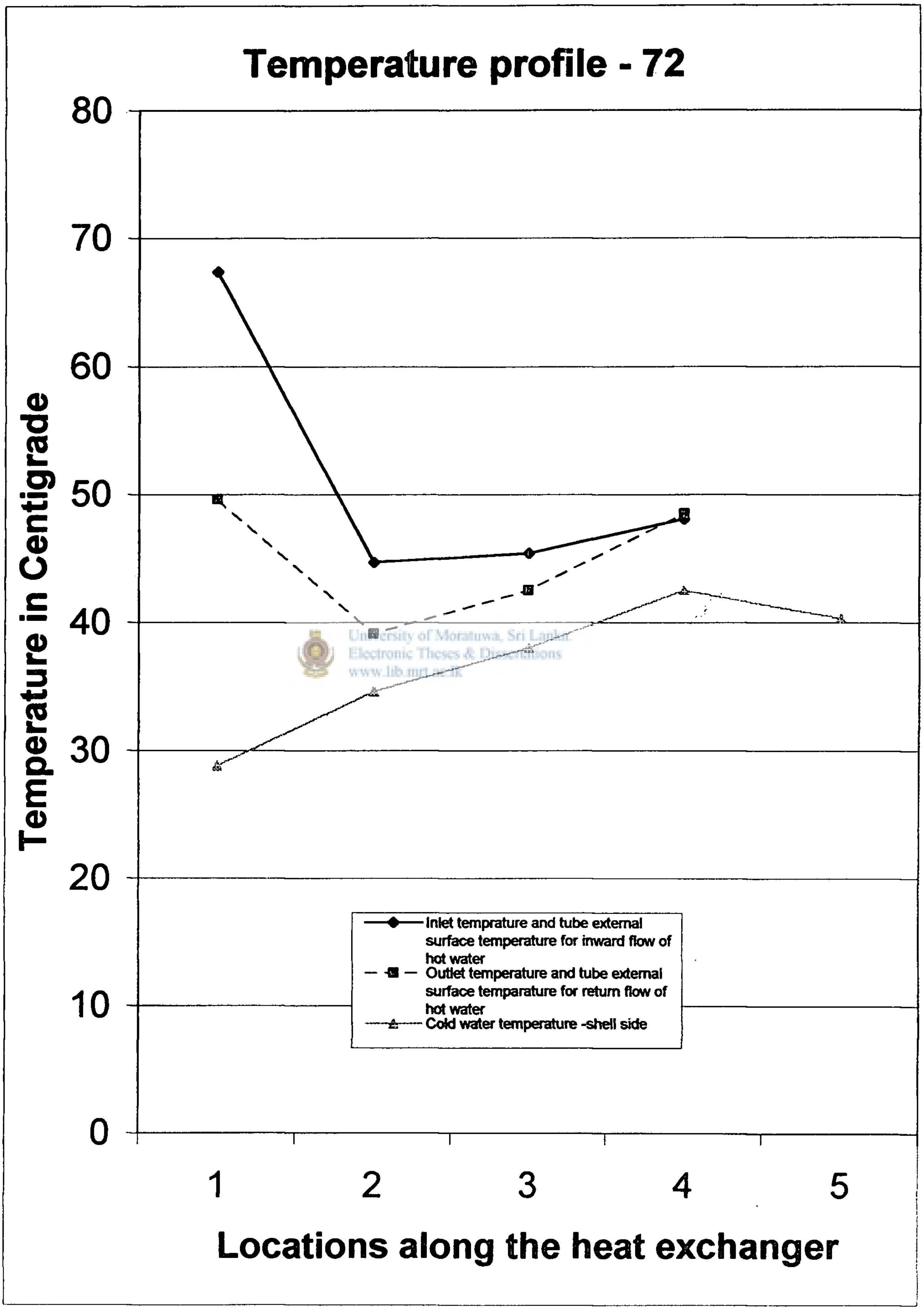


Temperature profile - 69
Temperature in Centigrade
70
60
50
40
30
20
10
0
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side

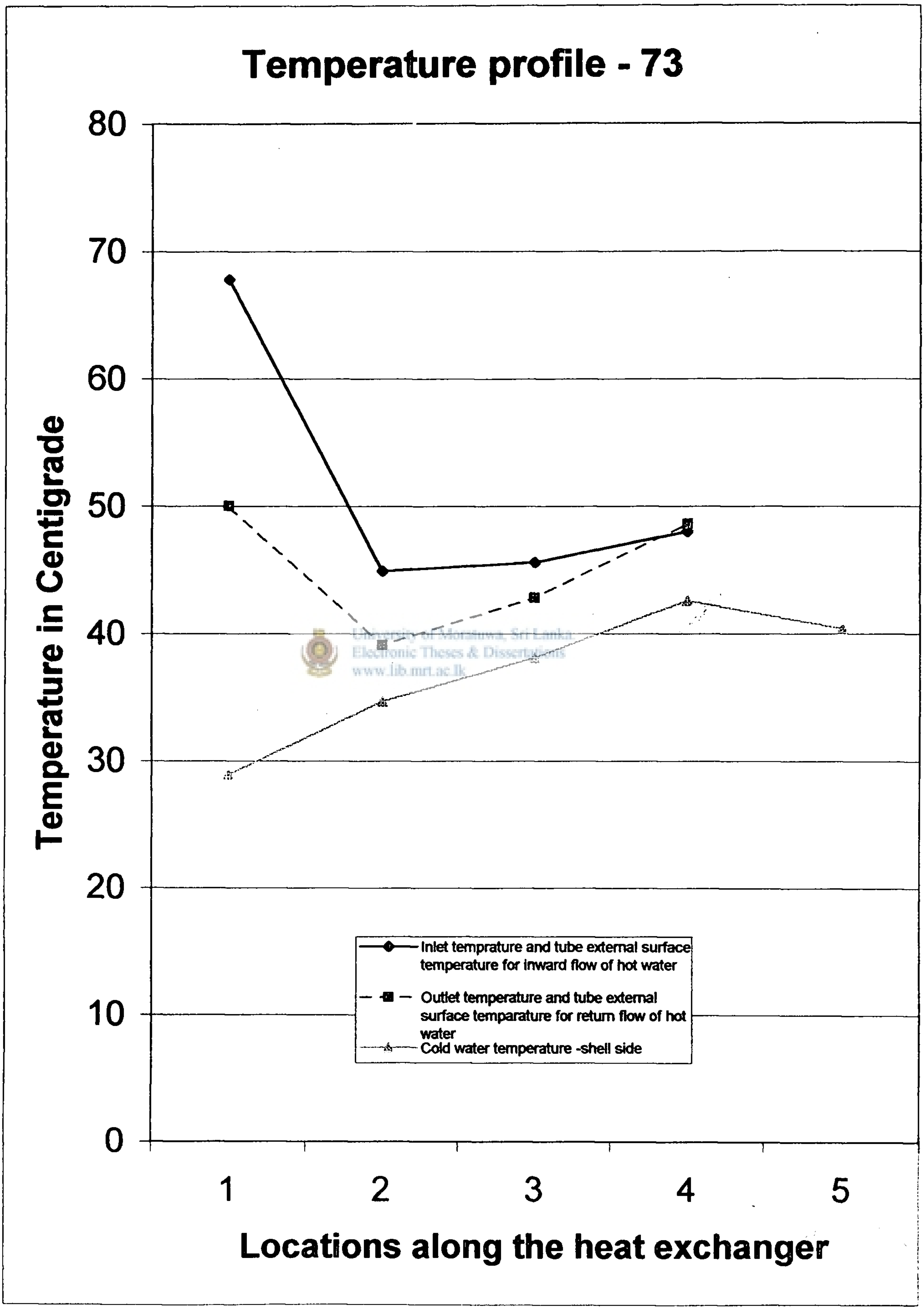


Temperature profile - 70
Temperature in Centigrade
70
60
50
40
30
20
10
0
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side

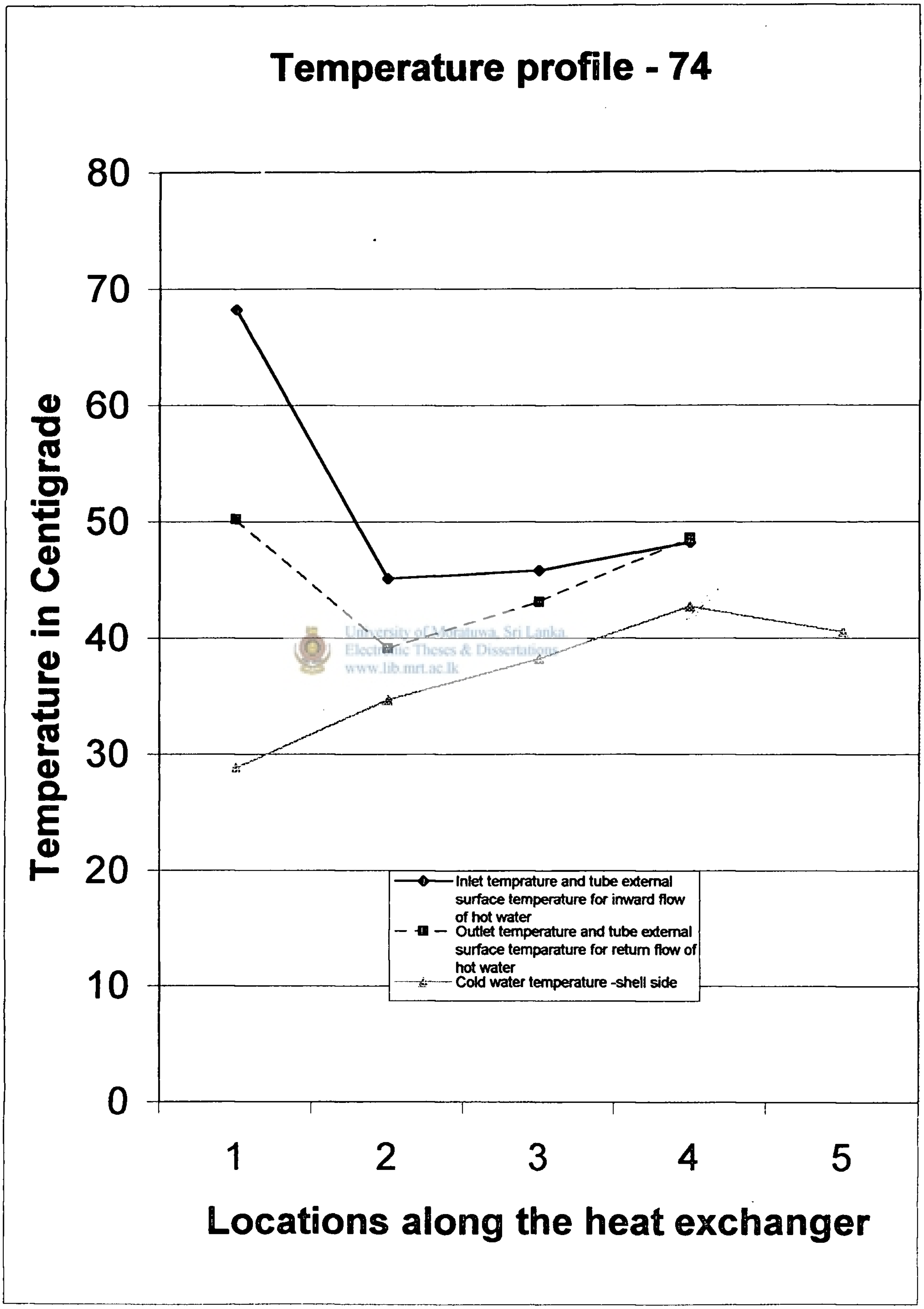

Temperature profile - 71
Temperature in Centigrade
80
70
60
50
40
30
20
10
0
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side



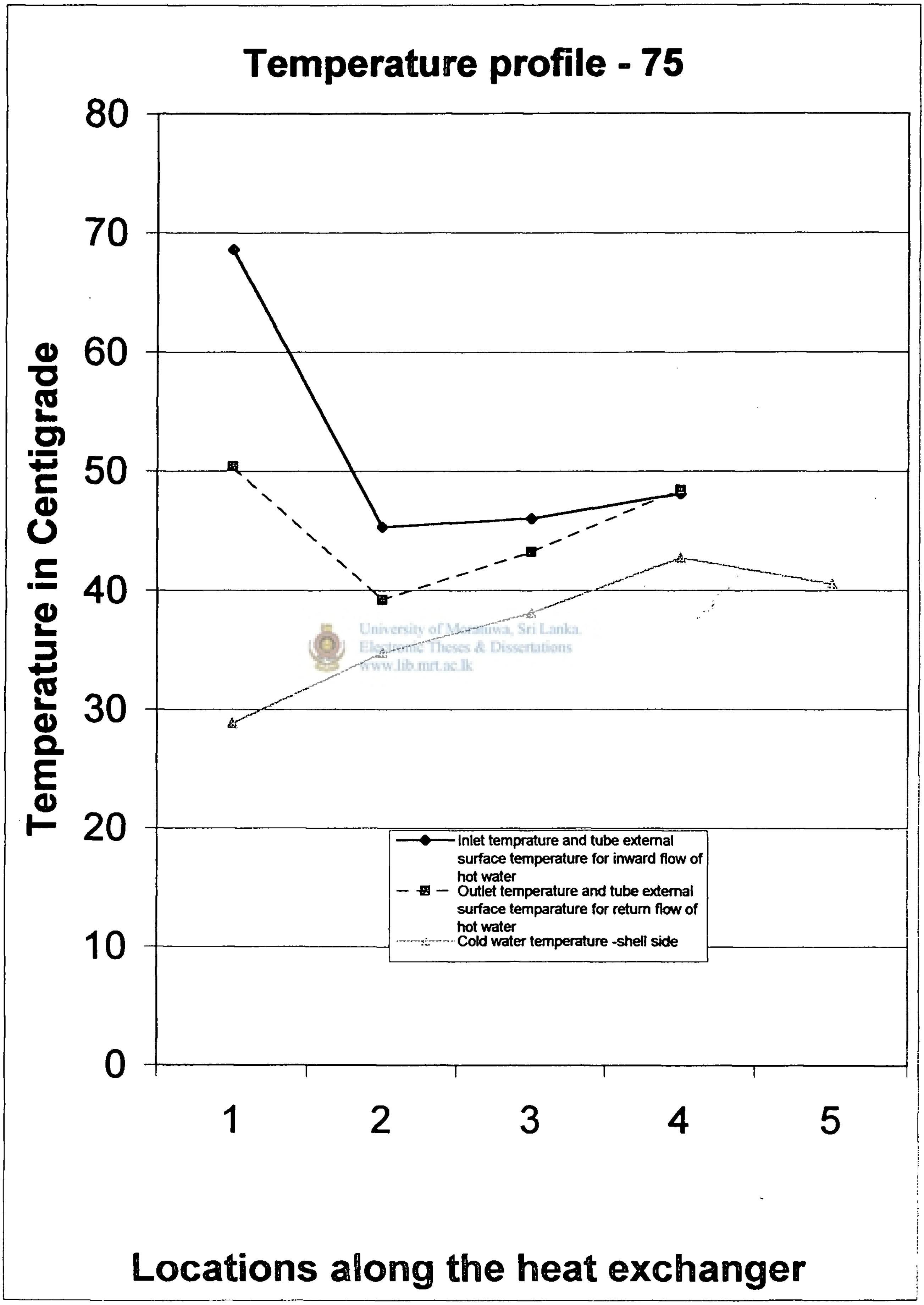
Temperature profile - 72
80
70
60
50
40
30
20
10
0
Temperature in Centigrade
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side



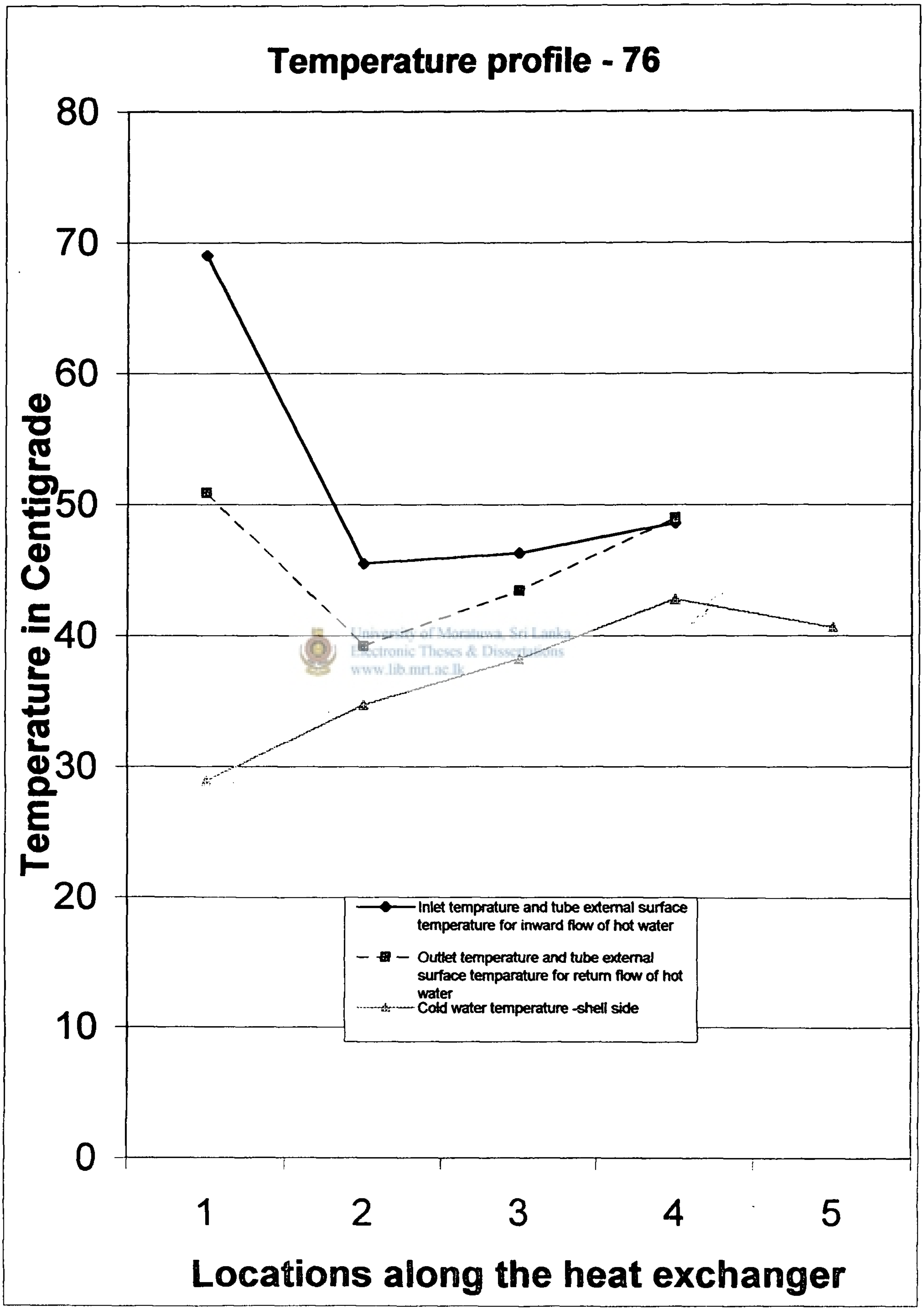
Temperature profile - 73
80
70
60
50
40
30
20
10
0
Temperature in Centigrade
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side

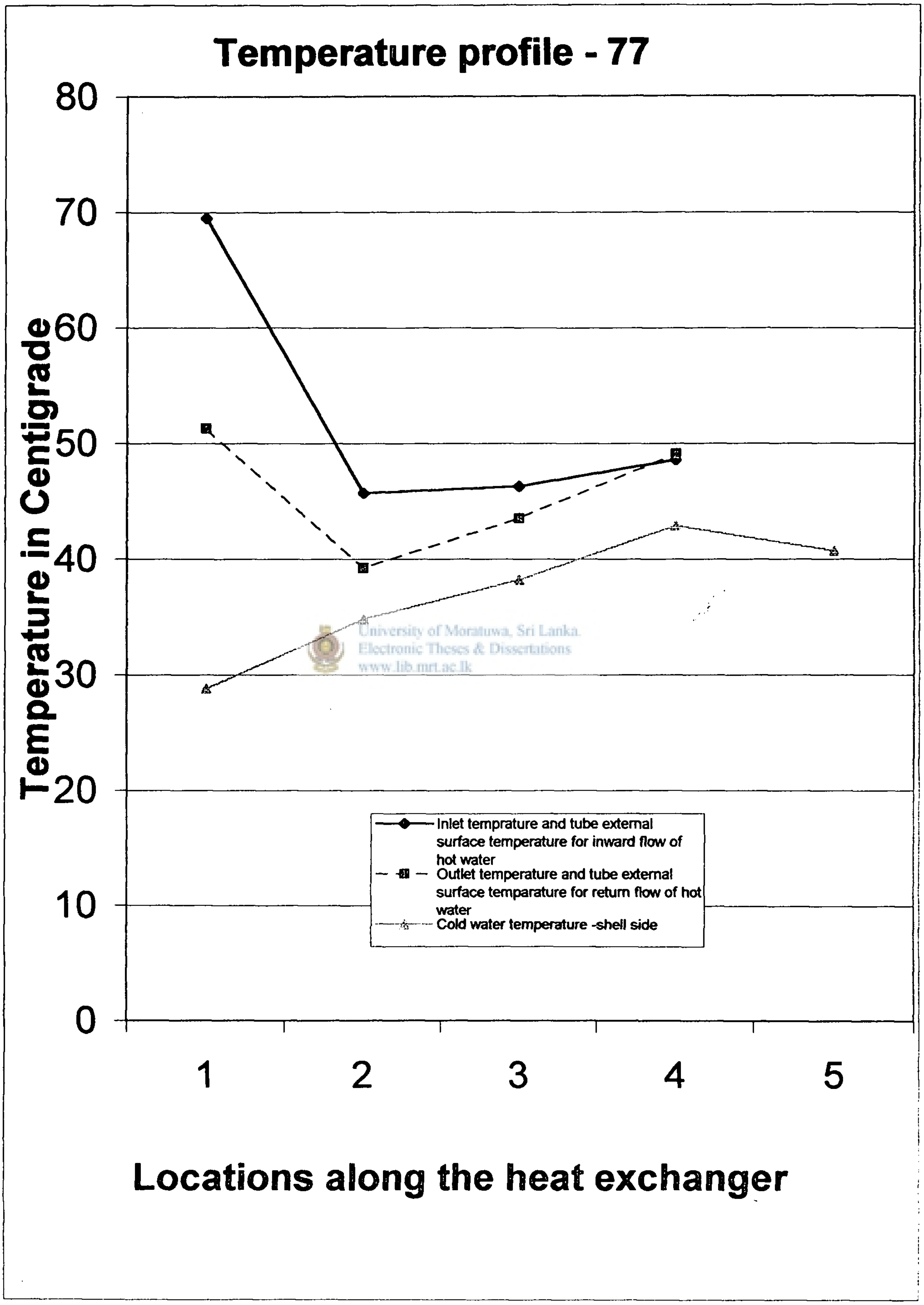


Temperature profile - 74
80
70
60
50
40
30
20
10
0
Temperature in Centigrade
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side

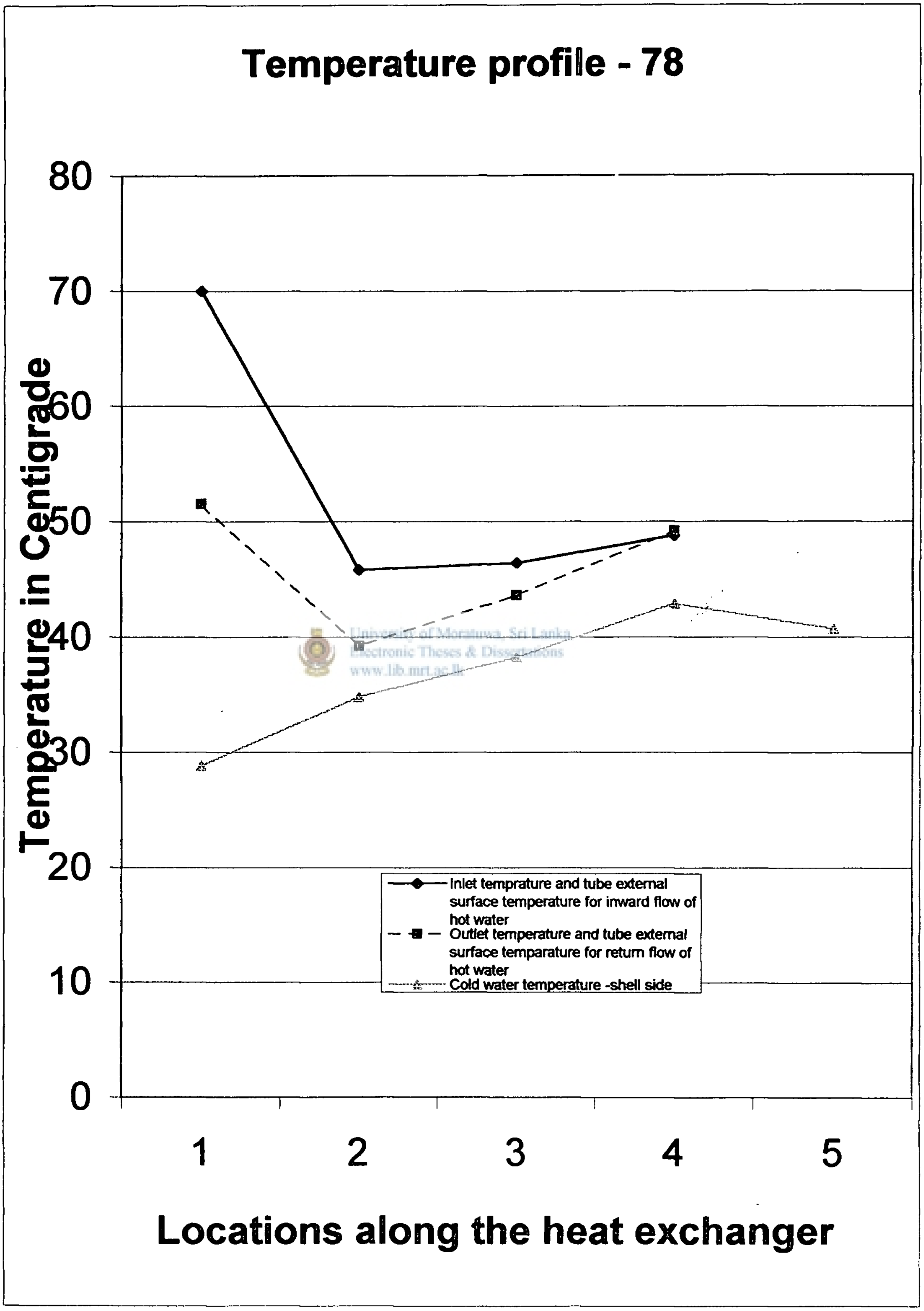


Temperature profile - 75
80
70
60
50
40
30
20
10
0
Temperature in Centigrade
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side


Temperature profile - 76
80
70
60
50
40
30
20
10
0
Temperature in Centigrade
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side



Temperature profile - 77
80
70
60
50
40
30
20
10
0
Temperature in Centigrade
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side



Temperature profile - 78
Temperature in Centigrade
80
70
60
50
40
30
20
10
0
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side
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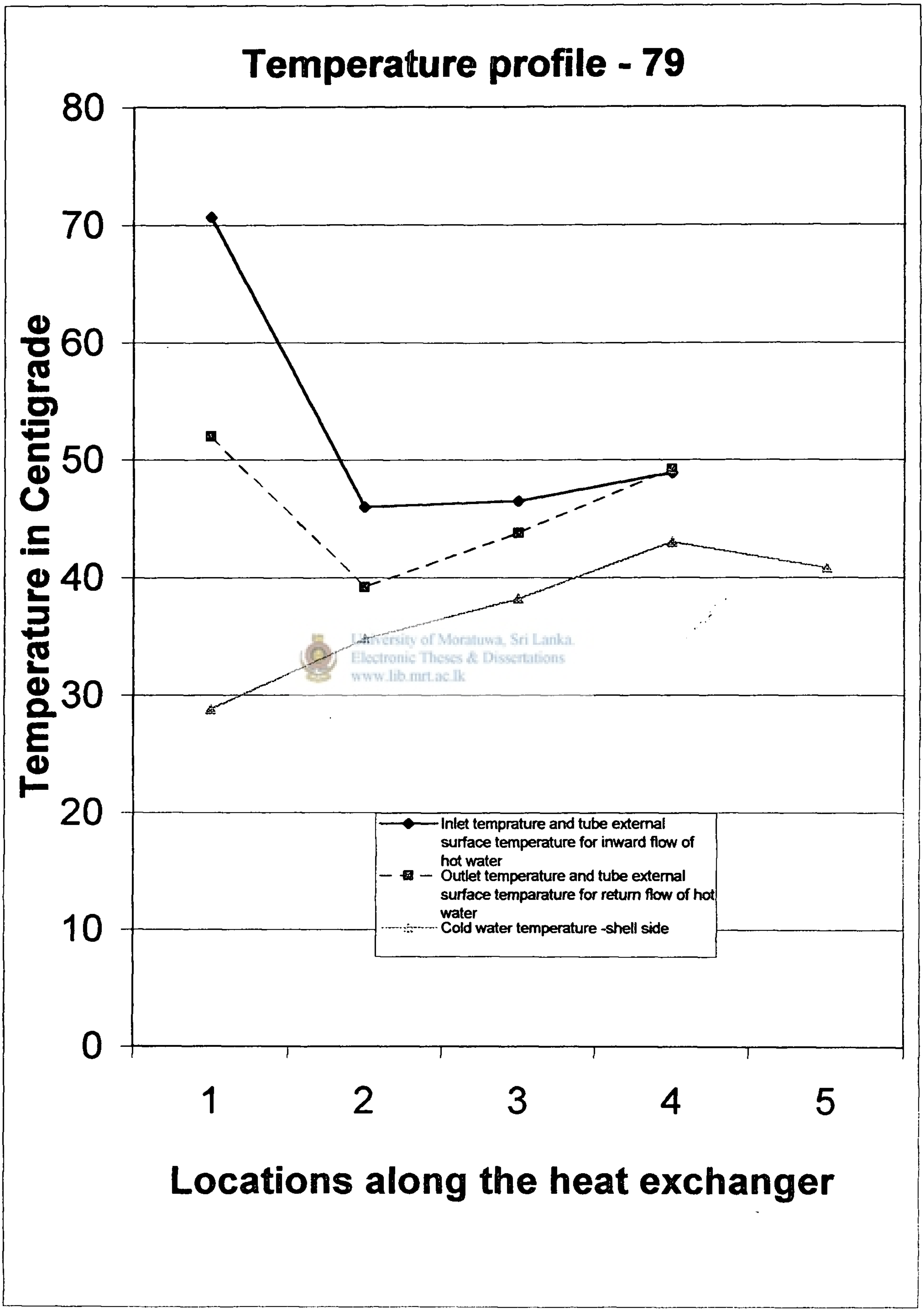
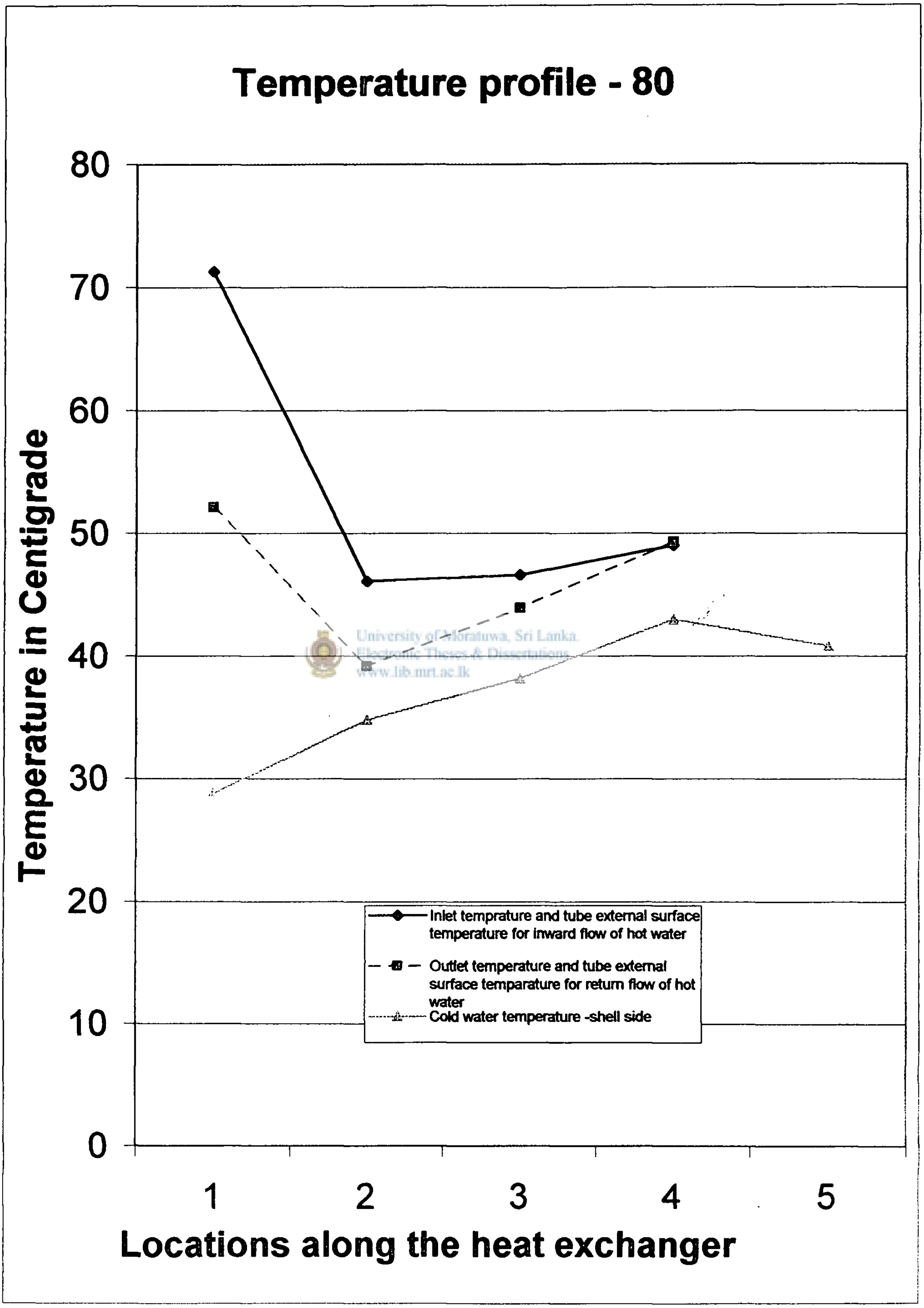
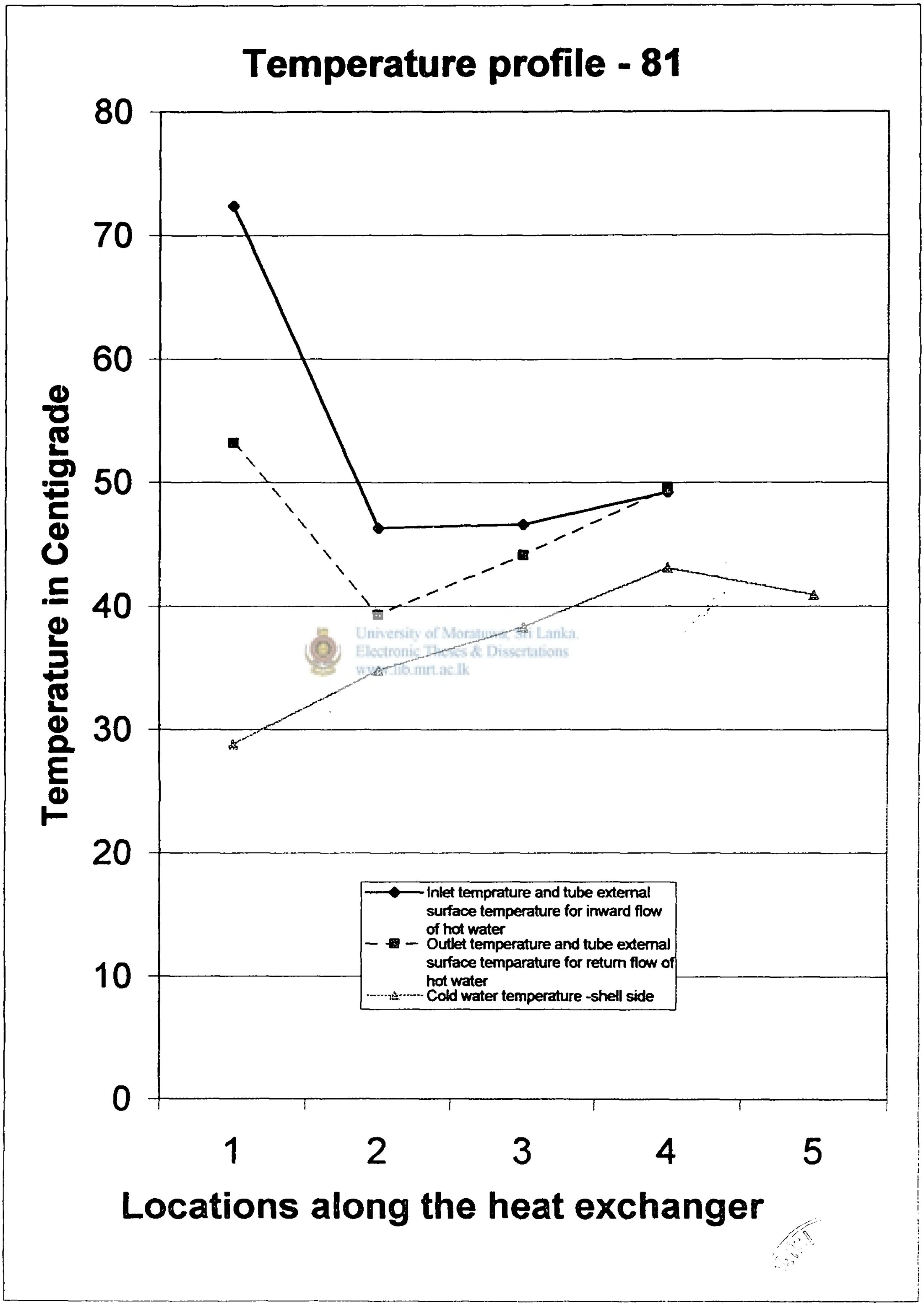
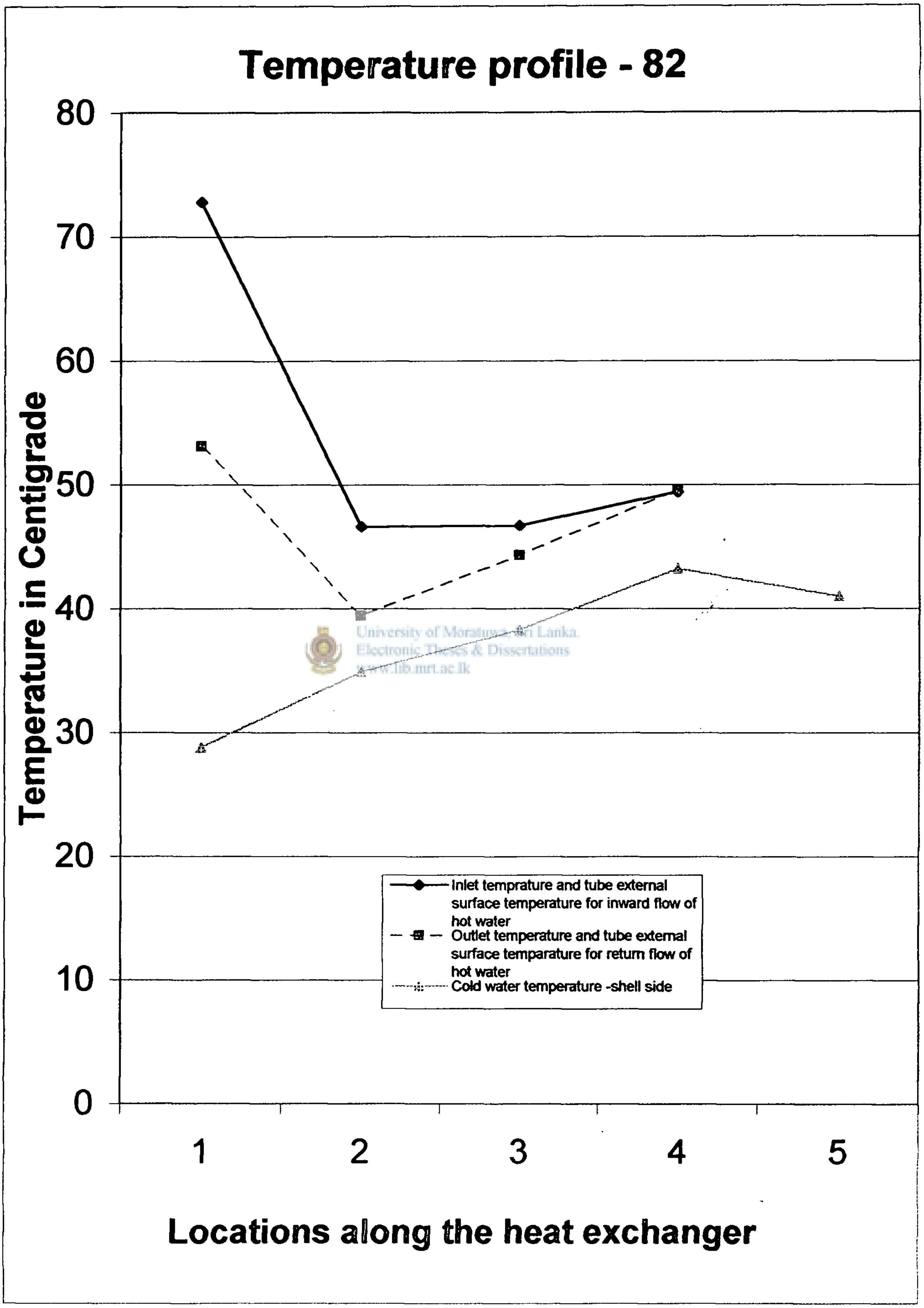


Temperature profile - 79
Temperature in Centigrade
80
70
60
50
40
30
20
10
0
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side

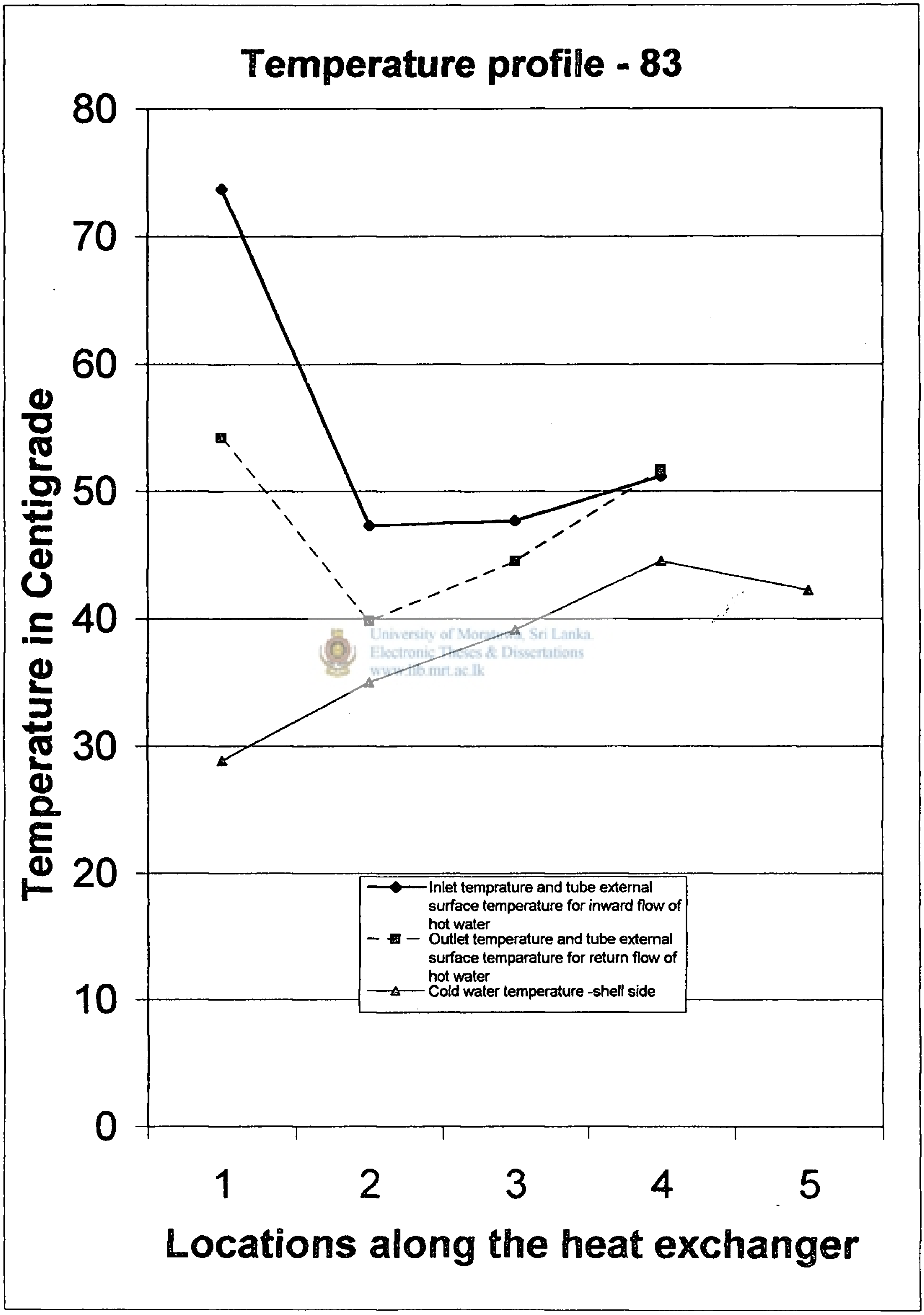


Temperature profile - 80
Temperature in Centigrade
0
10
20
30
40
50
60
70
80
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side

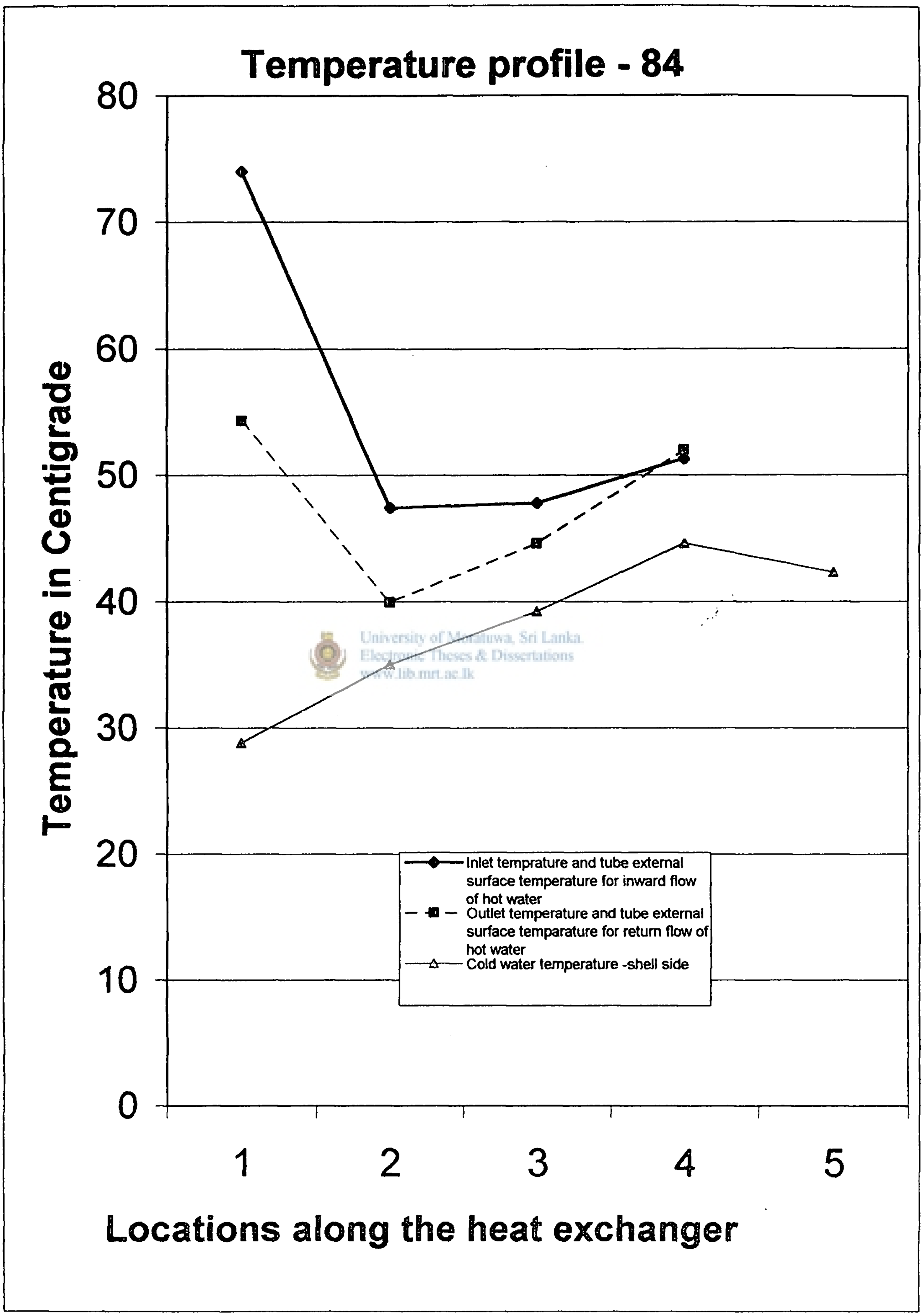

Temperature profile - 81
Temperature in Centigrade
80
70
60
50
40
30
20
10
0
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side



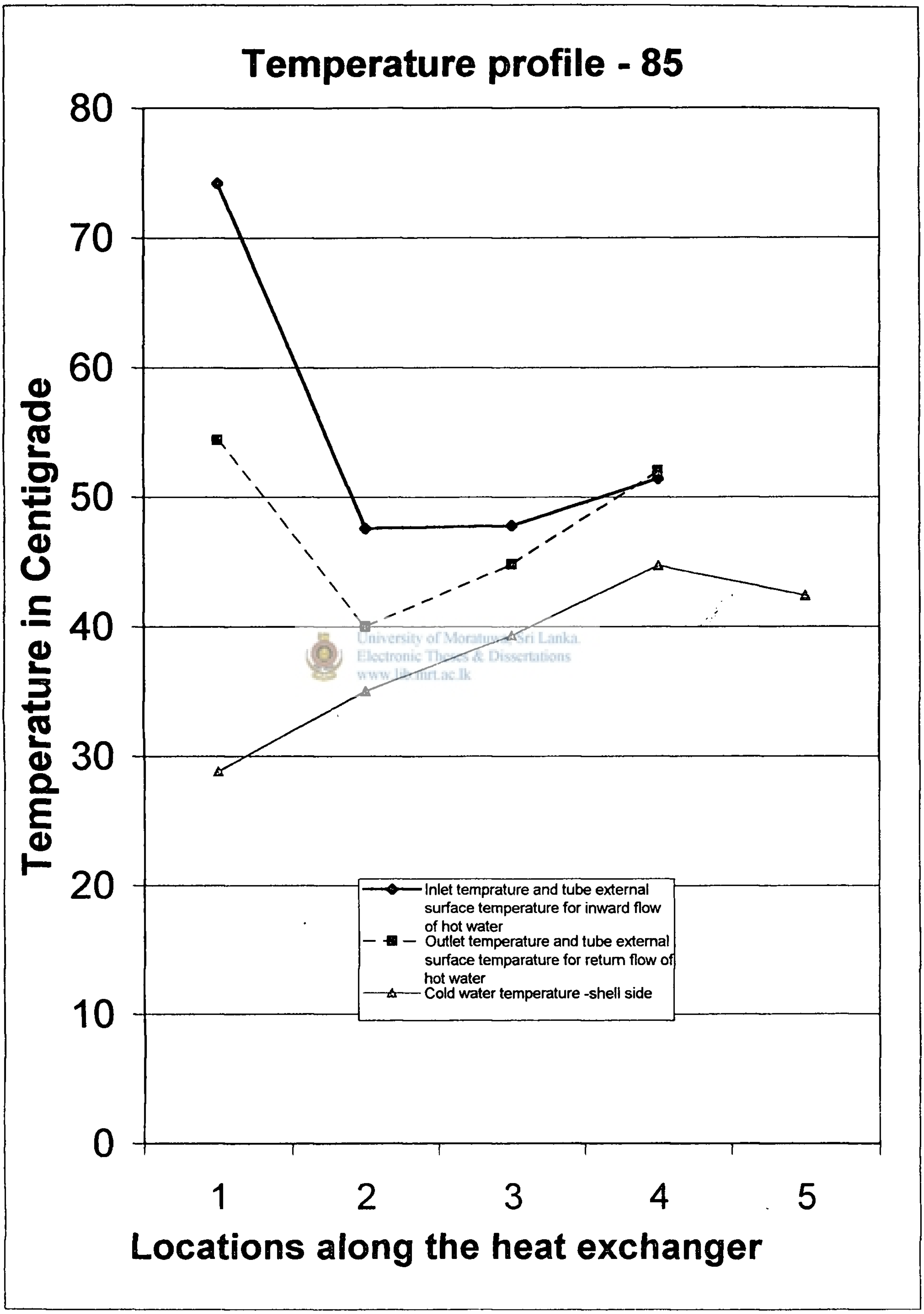
Temperature profile - 82
80
70
60
50
40
30
20
10
0
Temperature in Centigrade
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side



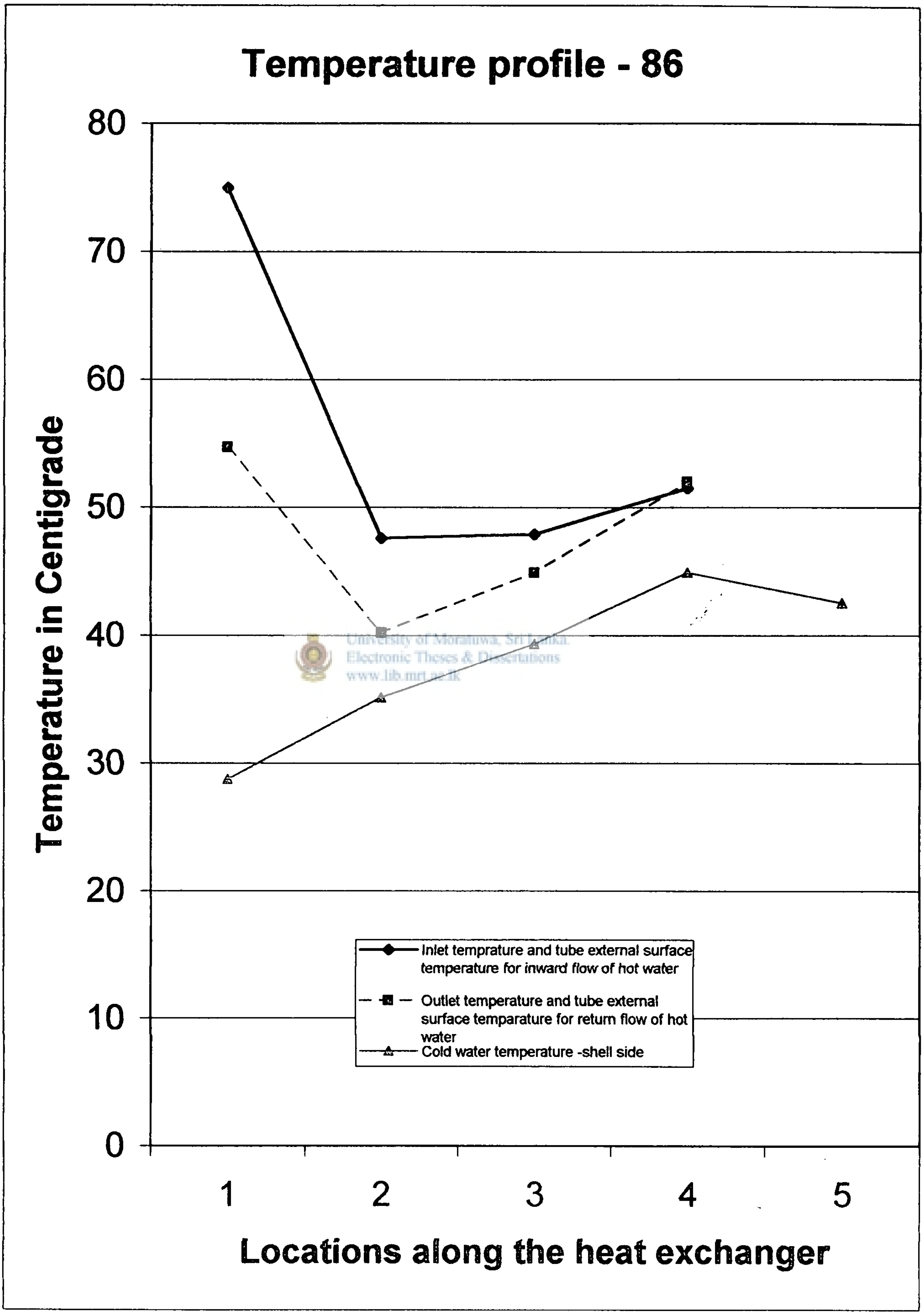
Temperature profile - 83
80
70
60
50
40
30
20
10
0
Temperature in Centigrade
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side



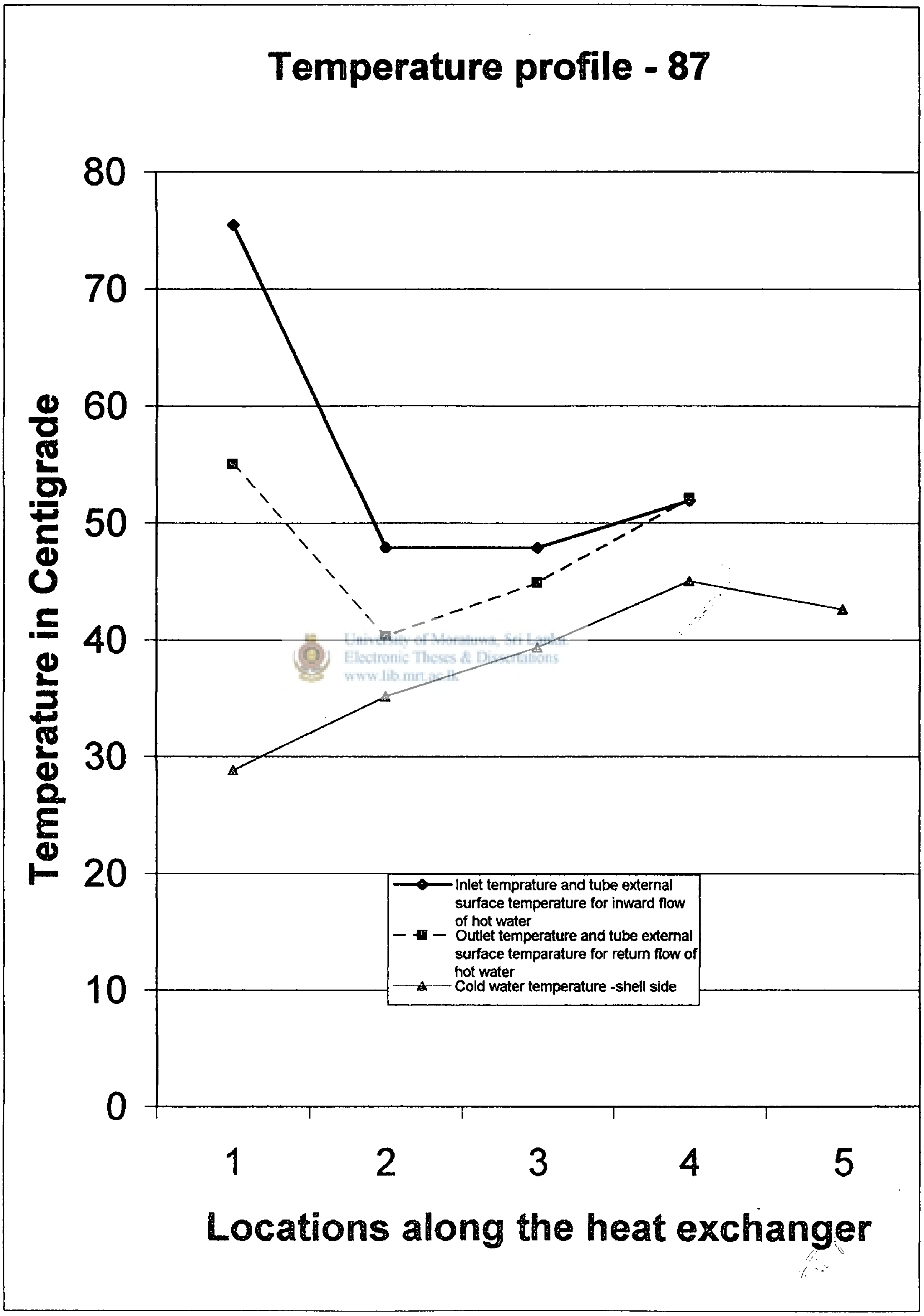
Temperature profile - 84
80
70
60
50
40
30
20
10
0
Temperature in Centigrade
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side
1
2
3
4
5
Locations along the heat exchanger



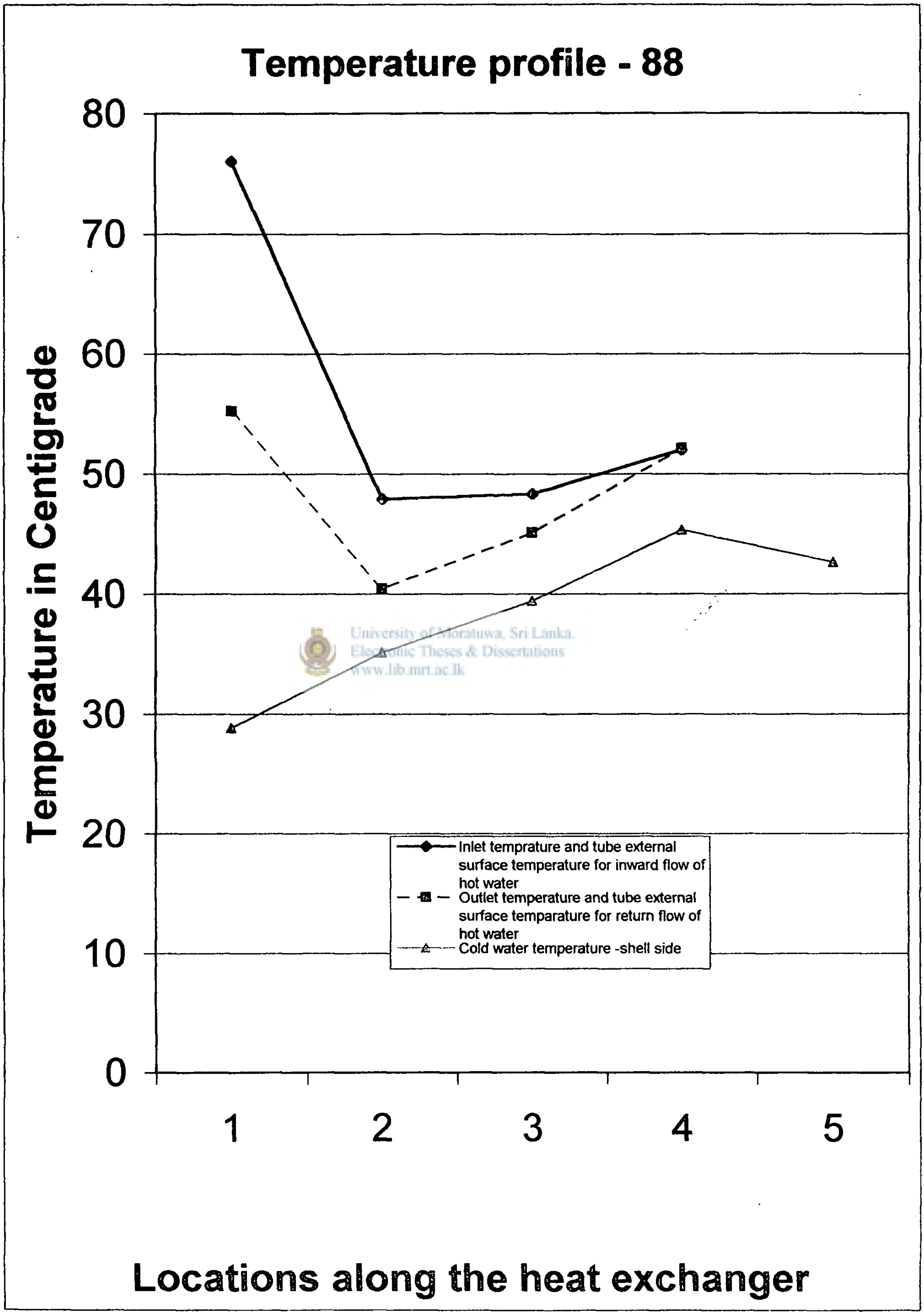
Temperature profile - 85
80
70
60
50
40
30
20
10
0
Temperature in Centigrade
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side

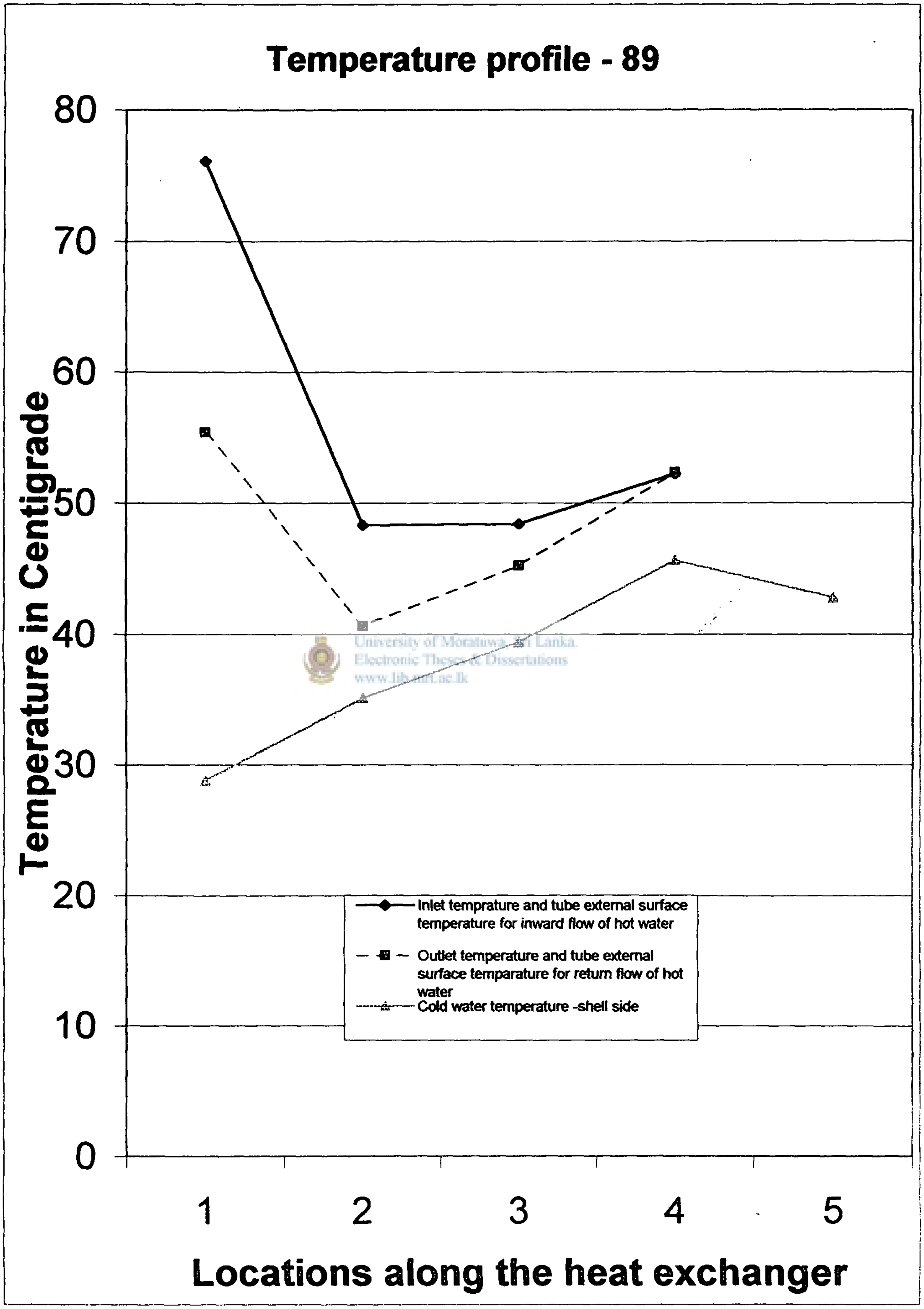


Temperature profile - 86
80
70
60
50
40
30
20
10
0
Temperature in Centigrade
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side

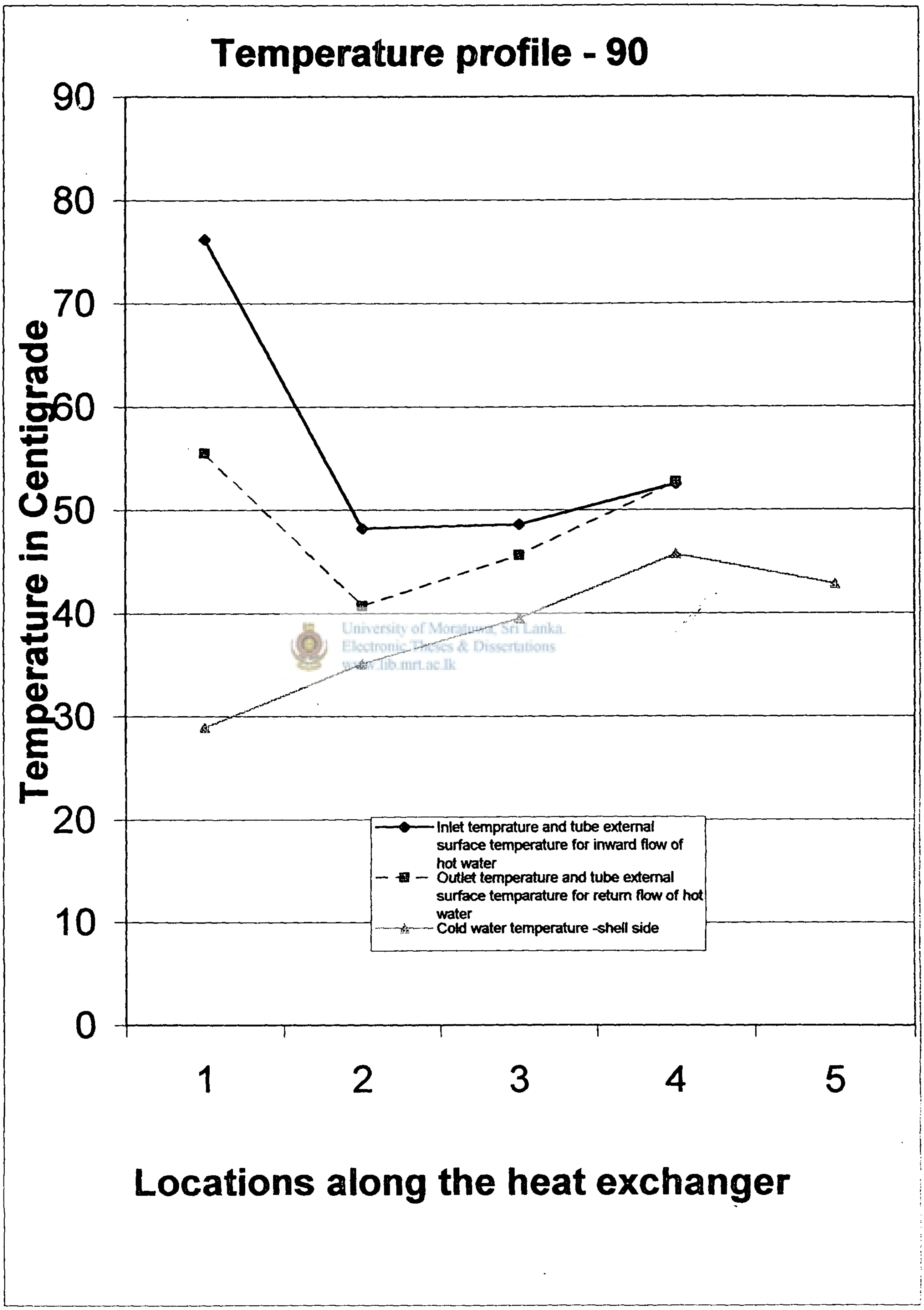


Temperature profile - 87
Temperature in Centigrade
80
70
60
50
40
30
20
10
0
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side

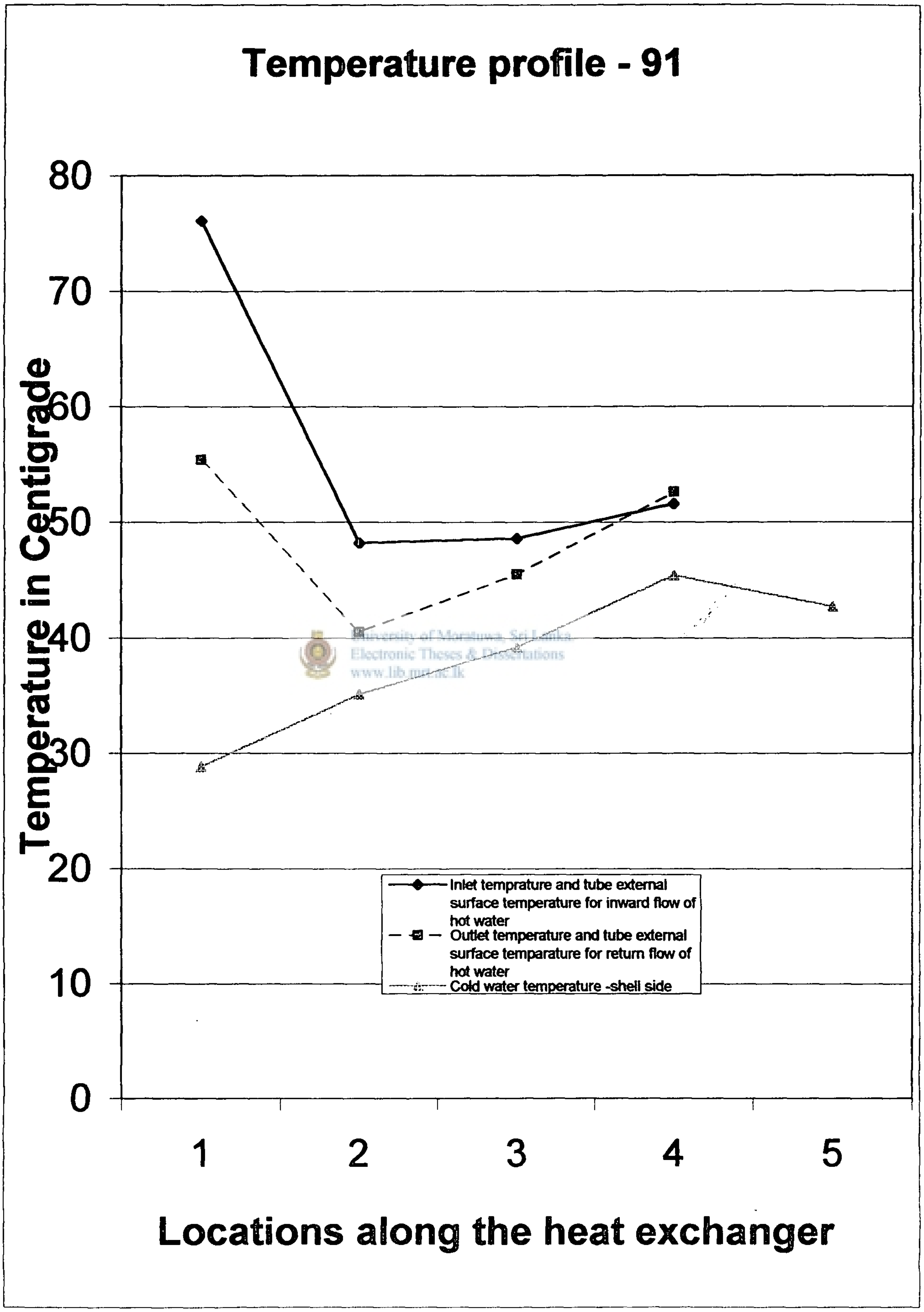

Temperature profile - 88
80
70
60
50
40
30
20
10
0
Temperature in Centigrade
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side



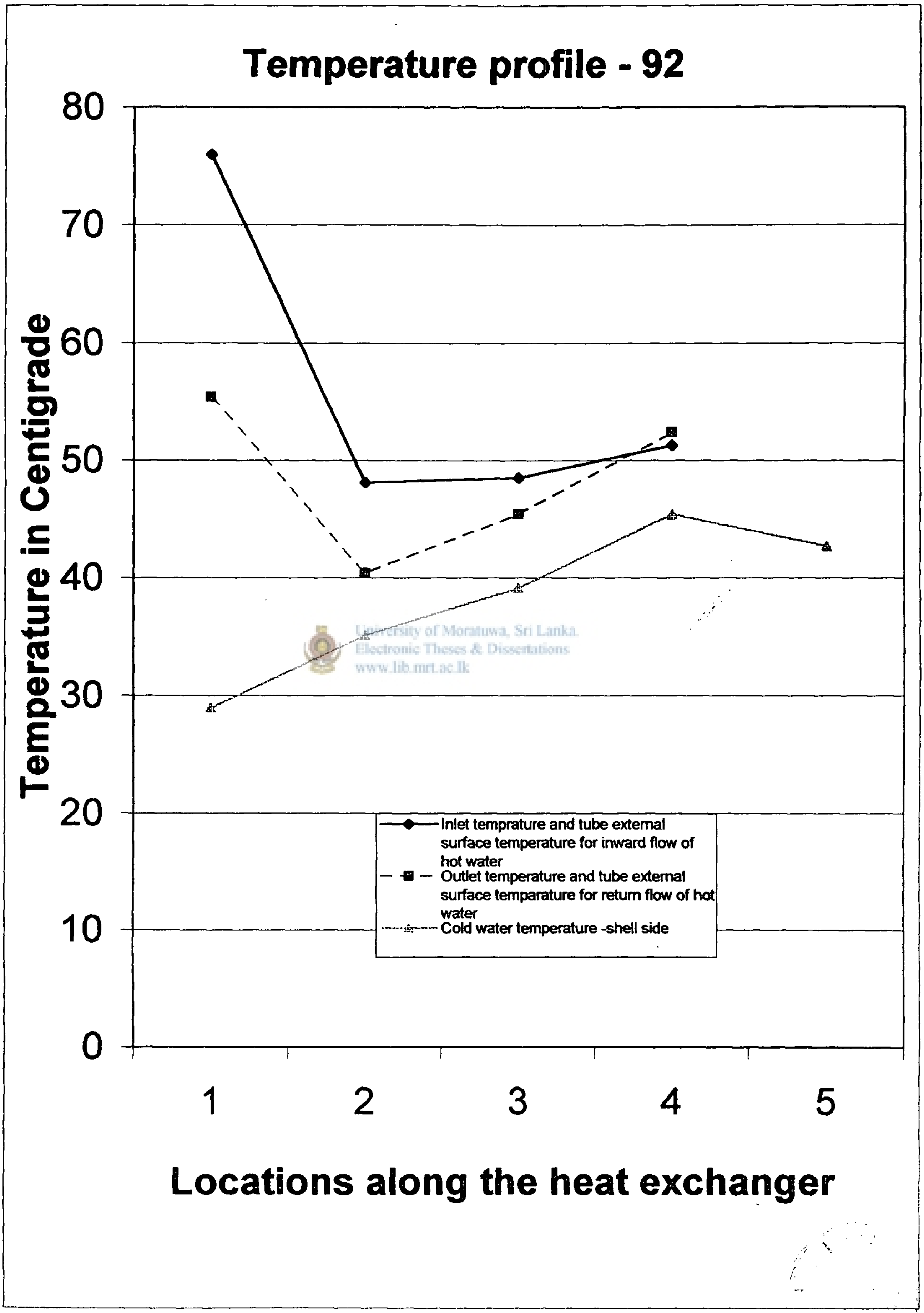
Temperature profile - 89
Temperature in Centigrade
80
70
60
50
40
30
20
10
0
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side

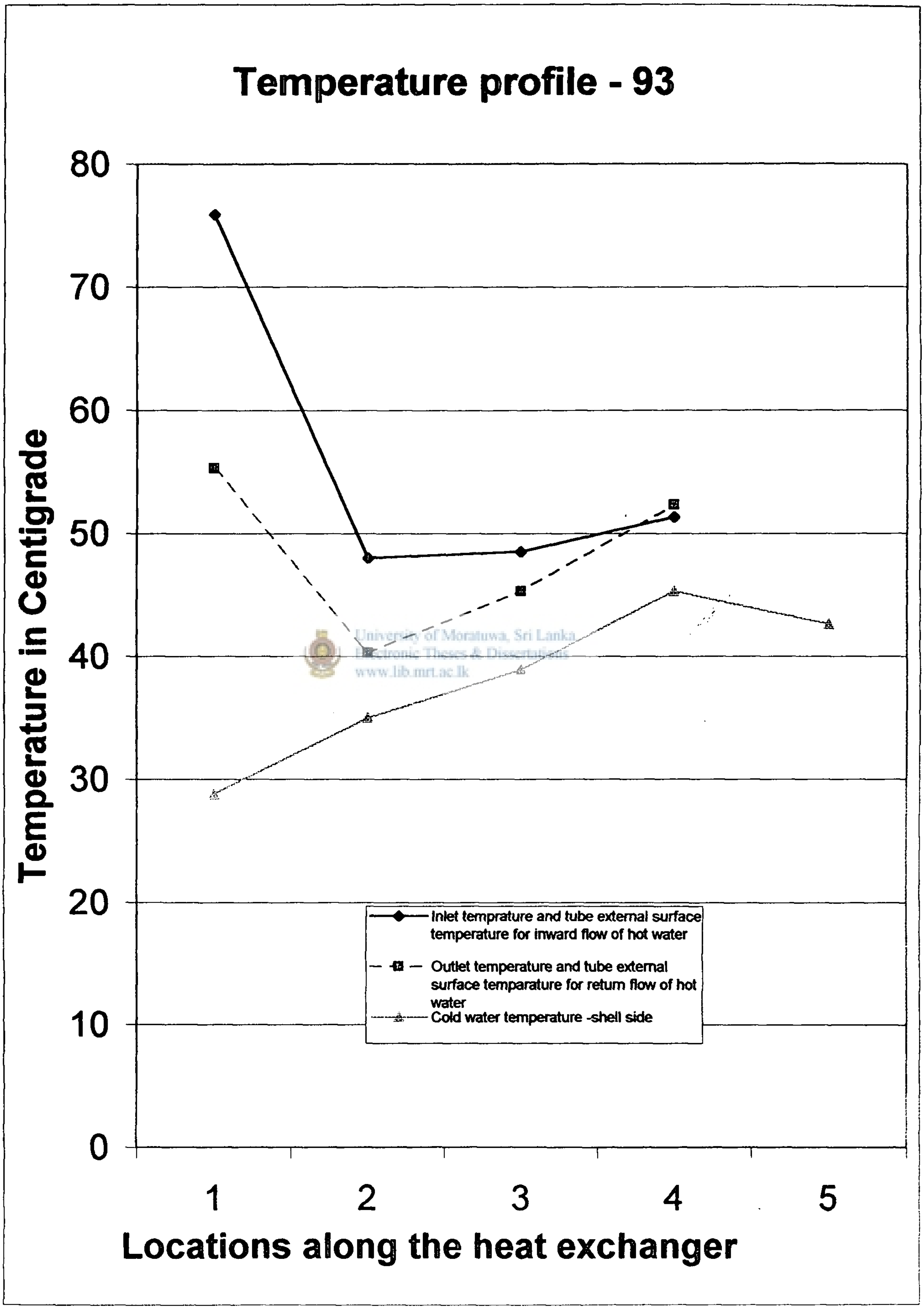


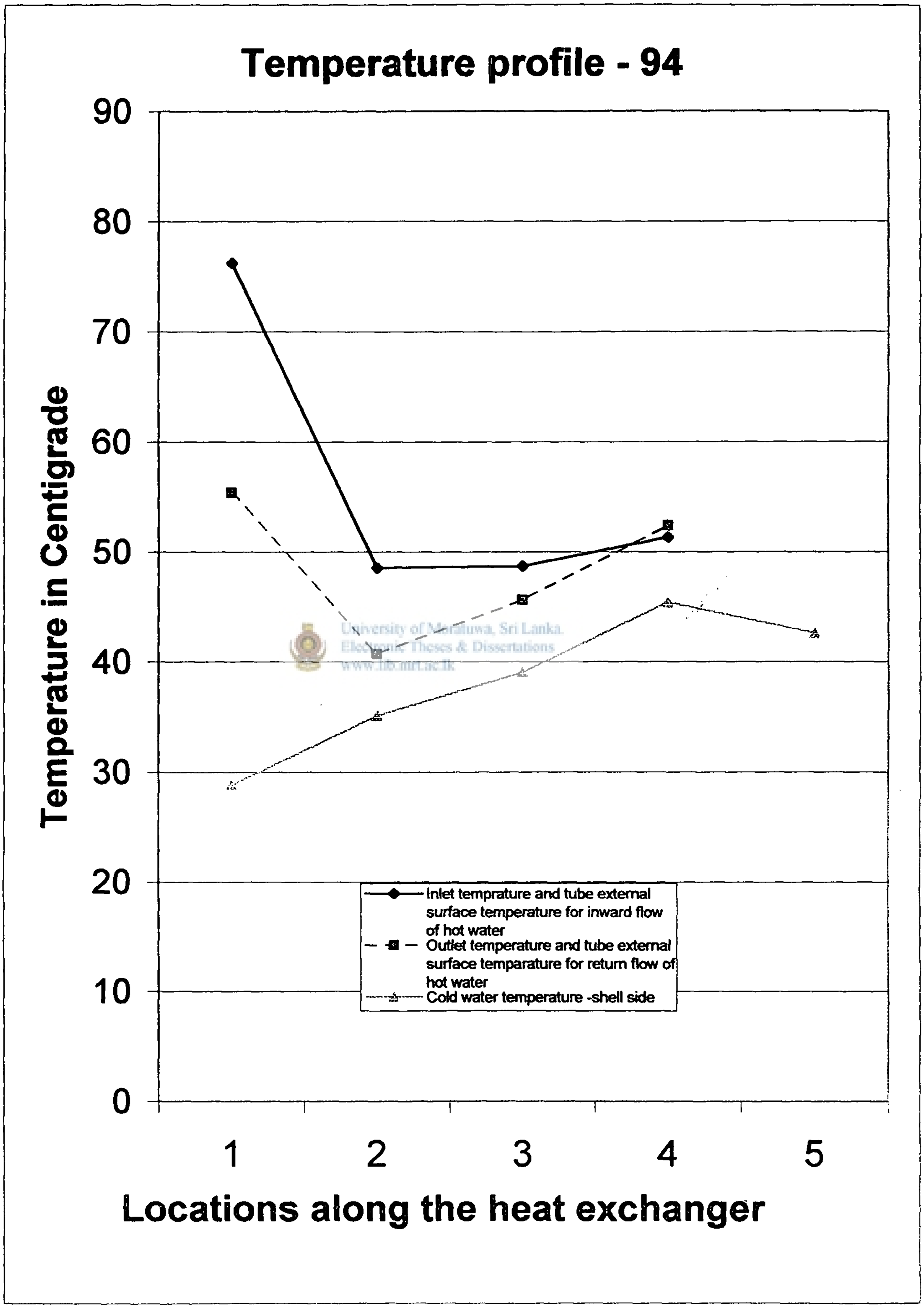
Temperature profile - 90
Temperature in Centigrade
0
10
20
30
40
50
60
70
80
90
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side



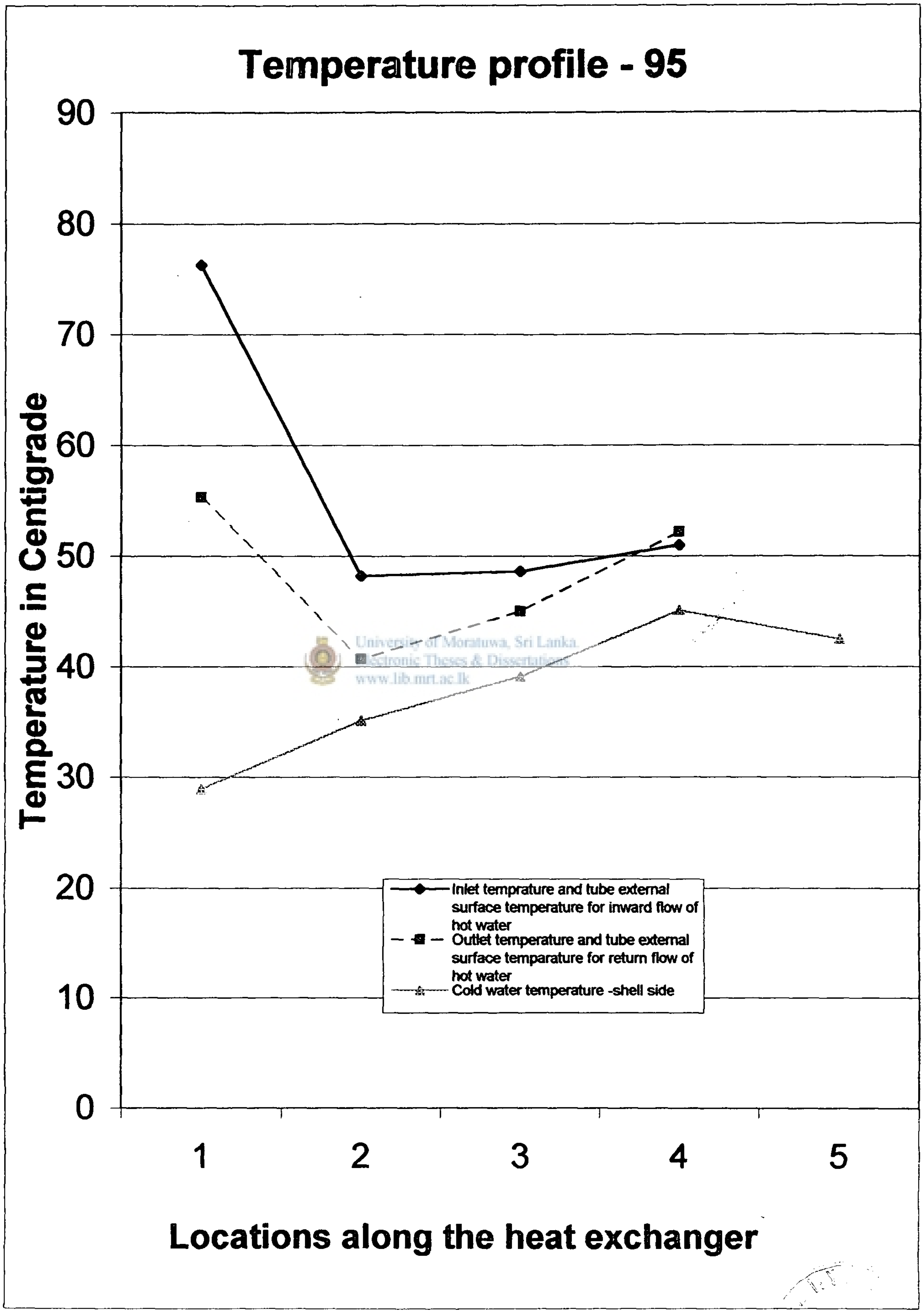
Temperature profile - 91
Temperature in Centigrade
80
70
60
50
40
30
20
10
0
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side


Temperature profile - 92
Temperature in Centigrade
80
70
60
50
40
30
20
10
0
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side

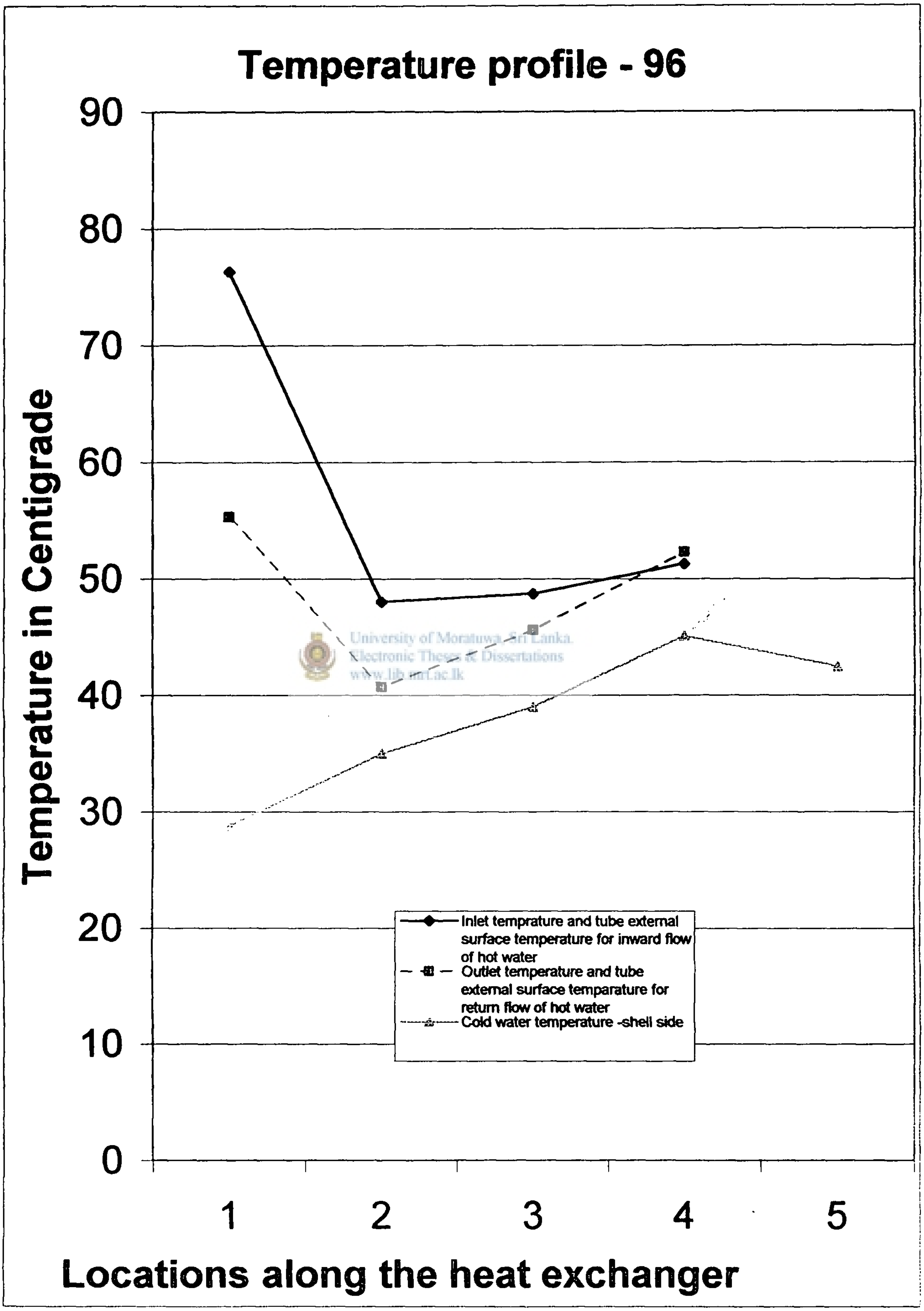

Temperature profile - 93
80
70
60
50
40
30
20
10
0
Temperature in Centigrade
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side



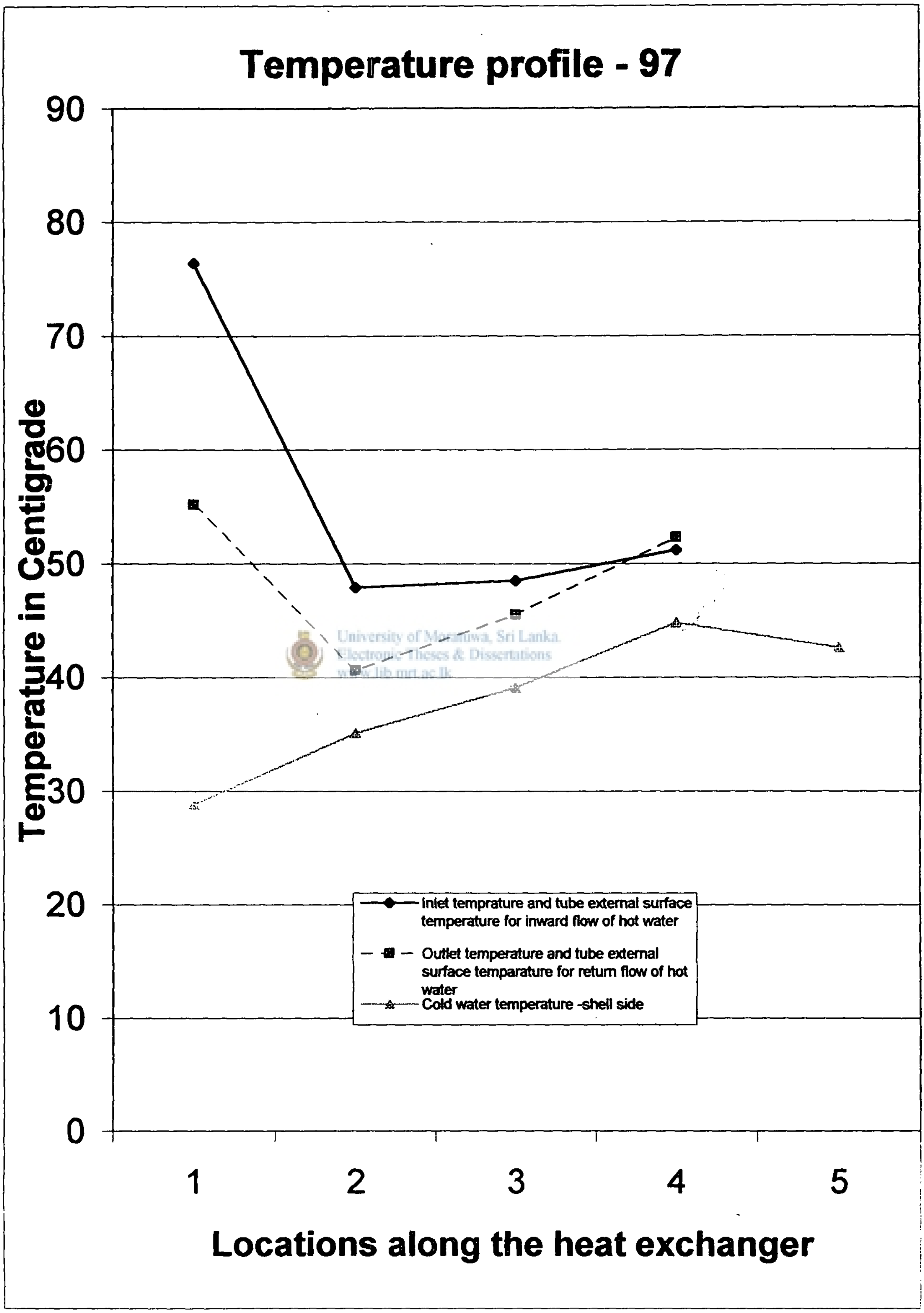
Temperature profile - 94
90
80
70
60
50
40
30
20
10
0
Temperature in Centigrade
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side
1
2
3
4
5
Locations along the heat exchanger



Temperature profile - 95
Temperature in Centigrade
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side



Temperature profile - 96
90
80
70
60
50
40
30
20
10
0
Temperature in Centigrade
1
2
3
4
5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side



Temperature profile - 97
90
80
70
60
50
40
30
20
10
0
Temperature in Centigrade
1
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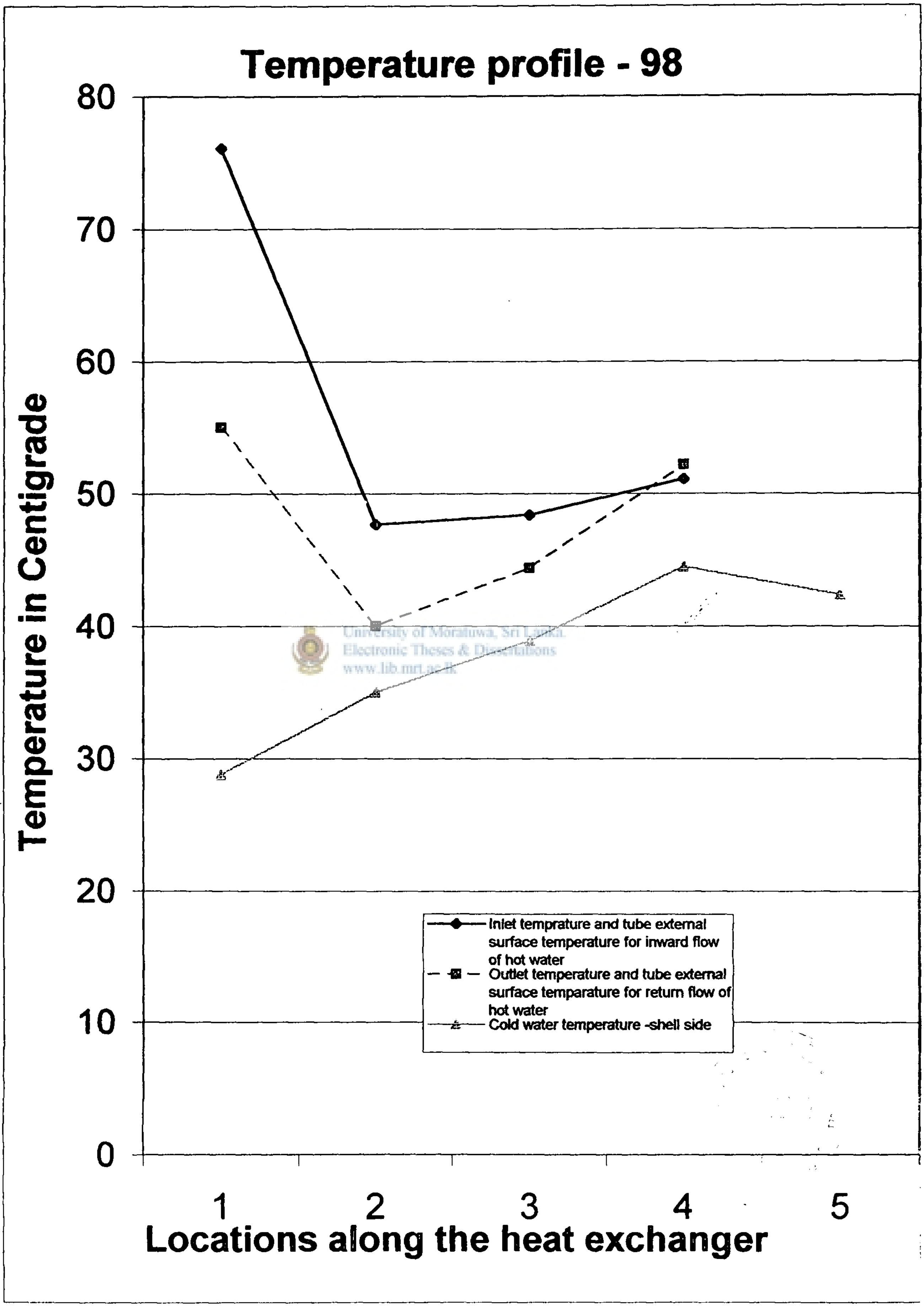
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side



Temperature profile - 98
Temperature in Centigrade
80
70
60
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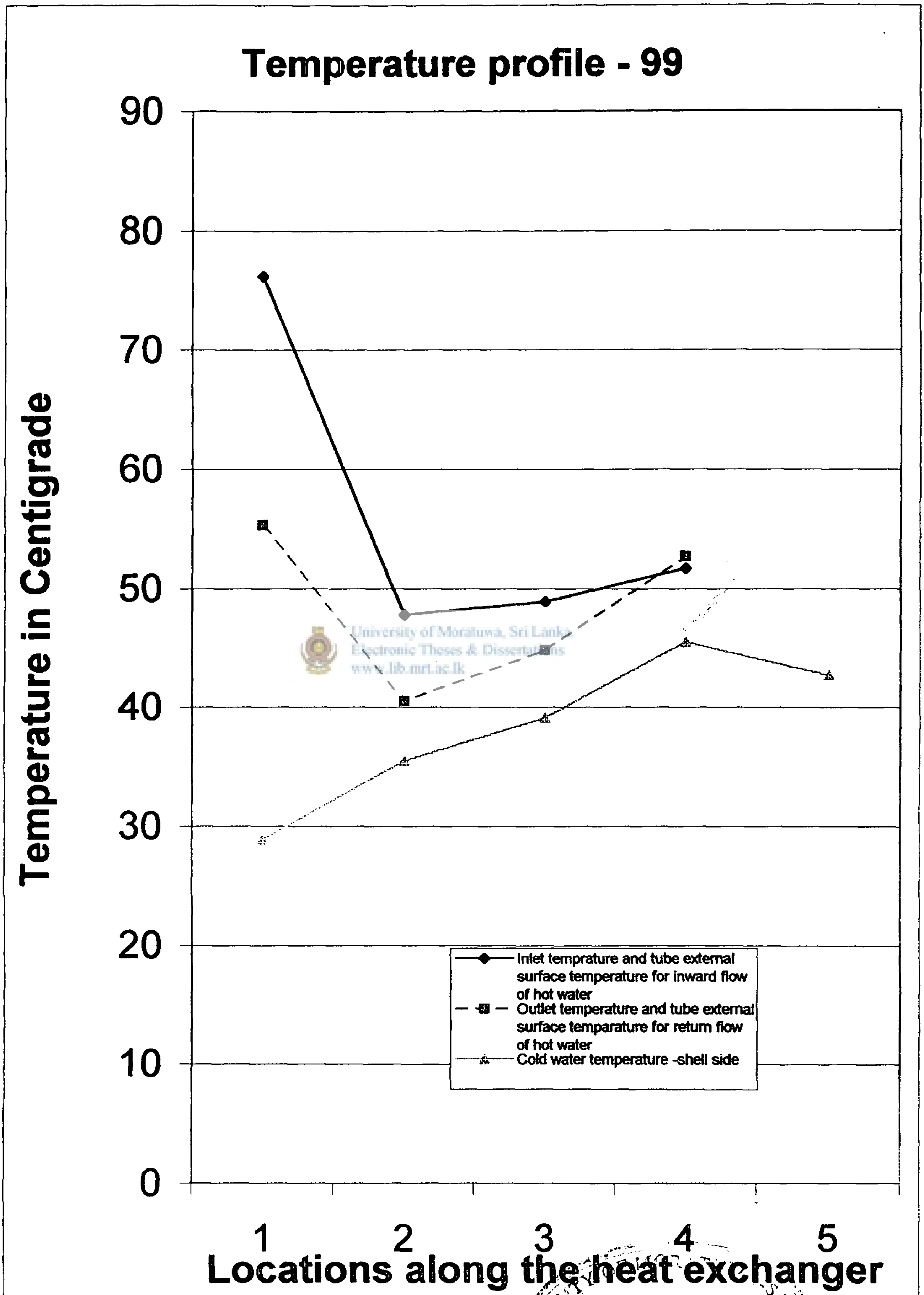
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side



Temperature profile - 99
Temperature in Centigrade
90
80
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60
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1
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5
Locations along the heat exchanger
Inlet temprature and tube external surface temperature for inward flow of hot water
Outlet temperature and tube external surface temparature for return flow of hot water
Cold water temperature -shell side