REPUBLIC OF TURKEY
KOCAELI UNIVERSITY
ASIM KOCABIYIK VOCATIONAL SCHOOL OF HIGHER EDUCATION
ELECTRICITY AND ENERGY DEPARTMENT
HEREKE / KOCAELI

INVESTIGATION REPORT

INVESTIGATION OF HEAT TRANSFER PERFORMANCE OF HYDROMX HEAT TRANSFER FLUID IN A BRAZED TYPE PLATE HEAT EXCHANGER

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PREPARED FOR : Kurumsal Marketing, Consulting, Chemical Industry and Commerce Inc.

PREPARED BY : **Dr. Mustafa SEÇİLMİŞ**
Head of Electrical and Energy Department

Yard.Doç.Dr. Mustafa SEÇİLMİŞ
Asım Kocabıyık M.Y.O. Müdürü

ABSTRACT:

In this study, a number of experiments have been carried out on the performance evaluation of Octrooicentrum Nederland patent numbered 1034917 and named “Hydromx Energy Saving Solution” at Asım Kocabıyık Vocational School of Higher Education Heating and Cooling Laboratory for Istanbul Kurumsal Marketing, Consulting, Chemical Industry and Commerce Inc. During the experiment, in order to compare their performances, heat transfer rates have been analyzed for 100 % water and 50 % percent water/50% Hydromx solution in a closed loop in a brazed type plate heat exchanger. In the comparison process, experimental data that was obtained under the same operating conditions both fluids have been used. In the experiment, brazed type plate heat exchanger with 8 plates and with a total heat transfer surface of 0.084 m^2 was used. In various volumetric flowrates such as 200, 250, 300, 350 and 400 Lt/h tap water was used as secondary fluid. The volumetric flowrate and heat transfer rate for the primary fluid and water were kept constant at (1100 Lt/h) and (9 kW). At the end of the experiment, brazed type plate heat exchanger input and output temperature difference, volumetric flowrate ratio and heat transfer rate were measured.

According to the increasing primary/secondary volumetric flowrate ratios in the brazed type heat exchanger, the heat transfer rate increased and ΔTm logarithmic temperature difference was measured to be 8% higher in Hydromx solution than to 100% water

With Hydromx solution in the primary circuit, the output temperature of tap water in the secondary circuit measured 2^0C higher as compared to tap water in the primary circuit.

It is observed that the heat transfer fluid input-output temperature difference increases while primary/secondary volumetric flowrate ratio is kept increased at the maximum volumetric flowrate ratio 50% temperature difference is reached when Hydromx solution was used.

1.0. INTRODUCTION:

Heat exchangers are devices that transfer heat between two or more fluids with different temperatures. Heat exchangers of various capacity, size and type are being used in systems such as manufacturing, refrigeration, heating, air conditioning and chemical plants. Usually in heat exchangers hot and cold fluids are separated by a heat transfer surface and heat is transferred from the hot fluid to the cold fluid through conduction and convection. If there are phase changes such as condensation and steam in the heat exchanger these are called phase changing heat exchangers. Heat exchangers with no phase change are called as sensible heat exchangers. Heat exchangers can be categorized according to the type of heat transfer, heat transfer area per unit volume, shape of the structure, fluid flow type sand heat transfer mechanism. There are 2 types of exchangers categorized according to the heat transfer process: direct contact heat exchangers and indirect contact heat exchangers.

Direct contact heat exchangers generate heat transfer from hot fluid to cold fluid without a separating wall. One of the fluids is usually gas and the other fluid is a low pressure liquid. A typical example of this type is cooling towers. In indirect contact heat exchangers, heat is transferred from hot fluid to the separating contact surface and afterwards to the cold fluid. A plate heat exchanger is an indirect contact heat exchanger and it is made of corrugated metal plates in order to transfer heat between two fluids. In heat transfer, the use of corrugated plates increases the transfer of heat rate and can transfer the same amount of heat with only 1/3-1/4 surface area when compared to the conventional shell and tube type heat exchangers. On each plate, there are input/output channels and a gasket for impermeability. Gasket system allows both fluids to flow separately from different channels and to achieve the desired heat transfer. In this study, a brazed type heat exchanger is used.

Brazed type heat exchangers are low-cost alternative to gasket type plate heat exchangers. Another advantage of brazed type heat exchangers is their capacity to work at higher temperatures and higher operating pressures. The operating principles are usually the same as the gasket plate heat exchangers. In brazed type heat exchanger, copper solder is used instead of a gasket. Stainless steel plates are exposed to high temperatures in vacuum ovens with a copper sheet to be soldered. The result is a compact type heat exchanger without a gasket. As they can be manufactured in standard sizes and their high heat transfer rates make them a low cost alternative. Thanks to the absence of gaskets that these heat exchangers can operate between temperatures -180°C/+200°C and up to 30 bars operating pressure. Due to high turbulence formation between the plates, the system can reach steady condition faster and increases the performance of the system. In the plated heat exchangers, the number and size of the plates depend on the flow of the fluid, physical properties of the fluid, pressure decrease and heat transfer mechanism.

In order to analyze the performance in heat exchangers, it is required to know the total heat transfer rate. The total heat transfer rate depends on thermal resistance factors of all the components in the system. Convective heat transfer coefficient which is one of the thermal resistance factors is an important parameter affecting the performance of heat exchangers. Theoretically convective heat transfer coefficient is formulated with empirical equations (developed from quasi-experimental results) using data validated with experimental studies. When empirical experiments are analyzed according to the flow type, application conditions, i.e. tube and plates, laminar and turbulence flow, dimensionless quantities Nusselt (Nu), Reynolds (Re) and Prandtl (Pr) are found. When these dimensionless quantities are studied, fluid density, specific heat, thermal conductivity, viscosity, steady state flow speed of the fluid in the tube, tube diameter (for tubes) are observed as parameters affecting the heat transfer process and convective heat transfer coefficient of the fluid. Convective heat transfer coefficient is inversely proportional (=a negative function of) to viscosity and directly proportional to (a positive function of) the other values. In other words, when thermal conductivity increases, heat transfer towards a fluid flowing in the tube will increase and when viscosity increases it will decrease. Consequently, the ideal heat transfer fluid is a fluid with high thermal conductivity and low viscosity. Water is known as the most efficient heat transfer liquid. Regardless of its freezing property, water would be the best heat transfer fluid for cooling applications.

In various industrial applications heat transfer fluids (such as ethylene glycol and propylene glycol antifreeze) are generally mixed with water with a certain volume ratio in order to lower freezing temperature and increase boiling temperature of water to prevent water in the system from freezing and boiling. The reason is that these fluids are added to the water is not to increase its heat convection and transfer capacity and to improve its heat transfer performance. On the contrary, both glycol mixtures are less efficient in transferring heat compared with water. In order to have the same level of thermal efficiency as the water, this type of heat transfer fluids will need higher volume flow or larger heat transfer area in the heat exchangers. Depending on the viscosity of fluid, higher fluid flow increases the loss of pressure, energy consumption in the pumps and corrosion levels on the equipment. It is possible to reduce energy costs of the systems by saving large amounts of energy with the use of a heat transfer fluid that has better heat transfer properties. The heat transfer properties of heat transfer fluids could be increased by improving their physical (thermophysical) and chemical properties. It is possible to achieve higher heat transfer rates in heat exchangers particularly by improving thermal conductivity and/or specific thermal value of the fluid. Some scientific studies show that with the use of additives, thermal conductivity of the fluids can improve up to 60%. On the other hand, similar scientific studies show that, although thermal efficiency of the heat exchanger increases, there is an increase in the reduction of pressure and pump power consumption increases with the increase of the Reynolds number and results in efficiency decrease. In other words, the increase in thermal conductivity leads to increase the viscosity of the heat transfer fluids as well. However, in some scientific studies conducted in constant heat load and lower volume flows, the use of heat transfer fluids with the same heat load resulted in less volume flow and lower pressure compared with water. The results show that heat transfer fluids will reduce the general size of the systems in industrial applications while increasing the performance. On the other hand, some other studies highlight that when you reduce the volumetric contribution ratios of additives in heat transfer fluids, the heat transfer rate increases and thermal separating area thickness decreases.

In this study, scientific studies on heat transfer fluids were taken into consideration. For this reason, the heat transfer performance fluids of Istanbul Kurumsal Marketing, Consulting, Chemical Industry and Commerce Inc.’s Octrooicentrum Nederland 1034917 patent numbered and named “Hydromx Energy Saving Solution” was investigated. In the experiment 50% Hydromx/50% water mixture heat transfer fluid was examined using a closed loop brazed type plate heat exchanger in constant heat load. By this way, different volume flow rates, heat exchanger temperature difference changes, heat difference rates and heat capacity were analyzed and compared. The measurements were taken between 20 ^{0}C and 90^{0}C.

2.0. INTRODUCTION TO EXPERIMENT SETUP AND ELEMENTS:

2.1. Experiment System Schema and Description:

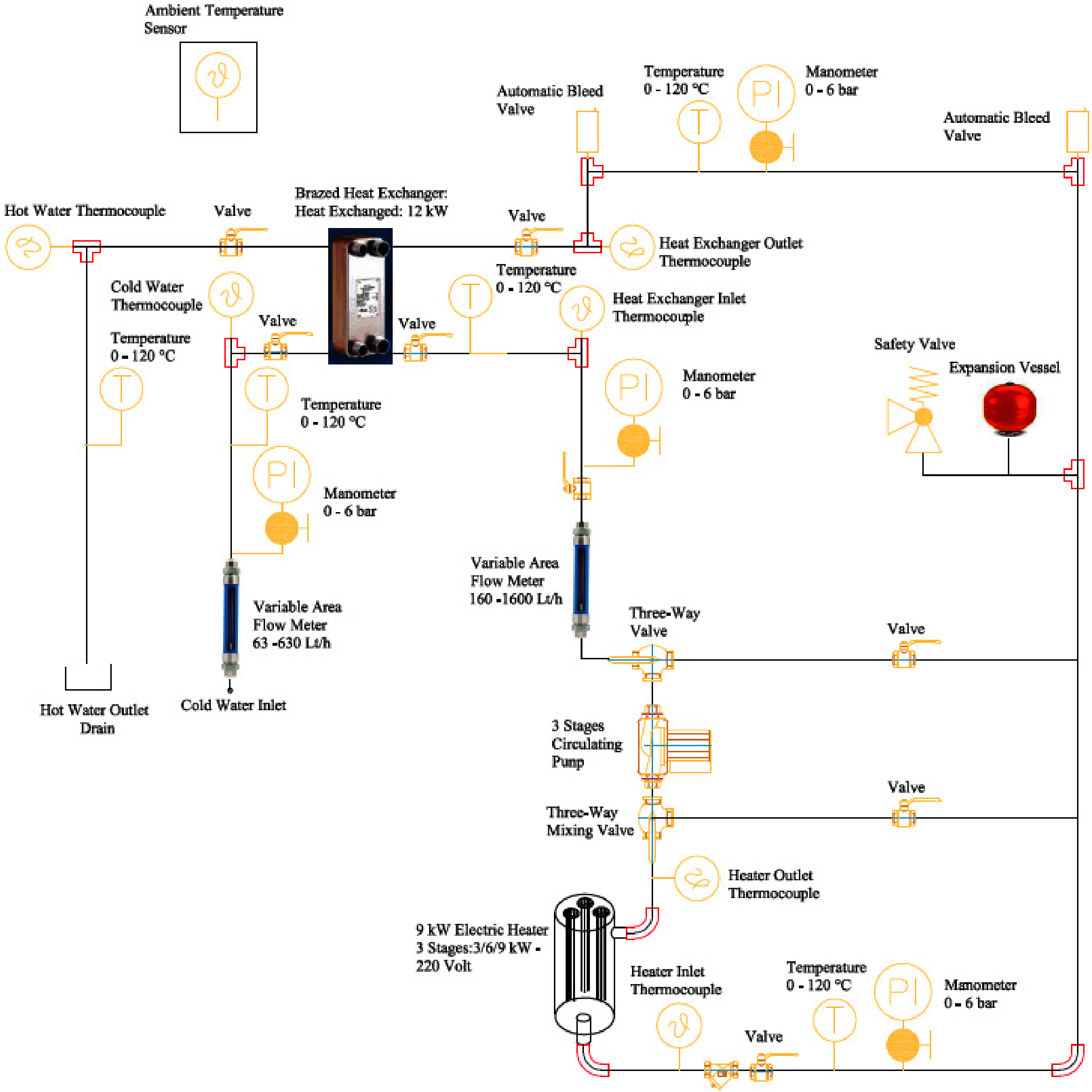


Diagram 2.1. Experiment setup schema

Experimental mechanism was equipped with 2 three-way valves in order to control the heat and flow of the fluid. One of the 3-way valves is installed as a mixing valve to control the fluid flow and the other one is a diverting valve installed to control the flow. A tube type 9 kW capacity electric heater for generation of necessary heat of the system and a brazed type plate heat exchanger was used and tap water connection was established to discharge total heat load. There is an open loop system in the tap water side of the brazed type plate heat exchanger. Cold water is supplied from the network and is allowed to enter into the plate heat exchanger then drain after being heated. The heat transfer fluid heated by an electric heater is located on the other side of the system. The system has a closed loop and is equipped with a 3 level circulating pump, a closed type expansion tank and a safety valve as seen in the Diagram 2. In order to measure the system temperature and flow of fluids, six (T- type class: 1- thermocouples and two 1% accuracy variable area flow meters were placed in the electrical heater and brazed type plate heat exchanger inlet and outlets. The capacity of the variable area flow meter installed on the tap water side is 64 – 640 Lt/h and the capacity of the variable area flow meter installed on closed loop side is 160 – 1600 Lt/h. To control and keep the closed loop pressure steady 0-6 bar scale glycerine filler pressure gauge was used. A temperature sensor was used to observe the ambient temperature. To prevent heat loss, the system and its components were completely insulated with rubber foam.

In the experimental mechanism, to measure the heat load generated by the electric heater, one digital power and energy meter was designed and installed to measure reactive and visible power values and active reactive energy values of each phase in the system. Technical specifications of the devices used in the experimental mechanism are listed in the following table.

Table 2.1. Technical specifications of the industrial type electrical heater used in the experiment setup

Tube Diameter (Ø)	Tube Material	Potential Difference (Volt)	Power (Watt)	Length (mm)
8.5	Cr-Ni	220	3 Stages : 3 / 6 / 9	350

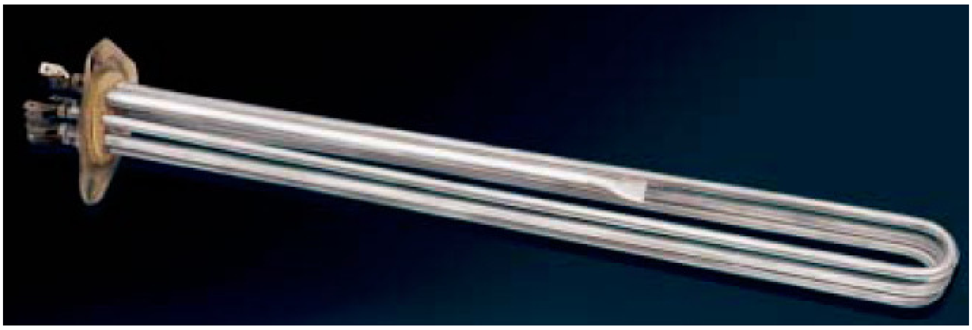
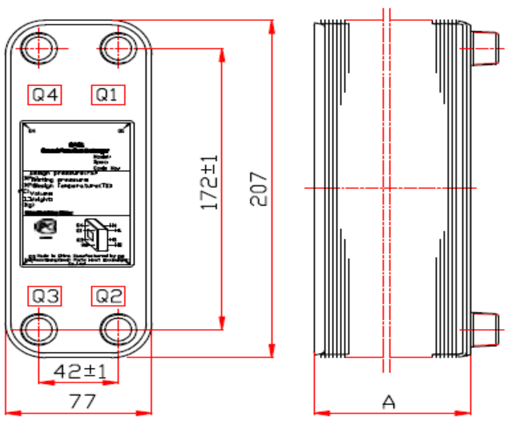


Diagram 2.2. Industrial type electrical heater

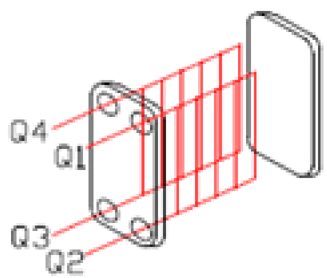
Table 2.2. Brazed type tap water heat exchanger technical specifications

MIT Brazed Heat Exchanger Datasheet

Plate type		B03-014	
Fluid		Water	Water
Density	kg/m³	971,8	1000
Sp. heat cap.	kJ/(kg*K)	4,184	4,204
Thermal conductivity	W/(m*K)	0,6692	0,5861
Viscosity	cP	0,3558	1,335
Flow rate	kg/h	430,1	1713
Inlet temperature	°C	90	7
Outlet temperature	°C	70	12
Pressure drop	kPa	4,59	48,89
Conn. pressure drop	kPa	0,1379	2,128
Velocity in connection	m/s	0,6155	2,367
Heat exchanged	kW	10	
LMTD	K	70,2	
k-value clean	W/(m²*K)	6543	
k-value service	W/(m²*K)	1017	
Shear stress	Pa	23,17	233,6
Low theta shear stress	Pa		
Heat transfer area	m²	0,14	
Fouling	m²*K/W	8,309	
Channel arrangement		1*5 H	1*6 H
Number of plates		12	
Plate material		AISI 316	
Margin	%	598	
Estimated price factor			
Price			
Number of units		1	
Connection Type		Outer Threaded	
Connection Diameter		3/4" - 1/2"	



Connection Schema



Q1: Cold Water In **Q2:** Cold Water Out
Q3: Hot Water In **Q4:** Hot Water Out

Table 2.3. Thermocouple specifications

Product :	Metronik/TRON
Model ;	10MT TS- 060 -030 P2/ GGx .FG03.I
Component Type :	T - Tipi Cu-Const (CuNi)
Tolerance Value:	Class 1 ±0,5 °C
Standard:	IEC 584-3 /DIN 43722
Measurement Range):	-40° to 350°C
Length (L) / Diameter (Ø):	60 mm /3 mm
Process Connection :	Fixed male R 1/4''
Protective Sheath:	DIN 1,4571
Cable:	K – FG2022S-R 2 x 0,22 mm2 Pfa
Conductor:	Teflon/FEP
Sheath:	Silicone
Length (LK):	3 mt
Shape:	

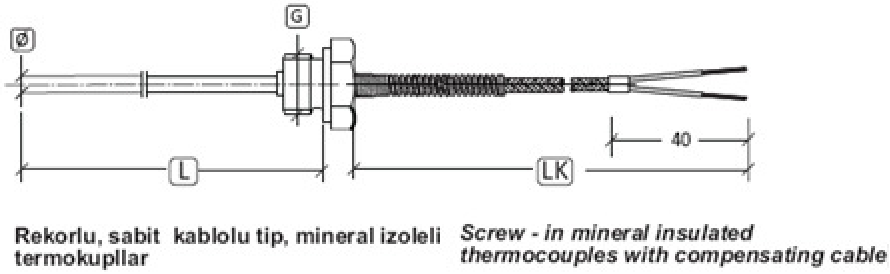


Diagram 2.3. Thermocouple

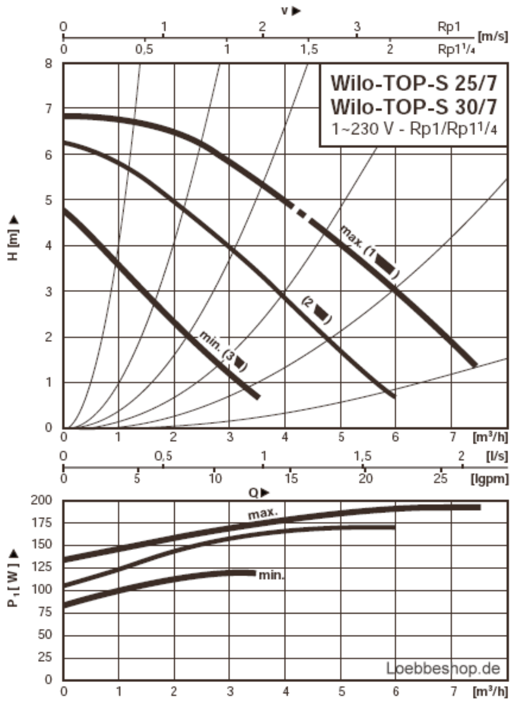
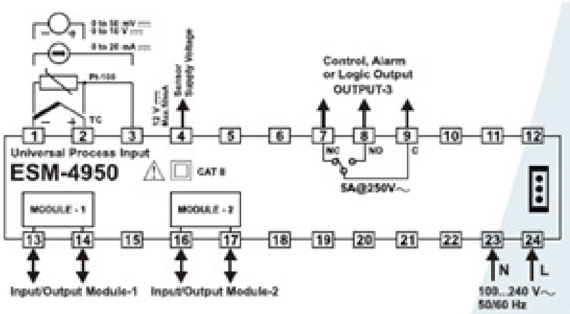


Chart 2.1. Circulating Pump Characteristic Curve

Process Controllers

"Smart I/O Module"System RS-232/485 Modbus RTU
Serial Communication

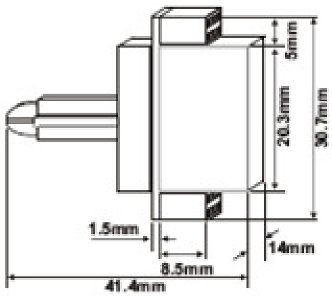


SPECIFICATIONS

PROCESS INPUT

Universal Input: TC, RTD,—Voltage/Current
Thermocouple (TC): L(DIN 43710) ,J , K , R , S , T , B , E and N (IEC584.1)(ITS90) ,C (ITS90)
Thermoresistance (RTD): PT-100 (IEC751)(ITS90)⎓
Input: mV, V, mA
Measurement Range: Please refer to Table-1 for selection of input type and scale
Accuracy: ± 0,25% of full scale for thermocouple, thermoresistance, mV, V
± 0.70% of full scale for mA input
Cold Junction Compensation: Automatically ± 0,1°C/1°C
Line Compensation: Maximum 10 Ohm
Sensor Break Protection: Upscale
Sampling Cycle: 3 samples per second
Input Filter: 0.0 to 900.0 seconds

Dimensions of Input/Output Modules



CONTROL

Control Form: ON/OFF, P, PI, PD, PID or Heating PID and Cooling PID together (Control form is programmable)

FG	Module-1	Module Codes
00	None	
01	Relay Output Module	EMO-400,EMO-700,EMO-900
02	SSR Driver Output Module (Maximum 20mA@18V ⎓)	EMO-410,EMO-710,EMO-910
03	Digital (Transistor) Output Module (Maximum 40mA@18V ⎓)	EMO-420,EMO-720,EMO-920
04	Current Output Module(0/4...20 mA ⎓) (or 0...10V ⎓ with appropriate mechanism)	EMO-430,EMO-730,EMO-930
07	Digital Input Module	EMI-400,EMI-700,EMI-900
08	Current Input Module(0/4...20 mA ⎓)	EMI-410,EMI-710,EMI-910
09	~ CT Input Module(0...5A~)	EMI-420,EMI-720,EMI-920
10	TC (Thermocouple) or 0...50mV ⎓ Input Module	EMI-430,EMI-730,EMI-930
11	PT-100 Input Module	EMI-440,EMI-740,EMI-940
12	0...10V ⎓ Input Module	EMI-450,EMI-750,EMI-950

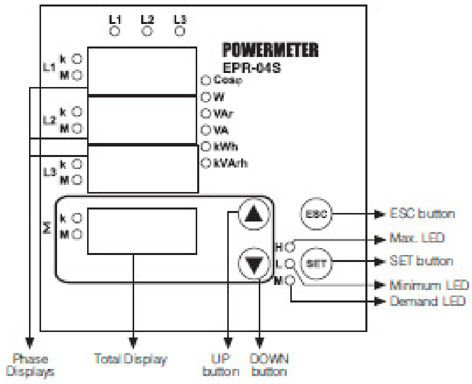
BC	Input Type(TC)	Scale(°C)	Scale(°F)
21	L ,Fe Const DIN43710	-100°C,850°C	-148°F ,1562°F
22	L ,Fe Const DIN43710	-100.0°C,850.0°C	-148.0°F,999.9°F
23	J ,Fe CuNi IEC584.1(ITS90)	-200°C,900°C	-328°F,1652°F
24	J ,Fe CuNi IEC584.1(ITS90)	-199.9°C,900.0°C	-199.9°F,999.9°F
25	K ,NiCr Ni IEC584.1(ITS90)	-200°C,1300°C	-328°F,2372°F
26	K ,NiCr Ni IEC584.1(ITS90)	-199.9°C,999.9°C	-199.9°F,999.9°F
27	R ,Pt13%Rh Pt IEC584.1(ITS90)	0°C,1700°C	32°F,3092°F
28	S ,Pt10%Rh Pt IEC584.1(ITS90)	0°C,1700°C	32°F,3092°F
29	T ,Cu CuNi IEC584.1(ITS90)	-200°C,400°C	-328°F,752°F
30	T ,Cu CuNi IEC584.1(ITS90)	-199.9°C,400.0°C	-199.9°F,752.0°F
31	B ,Pt30%Rh Pt6%Rh IEC584.1(ITS90)	44°C,1800°C	111°F,3272°F
32	B ,Pt30%Rh Pt6%Rh IEC584.1(ITS90)	44.0°C,999.9°C	111.0°F,999.9°F
33	E ,NiCr CuNi IEC584.1(ITS90)	-150°C,700°C	-238°F,1292°F
34	E ,NiCr CuNi IEC584.1(ITS90)	-150.0°C,700.0°C	-199.9°F,999.9°F
35	N ,Nicrosil Nisil IEC584.1(ITS90)	-200°C,1300°C	-328°F,2372°F
36	N ,Nicrosil Nisil IEC584.1(ITS90)	-199.9°C,999.9°C	-199.9°F,999.9°F
37	C , (ITS90)	0°C,2300°C	32°F,3261°F
38	C , (ITS90)	0.0°C,999.9°C	32.0°F,999.9°F
BC	**Input Type(RTD)**	**Scale(°C)**	**Scale(°F)**
39	PT 100 , IEC751(ITS90)	-200°C,650°C	-328°F,1202°F
40	PT 100 , IEC751(ITS90)	-199.9°C,650.0°C	-199.9°F,999.9°F

Diagram 2.4. Process Controllers Specifications

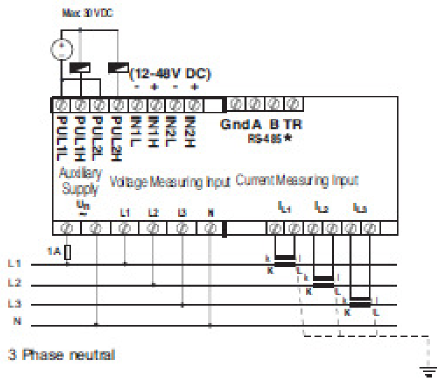
POWERMETER
EPR-04 / EPR-04S

TECHNICAL DATA

Operating Voltage (Un)	: Please look at the back labels on the device
Operating frequency (f)	: 45-65 Hz
Auxiliary supply Power Consumption	: < 4 VA
Measuring Input Power Consumption	: < 1VA
V_{In}	: 10-300VAC 45-65Hz. (L-N)
	: 10-500VAC 45-65Hz. (L-L)
I_{In}	: 0.05 - 5.5 A ~
	2-120 A ~ (for CT-25)
Measuring Range	: 0...215 M(W,VAr,VA)
	: 999999999.999 kWh,kVArh
Measuring Category	: CAT III
Class	: 1±1digit [(%10-%110) xFull Scale]
Voltage Transformer Ratio	: 0.1 ... 4000.0
Current Transformer Ratio	: 1 ... 2000
Max. Ctr x Vtr	: 40.000
Demand Time	: 1-60 min. (programmable)
Serial Interface (for EPM-04S)	: MODBUS RTU (RS 485)
	: Optically Isolated, programmable
Baud Rate (for EPM-04S)	: 2400-38400 bps
Address (for EPM-04S)	: 1-247
Parity (for EPM-04S)	: No , odd, Even, 8 Data Bits, 2 Stop Bits
Pulse Output	: NPN Transistor
Switch Period	: Min. 100 msec pulse perriod
	80 msec pulse width
Operation Current	: Max. 50 mA
Operation Voltage	: 5.....24 V DC, max. 30 VDC
Input	: 12...48 V DC
Ambient Temprature	: -5°C; +50°C
Display	: Red LED Display
Dimensions	: PR-19, PK-26
Equipment Protection Class	: Double Insulation-Class II (▣)
Box Protection Class	: IP 40
Box Material	: Non-flammable
Installation	: Panel Mounted (PR-19)
	Rail Mounted (PK-26)
Wire Crossection (for terminal block)	: 2.5 mm²
Weight	: 0.45 kg (PR-19, PK-26)
Installation Category	: Class III



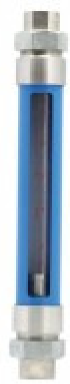
PK 26 Box Connection Diagram



3 Phase neutral

Diagram 2.5. Technical specifications of power and energy meter

Table 2.4. Variable area flow meter product specifications

O-Ring:	Viton	
Maximum operating temperature:	150°C	
Accuracy:	+/- 1 f.s.	
Length:	408 ... 431mm	
Buoy	Stainless Steel	
Body:	Epoxy Painted	
Buoy Stopper:	PTFE	
Maximum operating pressure:	12 Bar	
Connection:	R1” – DN25 mm	
Water measurement	63 – 630 L/h	
Heat transfer fluid measurement area	160 – 1600 L/h	

2.2. Data Control and Software:

The experimental mechanism, temperature sensor and power-energy meter data were monitored and recorded with a connection to the computer through RS485/USB convertor using RS-485 serial communication connection. To measure power and energy, ENTES EPR-04/S series RS485 serial communication output power and energy meter was used. As temperature sensor, universal process input multi-function control output RS485 serial communication and “Smart I/O Module” system EMKO ESM-4950 series process control equipment were used. For two temperature sensors one process control equipment was used. The computer communication was established serially interconnecting four process control equipments, a power and energy meter equipment, RS-485 serial communication connection and RS484/USB converter. EMKO ESM-4950 series process control equipment was monitored on the computer with EMKO Electronic Inc.’s PROTOKAL Data Logging Software V. 0.06 and ENTES EPR-04/S series power and energy meter was monitored with Entes Equipment Management System V 1.2.0.8 MPR-SW series software.

Diagram 2.6. MPR-SW Series Energy Management Software

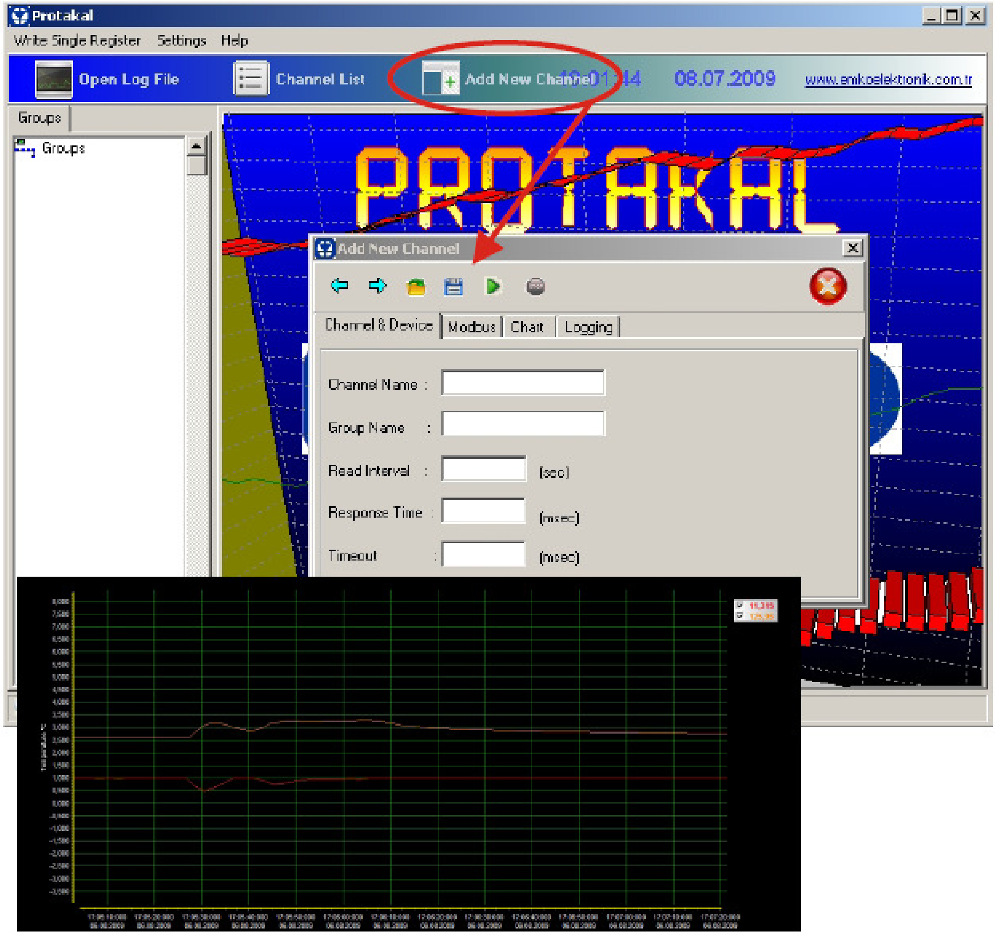


Diagram 2.7. Protakal Data Logging Software

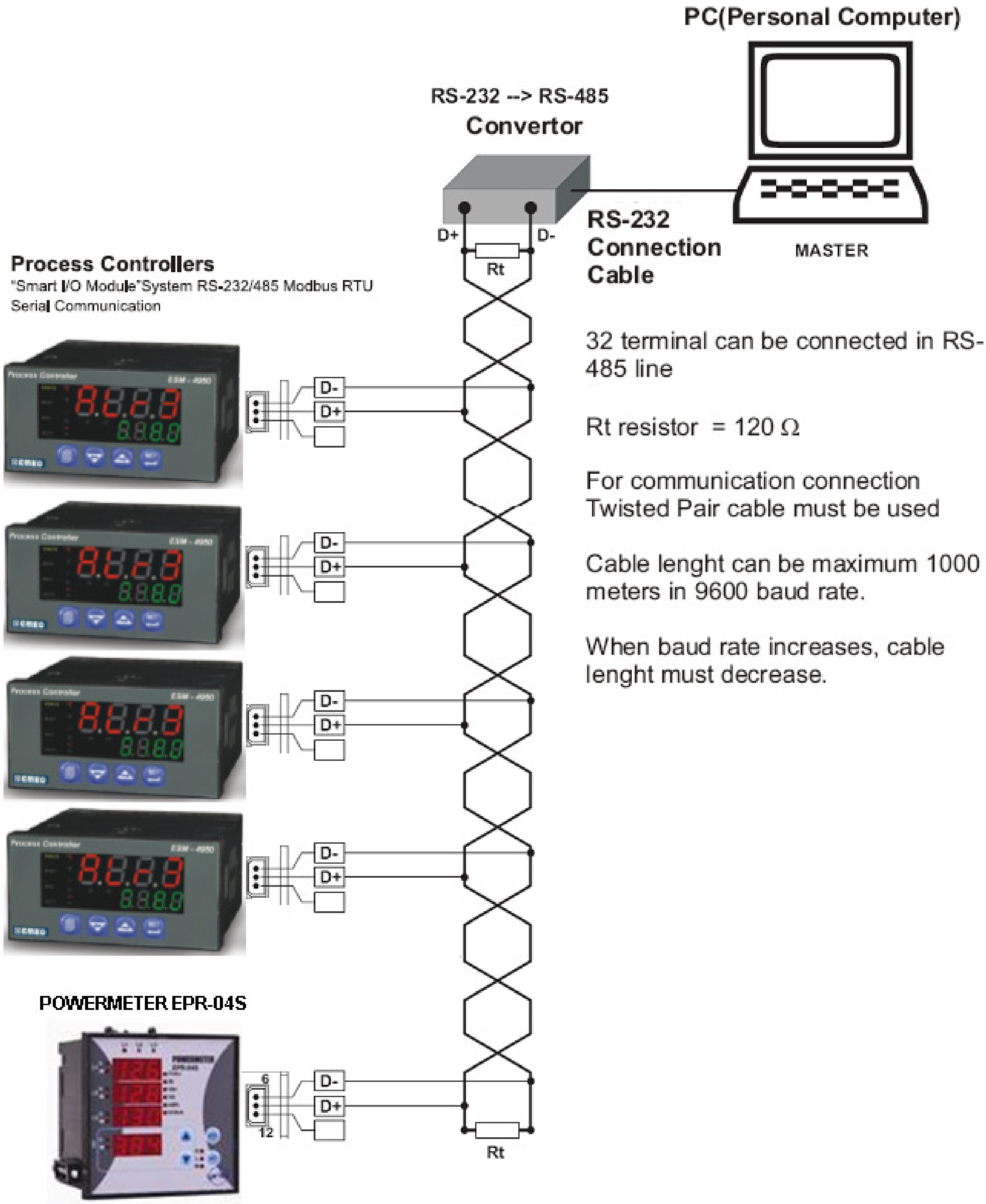


Diagram 2.8. Connection for RS-485 serial communication

2.3. Experimental Uncertainties:

In this experiment, T-type thermocouples compatible with IEC 584-3/DIN43722 standards with an accuracy value of ±0.5 were used. In the experimental mechanism, stainless steel glass type variable area working flow meters with a total scale value of ±1% (f.s.) accuracy and maximum operating temperatures 150^0C were used as volumetric flow meters. In the experiment, the measurement records were read when steady state conditions were reached and the values obtained from each measurement point were transferred to the data collection system every 10 seconds. In other words, sampling duration for every measurement point was 10 seconds and 180 samples were recorded by the data collecting system during the 30 minute steady-state regime period and these were used in transfer and flow calculations. In this study, the steady state conditions was considered to be reached when fluctuations were under 1% in the measurement of the temperature and volumetric flowrate for cold and hot fluid during a long period (for temperature measuring ±0.1 ^{0}C and for volumetric flowrate ± 6 - 10 Lt/h). In this study, approximately a 30 minute operating period was needed to reach the steady state conditions. Once the steady state condition was reached the measurement values were recorded within 25-30 minutes.

3.0. EXPERIMENT:

To measure the heat transfer performance of the brazed type plate heat exchanger in the experimental mechanism, experiments were carried out from water to water and from Hydromx/water solution to water according to the schema in the Diagram 2.1. In the experimental study, volumetric flowrate and heat load of the primary fluid were kept constant and 5 different volumetric flowrate ratios were used in the secondary fluid volumetric flow. Tap water was used as the cold fluid in the plate heat exchanger and its output was connected to the drainage system. The first experiment was conducted on water to water brazed type plate heat exchanger heat transfer performance. After the completion of the first experiment, the primary fluid closed loop water was pumped out and brazed plate heat exchanger heat transfer performance experiment started by putting 50%-50% Hydromx/water solution into the system. In both experiments, primary fluid was pumped into the system from a measured container using a water gauge until the dial manometer indicated 2 bars pressure in the closed loop electrical heating circuit.

Utmost care was taken to pump both fluids in equal volume into the closed loop electrical cycle, to be able to compare accurately the heat transfer performances of brazed type plate heat exchanger from water to water and from Hydromx/water heat transfer fluid to water. The experiments were carried out under the same conditions for both fluids. After the initial pressure of the system was set to 2 bars in the primary fluid stage, secondary fluid cycle was initialized with cold tap water flowing through the brazed type plate heat exchanger.

The first setting of the secondary fluid volumetric flow which was 400 Lt/h was kept constant with a variable type flow meter. Subsequently, the primary fluid circulation pump was started and primary fluid volumetric flowrate of the brazed type plated heat exchanger hot fluid side was set to 1100 Lt/h and electrical heater heating power was set to at 9 kW which was kept constant throughout the experiment. After a while, the system reached the steady-state condition. The first experiment results were recorded with the data logging system during a certain period (approximately 30 minutes). During the experiments, the first secondary fluid volumetric flowrate value 400 Lt/h was gradually decreased to 350, 300, 250 and 200 Lt/h. 5 different experimental results were obtained by varying the cold water flowrate for each primary fluid with a constant primary fluid volumetric flowrate and a constant heat transfer rate In order to compare the heat transfer performance of the brazed type plate heat exchanger.

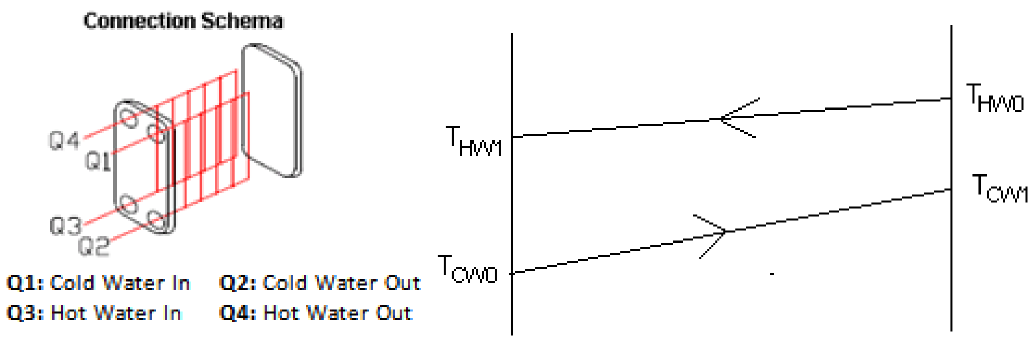
4.0. EVALUATION OF EXPERIMENT RESULTS:

In this section, the results of the experiment are explained and discussed.

Nomenclature

A	total heat transfer area (m^2)
Cp_{CW}	specific heat at average cold water temperature (kJ/ kg °C)
Cp_{HW}	specific heat at average hot (primary) fluid temperature (kJ/ kg °C)
$\dot{V}$	volumetric flowrate ratio
$\dot{V}_{CW}$	cold water flowrate (L/s)
$\dot{V}_{HW}$	hot (primary) fluid flowrate (L/s)
$\dot{Q}_{CW}$	heat transferred by cold water (W)
$\dot{Q}_{HW}$	heat transferred by (primary) fluid (W)
$\dot{Q}$ (%)	heat transfer rate difference from Hydromx solution to the cold water (%)
$\dot{Q}_{Average}$	average heat transfer between hot (primary) fluid and cold water (W)
$\dot{Q}_{Constant}$	constant heat rate (electrical heater heating power) (W)
T_{CWI}	cold water temperature at inlet (°C)
T_{CWO}	cold water temperature at outlet (°C)
T_{HWI}	hot (primary) fluid temperature at inlet (°C)
T_{HWO}	hot (primary) fluid temperature at outlet (°C)
ΔT_{CW}	temperature change of cold water (°C)
ΔT_{HW}	temperature change of hot (primary) fluid (°C)
ΔT_m	log mean temperature difference (LMTD)
ΔT_{outlet}	temperature difference of hot (primary) fluid and cold water measured at outlet of heat exchanger (°C)
ΔT_M(%)	log mean temperature difference change for primary fluids (%)
ΔT_{Heater}	difference between primary fluid heater input and output temperature
ΔX	plate spacing (mm)
ρ_{CW}	water density at average cold water temperature (kg/ m^3)
ρ_{HW}	water density at average hot (primary) fluid temperature (kg/m^3)

4.1. Investigation of Heat Distribution and Logarithmic Mean Temperature Difference in Brazed Type Heat Exchanger



Şekil 4.1. Brazed type plate heat exchanger heat distribution

In this section, heat exchanger input and output difference and Logarithmic Mean Temperature difference was analyzed according to different volumetric flowrate ratios during the heat transfer of the water and Hydromx as the primary fluid to the secondary fluid cold water.

Heat exchanger input and output difference and Logarithmic Mean Temperature (LMT) were calculated with the following equations:

$$\Delta T_{HW}=(T_{HW1} - T_{HW0}) \quad (1)$$

$$\Delta T_{CW} =(T_{CW1} - T_{CW0}) \quad (2)$$

$$\Delta T_M = \frac{(T_{HWI} - T_{CWO}) - (T_{HWO} - T_{CWI})}{\ln \frac{(T_{HWI} - T_{CWO})}{(T_{HWO} - T_{CWI})}} \quad (3)$$

ΔT_{HW} represents primary (hot) fluid Hydromx or water temperature difference (°C), ΔT_{CW} is secondary (cold) fluid cold water temperature difference (°C) and ΔT_m represents Logarithmic Mean Temperature Difference.

Volumetric flowrate ratio was used to analyze the experimental data and the change was calculated with the following equation:

$$\dot{V} = \frac{\dot{V}_{HW}}{\dot{V}_{CW}} \quad (4)$$

Here $\dot{V}_{HW}$ represents (hot) fluid volumetric flowrate (L/h) and $\dot{V}_{CW}$ represents cold water volumetric flowrate (L/h). During the experiment, primary fluid flowrate was constant $\dot{V}_{HW}$ and secondary fluid flowrate was changed to $\dot{V}_{CW}$. Change in the parameter values measured during the experiment was observed based on the volumetric flowrate difference ratio of these two fluids.

Table 4.1. Brazed type plate heat exchanger hot and cold fluid temperature difference change

PRIMARY (HOT) FLUID $\dot{V}_{HW}$ (Lt/h)	COLD FLUID VOLUMETRIC FLOW $\dot{V}_{CW}$ (Lt/h)	VOLUMETRIC FLOWRATE RATIO $\dot{V} = \frac{\dot{V}_{HW}}{\dot{V}_{CW}}$	-HEAT EXCHANGER INPUT-OUTPUT TEMPERATURE DIFFERENCE FOR COLD WATER AS SECONDARY FLUID WHEN HYROMX IS USED AS PRIMARY FLUID ΔT_{CW} (°C)	HEAT EXCHANGER INPUT-OUTPUT TEMPERATURE DIFFERENCE FOR COLD WATER AS SECONDARY FLUID WHEN WATER IS USED AS PRIMARY FLUID ΔT_{CW} (°C)	HEAT EXCHANGER INPUT-OUTPUT TEMPERATURE DIFFERENCE FOR WATER AS PRIMARY FLUID ΔT_{HW} (°C)	HEAT EXCHANGER INPUT-OUTPUT TEMPERATURE DIFFERENCE FOR HYDROMX AS PRIMARY FLUID ΔT_{HW} (°C)
1100	**400**	2,75	17,74	18,02	4,97	6,14
1100	350	3,14	21,32	20,75	4,93	6,05
1100	300	3,67	24,73	23,76	4,48	5,61
1100	250	4,40	30,46	28,68	4,51	5,87
1100	200	5,50	39,12	36,96	4,61	5,84

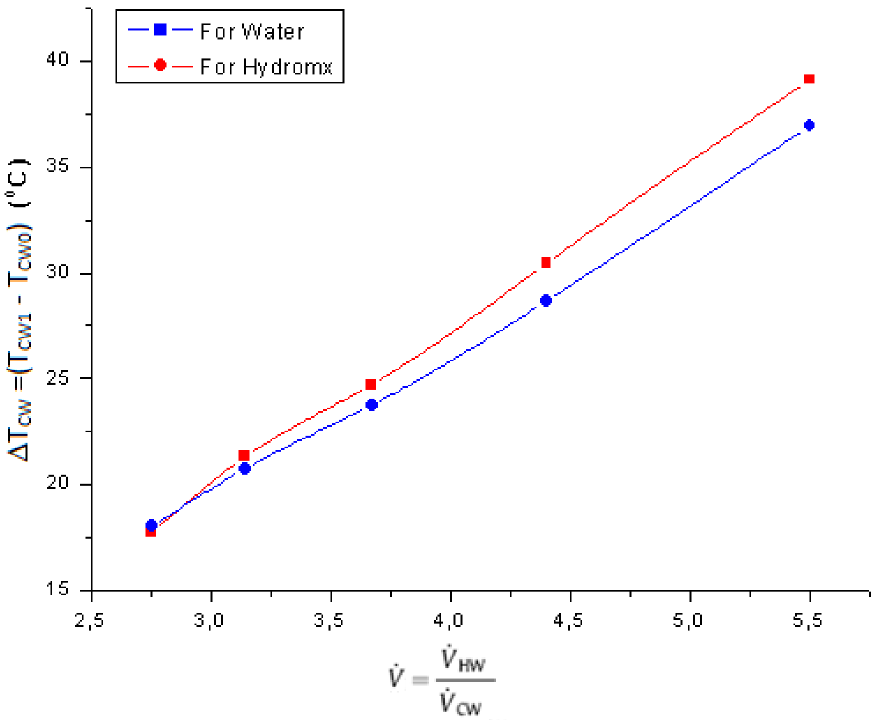


Chart 4.2. Heat exchanger input-output temperature difference in different volumetric flowrate ratios for cold water as secondary fluid by using water and Hydromx solution as primary fluid.

As is clearly seen that, heat exchanger input and output temperature difference increases are higher when Hydromx is used than water as the volumetric flowrate ratio increases (Chart 4.2.). It was observed that the temperature difference in the heat exchanger increased when cold water secondary fluid volumetric flowrate ratio increased and this difference reached 2.16 ^{0}C in the maximum flowrate ratio.

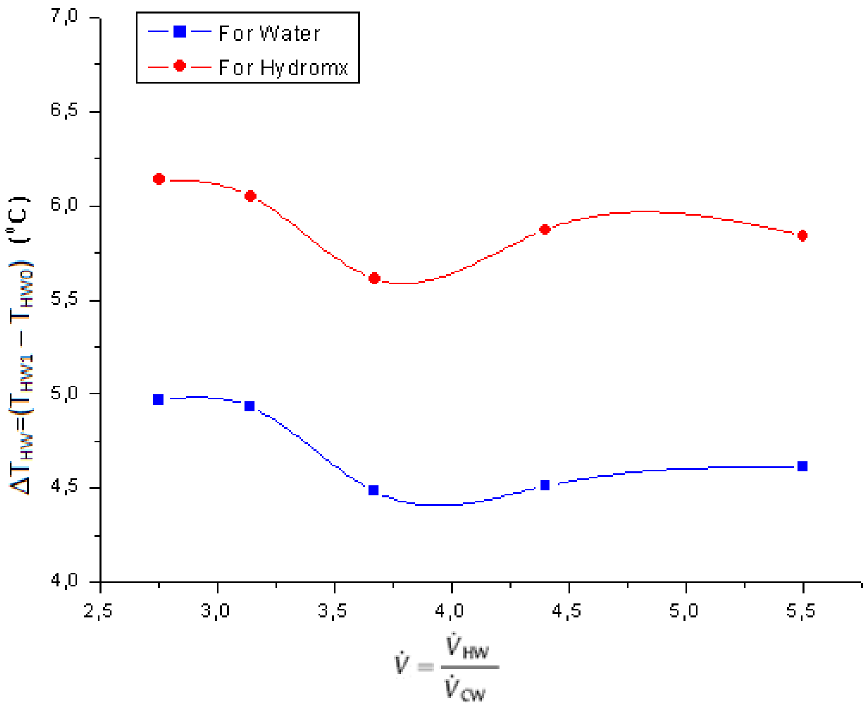


Chart 4.3. Heat exchanger input - output temperature difference in different volumetric flowrate ratios for water as well as Hydromx solution as primary fluid.

In Chart 4.3., heat exchanger input and output temperature difference for the primary fluid Hydromx compared with water in all volumetric flowrate ratios were between 1 ^{0}C and 2 ^{0}C. In other words, in comparison with water, under the same operating conditions and with constant heat load, Hydromx provided higher temperature increase and increased thermal performance of the heat exchanger.

Table 4.3. Logarithmic Mean Temperature Difference Change for water and Hydromx solution as primary fluids

VOLUMETRIC FLOW RATIO $\dot{V} = \frac{\dot{V}_{HW}}{\dot{V}_{CW}}$ (L/h)	LOGARITHMIC MEAN TEMPERATURE DIFFERENCE CHANGE (°C) ΔT_M		LOGARITHMIC MEAN TEMPERATURE DIFFERENCE CHANGE FOR HYDROMX COMPARED TO WATER ΔT_M(%)	AVERAGE WORKING TEMPERATURE (^{0}C)
	HYDROMX	WATER		
2,75	12,925	11,783	9,69%	38,9
3,14	13,549	12,438	8,93%	42,8
3,67	14,192	13,175	7,72%	46,7
4,40	15,747	14,77	6,61%	52,4
5,50	18,244	16,714	9,15%	60,45

ΔT_M values in Table 4.3. were calculated with the following:

$$\Delta T_M(\%) = \frac{(\Delta T_{M\,Hydromx} - \Delta T_{M\,Water})}{\Delta T_{M\,Water}} \times 100 \quad (\%) \qquad (5)$$

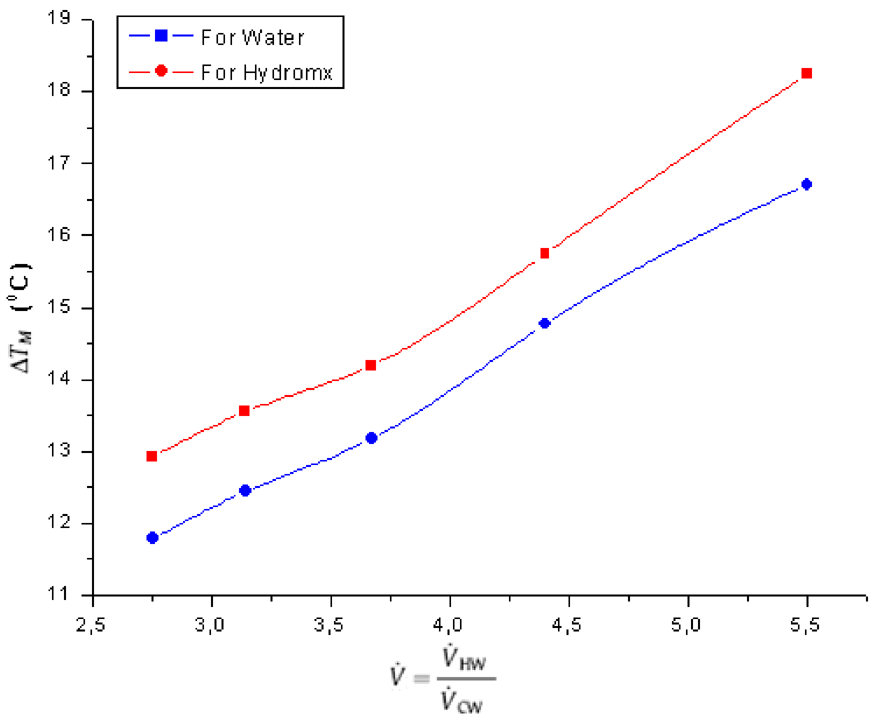
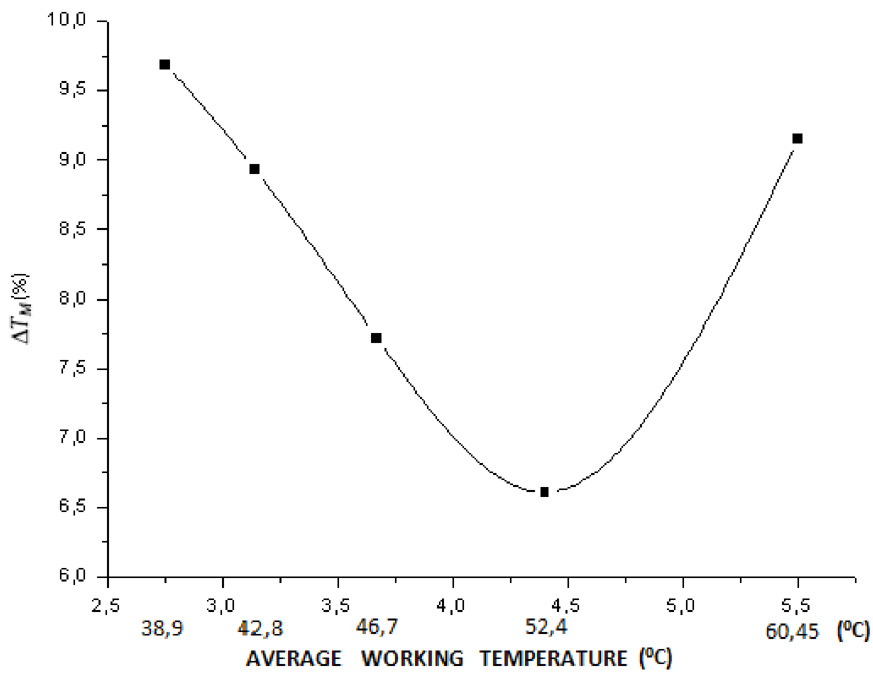


Chart 4.4. Logarithmic Mean Temperature Difference change for Hydromx solution and water as primary fluid in different volumetric flowrate ratios



$$\dot{V} = \frac{\dot{V}_{HW}}{\dot{V}_{CW}}$$

Chart 4.5. Logarithmic Mean Temperature Difference change ratio (%) for Hydromx solution compared to water in different volumetric flowrate ratios

In Chart 4.4. It was observed that the Logarithmic Mean Temperature Difference was higher for the heat exchanger between 1 ^{0}C and 2 ^{0}C based on volumetric flowrate ratio. Consequently, Hydromx solution Logarithmic Mean Temperature Difference change for the heat exchanger was calculated to be 8% higher than water (Chart 4.5.). Average logarithmic temperature difference decreases when operating temperature is under 55 ^{0}C. Nevertheless when operating temperature is above 55^{0}C logarithmic temperature difference increases because Hydromx has a better performance in higher average operating temperatures.

4.2. Comparaison of Hydromx Solution Fluid and Water Heat Transfer Rates in the Brazed Type Plate Heat Exchanger

In this section, heat transfer rates of water and Hydromx solution as primary fluids to the secondary fluid with the heat exchanger were analyzed and compared.

Heat transfer rates in the heat exchanger were calculated with the following equations:

$$\dot{Q}_{HW} = \rho_{HW} C_{P_{HW}} \dot{V}_{HW} (\Delta T_{HW}) \qquad (6)$$

$$\dot{Q}_{CW} = \rho_{CW} C_{PCW} \dot{V}_{CW} (\Delta T_{CW}) \qquad (7)$$

$$\dot{Q} = \frac{\dot{Q}_{CW}}{\dot{Q}_{Constant}} \qquad (8)$$

Here $\dot{Q}_{HW}$ represents the heat load transferred in the heat exchanger from Hydromx solution and water as primary fluid and $\dot{Q}_{CW}$ is the heat load transferred to the cold water as secondary fluid from the heat exchanger

$\dot{Q}_{Constant}$ is constant heat load transferred from the heat exchanger to the Hydromx solution and water as primary fluid. Its unit is in Watts.

$\dot{Q}$ represents the heat load ratio difference for cold water from the Hydromx/water solution as primary fluid (%) transferred in the heat exchanger to the cold water. It is used in comparison of heat load ratios transferred to the cold water for both fluids.

Table 4.4. Comparaison of heat transfer rates for water as primary fluid and Hydromix solution to the cold water in the brazed type plate heat exchanger

VOLUMETRIC FLOW RATIO $\dot{V} = \frac{\dot{V}_{HW}}{\dot{V}_{CW}}$ (L/h)	CONSTANT HEAT LOAD (ELECTRICAL HEAT POWER) $\dot{Q}_{Constant}$ (WATT)		HEAT TRANSFER RATE TO COLD WATER $\dot{Q} = \frac{\dot{Q}_{CW}}{\dot{Q}_{Constant}}$		HEAT TRANSFER RATE DIFFERENCE FROM HYDROMX SOLUTION TO THE COLD WATER COMPARED WITH WATER $\dot{Q}$ (%)
	FOR HYDROMX AS PRIMARY FLUID	FOR WATER AS PRIMARY FLUID	PRIMARY FLUID HYDROMX	PRIMARY FLUID WATER	
2,75	8697	8746	0,948	0,948	0,00%
3,14	8670	8670	1,001	0,974	2,77%
3,67	8728	8680	0,988	0,955	3,46%
4,40	8790	8560	1,007	0,974	3,39%
5,50	8650	8646	1,052	0,987	6,59%

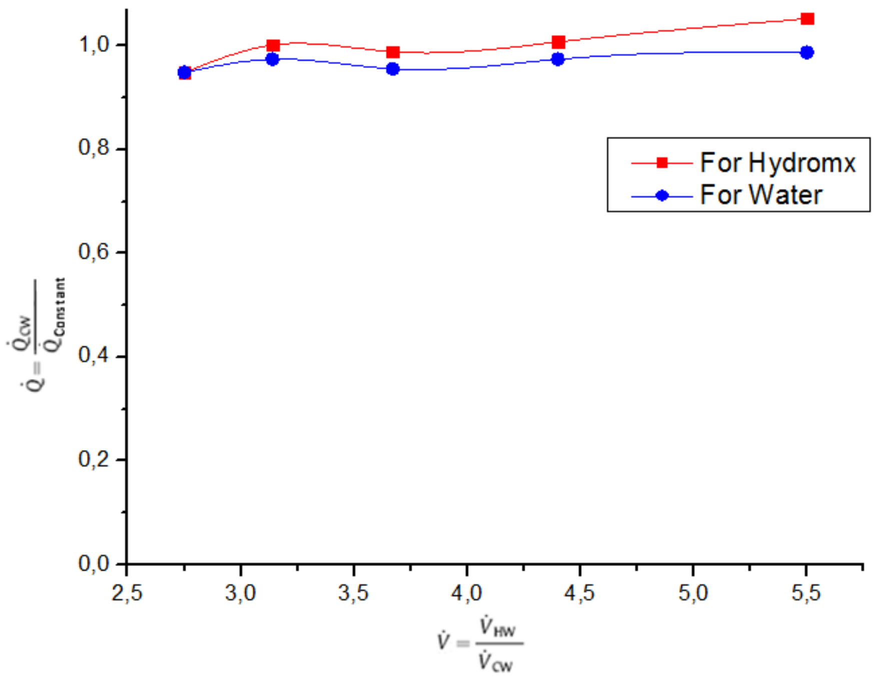


Chart 4.6. Heat transfer rates for Hydromx solution and water to cold water in different volumetric flowrate ratios in brazed type heat exchanger

Chart 4.6. Shows that heat transfer rate in the brazed type plate heat exchanger increases more when Hydromx solution is used than water with the increase in the volumetric flowrate.

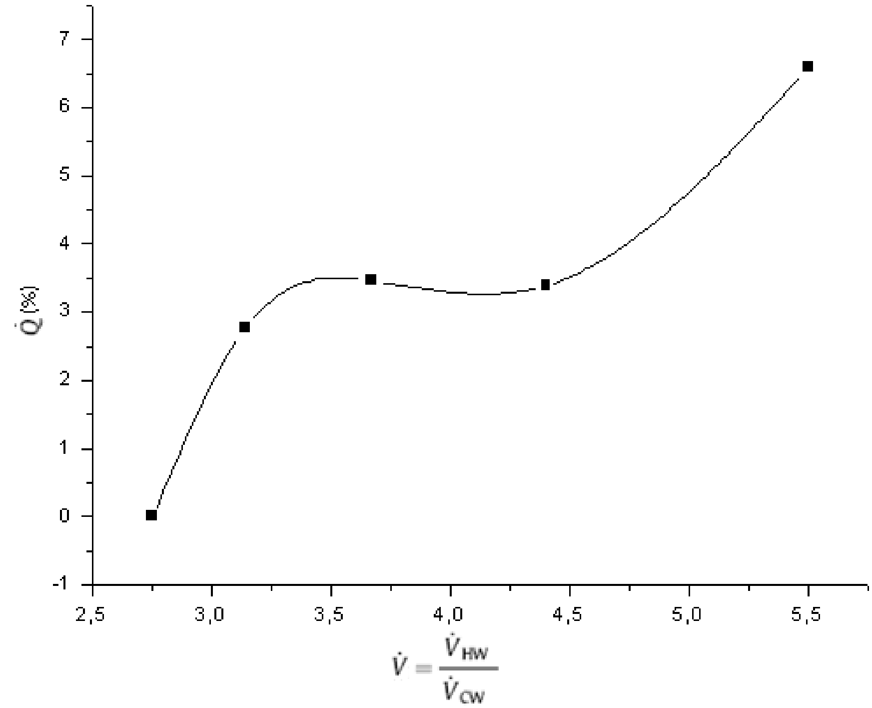


Chart 4.7. Heat transfer rate difference for Hydromx solution and water in different volumetric flowrate ratios in brazed type heat exchanger (%)

There is a 6.59% performance increase in the heat transfer rate with the use of Hydromx solution compared to water in the maximum volumetric flowrate ratios (Chart 4.7.). In other words, with the use of Hydromx solution there is an increase in the performance of the plate heat exchanger.

When Hydromx is mixed with water with a 50% ratio and used as a heat transfer fluid, thermal performance of the heat exchanger increases and results in energy savings and reduction in energy costs. There will also be a decrease in the investment costs because of dimensional reduction in the equipment size used in system design.

4.3. Comparaison of Input-Output Temperatures for Hydromx Solution as Primary Fluid with Water In the Case of Constant Heat Load and with Heat Exchange:

In this section, input and output temperature differences and heat increase ratios were anaylzed for water and Hydromx solution as primary fluid in constant heat load and during heat transfer in the heat exchanger to cold water.

The difference in input and output temperatures of the heater were calculated according to the following equation:

$$\Delta T_{Heater} = (T_{H1} - T_{H0}) \quad (9)$$

Here ΔT_{Heater} is the difference between (T_{H1}) Hydromx solution and water as primary fluid heater output and heater input (T_{H0}) temperatures.

And the increase rate between constant heat load input and output temperatures is represented with the following:

$$\frac{\Delta T_{\text{Heater}}}{\dot{Q}_{\text{Constant}}}.$$

This represents heat increase obtained per unit heat load for water and Hydromx solution as primary fluid. Heat increase rate was also analyzed as percentage (%) in comparison of water and Hydromx solution:

$$(\%) = \frac{\left(\frac{\Delta T_{\text{Heater}}}{\dot{Q}_{\text{Constant}}}\right)_{\text{hydromx}} - \left(\frac{\Delta T_{\text{Heater}}}{\dot{Q}_{\text{Constant}}}\right)_{\text{water}}}{\left(\frac{\Delta T_{\text{Heater}}}{\dot{Q}_{\text{Constant}}}\right)_{\text{water}}} \quad (10)$$

Table 4.5. Input and output temperature difference for Hydromx solution and water in constant heat load, heat exchange and in different volumetric flowrate ratios

VOLUMETRIC FLOW RATIO $\dot{V} = \frac{\dot{V}_{HW}}{\dot{V}_{CW}}$ (L/h)	CONSTANT HEAT LOAD (ELECTRICAL HEAT POWER) $\dot{Q}_{\text{Constant}}$ PRIMARY FLUID (Watt)		HEATER INPUT AND OUTPUT TEMPERATURE DIFFERENCE ΔT_{Heater} (°C)		CONSTANT HEAT LOAD HEAT INCREASE RATIO $\frac{\Delta T_{\text{Heater}}}{\dot{Q}_{\text{Constant}}}$ (°C/W)		HEAT INCREASE RATE DIFFERENCE FOR HYDROMX/WATER SOLUTION COMPARED TO WATER (%)
	PRIMARY FLUID HYDROMX	PRIMARY FLUID WATER	PRIMARY FLUID HYDROMX	PRIMARY FLUID WATER	PRIMARY FLUID HYDROMX	PRIMARY FLUID WATER	
2,75	8697	8746	5,7	4,86	0,00064	0,00056	14,29%
3,14	8670	8670	5,9	5,02	0,00067	0,00058	15,52%
3,67	8728	8680	6,48	5,19	0,00074	0,0006	23,33%
4,4	8790	8560	7,2	5,41	0,00082	0,00063	30,16%
5,5	8650	8646	8	5,31	0,00092	0,00061	50,82%

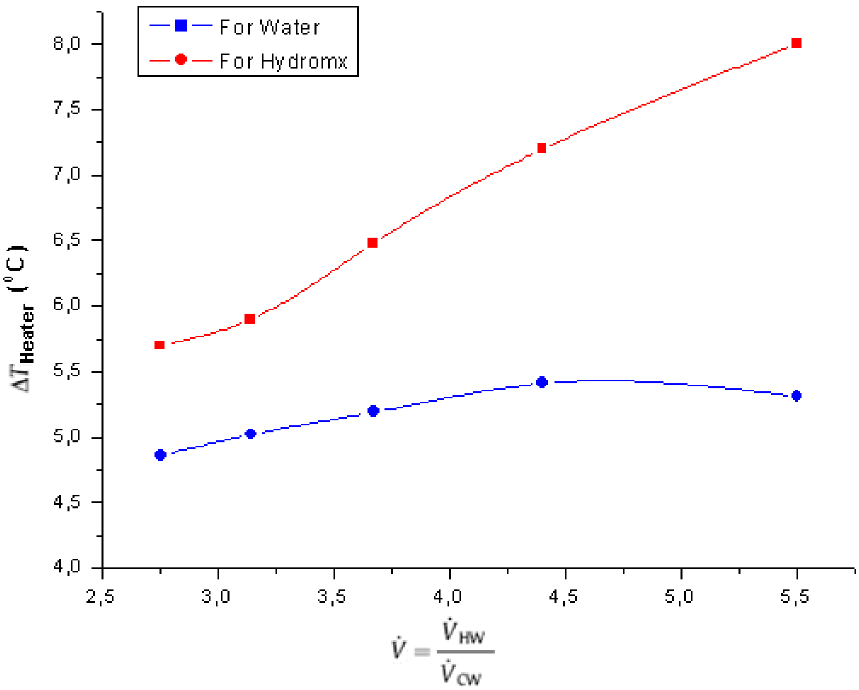


Chart. 4.8. Input and output temperature difference in different volumetric flowrate ratios and constant heat load for Hydromx solution and water.

When the difference between input and output temperatures of the heater, heating the Hydromx solution and water was compared (Chart 4.8.). It was observed that Hydromx solution had a higher input and output temperature difference than water based on the volumetric flowrate ratios increase and in the same heat load. This temperature difference increased with the volumetric flowrate ratio.

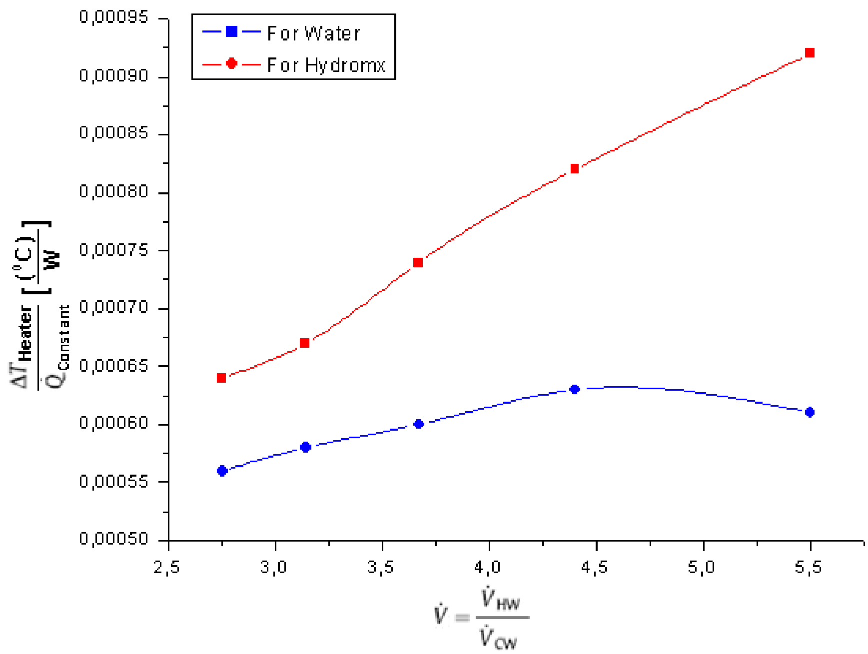


Chart 4.9. Heat increase rate in different volumetric flow ratios and constant heat load for Hydromx solution and water

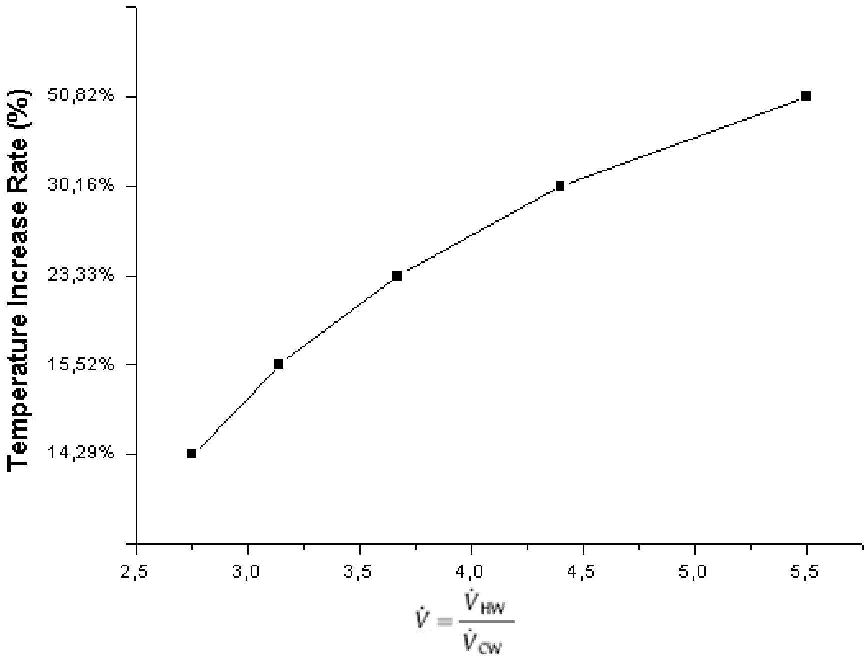


Chart 4.10. Heat increase rate difference in different volumetric flow ratios and constant heat load(%) for Hydromx solution and water

When the Chart 4.9. and Chart 4.10. are examined, the mean value of difference was 26% higher than water as primary fluid and is 50% in maximum flowrate ratio. In the same operating conditions and constant heat load, the difference in the temperature increase shows that Hydromx solution heats faster that leads to higher temperature increase than water in the heater. As a result, Hydromx solution fluid use improves the thermal performance and the energy savings in heaters such as combination boilers, etc.

4.4. Comparaison of Input-Output Temperatures for Hydromx Solution as Primary Fluid with Water In the Case of Constant Heat Load and without Heat Exchange:

Finally, heater input and output temperature difference for water and Hydromx solution as primary fluids and temperature increase rates were analyzed in cases where no heat exhange took place (in other words, whithout heat transfer in plate type heat exchanger between primary fluid and secondary fluid) in constant heat load.

Based on heater input and output temperatures, heat tranfer rate from the heater to water and Hydromx solution as primary fluid was calulated by the following equation.

$$\dot{Q}_{Constant} = \dot{Q}_{Heater} = \rho_{HW} C_{P_{HW}} \dot{V}_{HW} (\Delta T_{Heater}) \quad (11)$$

Here $\dot{Q}_{Heater}$ (W) represents heat transfer rate to the primary fluid, ΔT_{Heater} (^{0}C) is heater input and output temperature difference, ρ_{HW} (kg/m^3) is density of water or Hydromx as primary fluid , $C_{P_{HW}}$ (kJ/kg^{0}C) represents specific heat value of water or Hydromx solution and $\dot{V}_{HW}$ is volumetric flowrate. When the heat loss to the environment is omitted, the result is expessed as $\dot{Q}_{Constant} = \dot{Q}_{Heater}$.

With equation no. (11), specific heat value and thermal capacity for water and Hydromx as primary fluid was calculated as follows:

Specific heat value was approximately calculated by the equation given below.

$$C_{P_{HW}} = \frac{\dot{Q}_{Heater}}{\Delta T_{Heater}\ \rho_{HW}\ \dot{V}_{HW}} \quad (12)$$

In this equation, Hydromx solution was compared to water. It was assumed that its density changed with the same rate as its heat and was equal to water and specific heat value was calculated relative to water.

Thermal capacity of the fluids was found by multiplying mass of flowrate with the specific heat capacity and it represents the heat transfer rate per unit temperature change during the flow of the fluid.

It was calculated with the following equation and its unit is (W/^{0}C)

$$\dot{m}_{HW}\, C_{P_{HW}} = \rho_{HW} C_{P_{HW}} \dot{V}_{HW} = \frac{\dot{Q}_{Heater}}{\Delta T_{Heater}} \quad (13)$$

Here $\dot{m}_{HW}$ represents mass flowrate of the fluid and its unit is (kg/s)

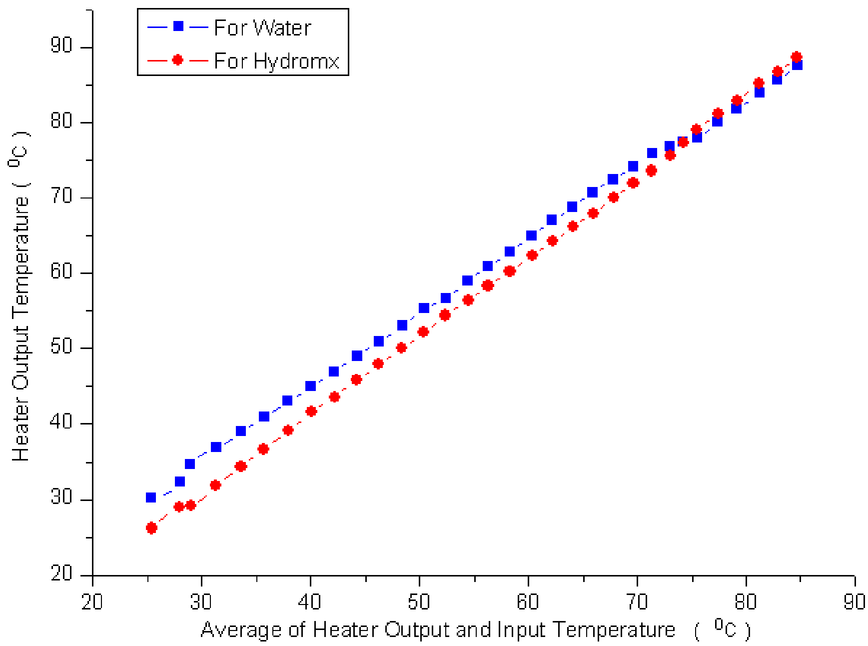


Chart 4.11. Change in input and output average temperatures for the heater output temperature

Chart 4.11. In constant heat load and constant volumetric flowrate, heater input and output temperature were analyzed for heating of Hydromx solution and water in an isolated system without heat exchange. Around and above 75^{0}C average heater input and output temperatures, Hydromx solution output temperature increase was observed to be higher than water.

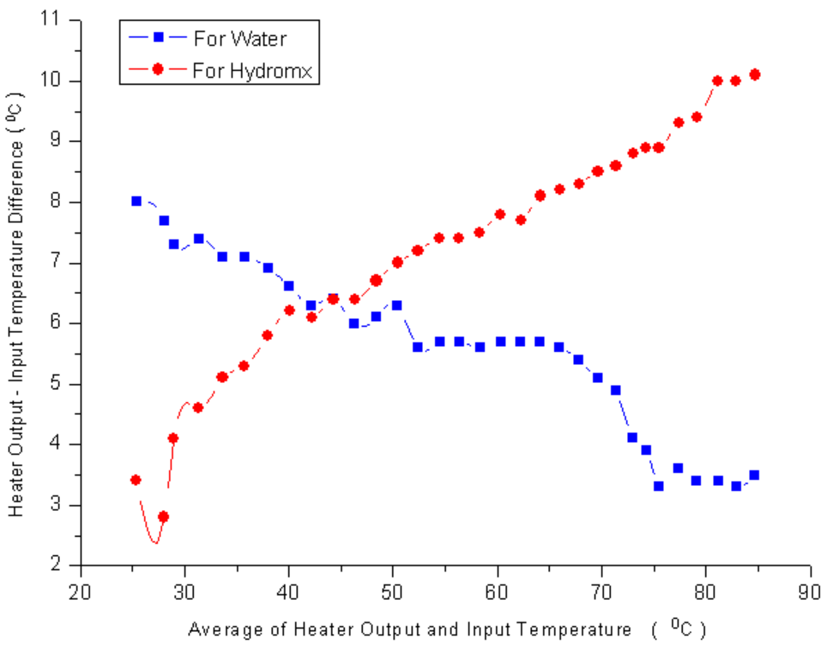


Chart 4.12. Heater output and input temperature differences according to average heater input and output temperatures

According to the Chart **4.12.**, **w**ater input and output differences were analyzed and consequently temperature differences increase due to average heater input and output temperatures are observed. So, these differences increased even higher as the temperature increased. The increase in ratio of water temperature difference is higher than Hydromx solution up to the 50^{0}C temperature. On the other hand, the increase in ratio of Hydromx temperature difference is observed higher than water about 50^{0}C and above.

This result obtained through experiments, particularly based on the results analyzed here, proved that Hydromx solution compared to water shows a much better heating performance in operating conditions about 75^{0}C and above.

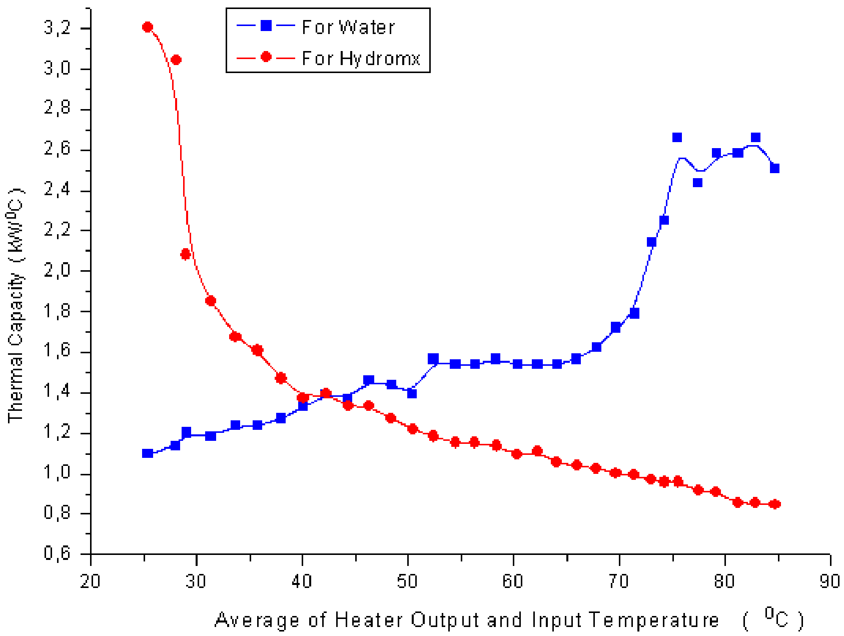


Chart 4.13. Changes based on input and output temperatures for water and Hydromx solution as primary fluid thermal capacity

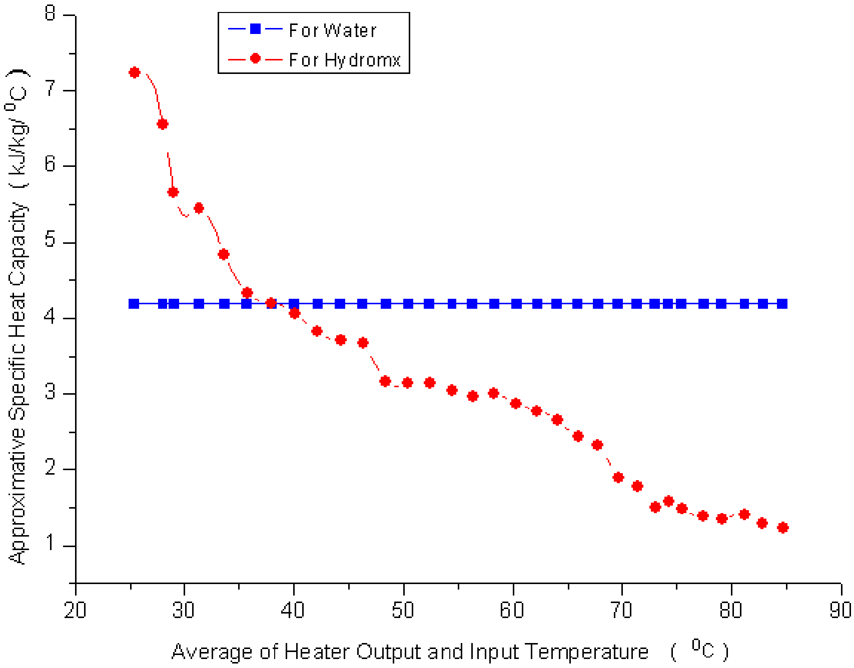


Chart 4.14. Changes based on average heater input and output temperatures for water and Hydromx solution as primary fluid specific heat values

When compared to water, relative specific heat value and thermal capacity of Hydromx solution were observed to decrease in increasing temperatures between 20 ^{0}C and 90^{0}C in which the experiment was carried out (Chart 4.13. and Chart 4.14).

The specific heat is the amount of heat per unit mass required to raise the temperature by one degree Celsius. To this extent same temperature increase is achieved with less energy using the Hydromx solution than is achieved in water due to different specific heat and other thermal properties.

At typical Low Pressure Hot Water (LPHW) heating system operating temperatures of 75^{0}C Hydromx has lower specific heat capacity and the rate of increase in temperature is higher that water and this increases with higher flow rates. Hydromx therefore heats up to the boiler output operating temperature with less energy than water at higher flow rates and average boiler temperatures of 75 ^{0}C.

5.0. CONCLUSION:

In conclusion, the analysis of the heat transfer performance of Octrooicentrum Nederland Patent No. 1034917 and named “Hydromx Energy Saving Solution” were conducted at Asım Kocabıyık Vocational School of Higher Education, Heating and Cooling Laboratory upon the request of Istanbul Kurumsal Marketing, Consulting, Chemical Industry and Commerce Inc. and is presented in this investigation report.

This experiment evaluates the heat transfer rates by means of 100 % water and 50% Hydromx/50 % water solution in a closed loop using a brazed type plate heat exchanger in order to compare their performances. In the comparison process, experimental data was obtained using the same system in the same operating conditions both for Hydromx solution and water. During the experiment, the temperature interval within which Hydromx and water fluids were tested was between 20 ^{0}C and 90 ^{0}C.

Below are the final results of the comparison between Hydromx solution and water.

- With Hydromx solution, as the flowrate ratio increased, heat exchanger input and output temperature differences increased higher than water. In high flowrate ratios, temperature difference in the heat exchanger reached approximately to 2^{0}C (Chart 4.2, Chart 4.3, Chart 4.4.). As a result, Logarithmic Mean Temperature Difference for Hydromx solution in comparison with water was calculated to be 8% higher than water in the brazed type plate heat exchanger (Chart 4.5.). As Hydromx solution flow ratio compared to water increases higher, heat exchanger input and output temperature differences also increases higher.

- As a result of the increase in the temperature and flowrate, the heat transfer rate increases higher in Hydromx solution compared to water in the brazed type plate heat exchanger (Chart 4.6.). According to the experiment results, at the highest flowrate ratio, there is a 6.59% performance improvement in the heat transfer rate in Hydromx solution compared to water (Chart 4.7.). In other words, with the use of Hydromx solution, heat transfer performance increased parallel to the increase in the flowrate ratio in plate heat exchanger. Under the same operation conditions, Hydromx solution compared to water indicated a much better heat transfer performance. When fluid flow is increased this performance improves even further in the same system. Therefore, a performance improvement analysis based on the increase in the flowrate, should be carried out and an optimum operation interval should be determined. Depending especially on the increase of the flowrate, this property of Hydromx gains importance in systems where thermal performance increase is crucial.

- Additionally, higher heater input and output differences and 26% mean increase is observed in the same heat load of Hydromx solution compared to water when the heater input and output temperature difference of heater produces constant heat load is investigated (Chart 4.10, Chart 4.9.).

- In the maximum flow ratio, with Hydromx solution, this temperature difference was measured to be 50% higher compared to water (Chart 4.10). Under the same operating conditions and same heat load, this difference in temperature, show that Hydromx solution heated faster and resulted in higher increase in temperature compared to water. The fact that Hydromx solution heats faster and results in higher temperature increase than water will have the advantage of improving thermal performance and saving energy in heaters such as boilers, combination boilers, etc.

- During the heating of Hydromx solution and water in constant heat load and constant volumetric flowrate the heater temperature difference between input and output temperatures were analyzed in an isolated system without heat exchange. The temperature differences increased according to average heater input and output temperatures and when the temperature increased these differences increased even higher. The increase in ratio of water temperature difference is higher than Hydromx solution up to the 50^0C temperature. On the other hand, the increase in ratio of Hydromx temperature difference is observed higher than water about 50^0C Chart 4.12. and Chart 4.11.. When compared to water, relative specific heat value and thermal capacity of Hydromx solution were observed to decrease in increasing temperatures between 20 ^{0}C and 90^0C in which the experiment was carried out. Taking the experimental results into consideration, the density changed in the same rate as the temperature and it was equal to water. Using equations no. (12), (13) relative specific heat and thermal capacity values was calculated approximately and illustrated in charts (4.13.), (4.14.). These charts indicate that with Hydromx solution, within the 20 ^{0}C and 90^0C interval of the experiment temperatures, specific heat and thermal capacity decreased as the temperatures increased compared to water. By definition, specific heat is the amount of heat per unit mass required to raise the temperature by one degree Celsius. To this extent, providing the much temperature increase with less heat load Hydromx solution's specific heat and thermal capacity values are obtained less than water.

The analyses of the experimental results indicate that, temperature of the Hydromx solution and improved performance of the system does not depend only on the thermal conductivity and specific and thermal capacity values. Other physical and chemical properties of the fluid also affect the overall heat transfer performance. Particularly, thermal performance of Hydromx solution, compared to water, increases with the rise in flow rates and fluid temperature. Thus, the effect of the thermophysical properties (density, heat conductivity, specific heat values, etc.) of fluid and the heat convection event is clearly seen. The heat convection events based on flow type (such as laminar and turbulent flow) and operating conditions, quasi-experimental, empirical equations with Dimensionless numbers such as Nusselt (Nu), Reynolds (Re) and Prandtl (Pr) are being used. In the solutions of heat convection problems terms of steady flowrate, viscosity, and heat conductivity of the fluid, Reynolds (Re) and Prandtl (Pr) dimensionless numbers are important. Heat convection coefficient is inversely proportional to the viscosity and changes directly proportional to the other physical parameters. In other words, heat transfer towards a fluid flowing inside a tube increases with the rise in thermal conductivity and decreases with an increase in viscosity. It is important to accurately determine the operational interval and thermal performance of Hydromx as a heat transfer fluid in terms of Reynolds and Prandtl numbers. In higher Reynolds numbers, friction will increase with the rise in speed of the fluid inside the tube and this will result in higher pressure loss. Viscosity of the fluid should be low enough to ensure that the pressure loss in the system remains at a reasonable level. Further higher, it is well known that with these types of fluids the conductivity rate has a major effect and Prandtl (Pr) number plays an important role. On this account, in order to determine fields of application for Hydromx heat transfer fluid, physical and chemical properties of the fluid should be identified and measured.

It is particularly important to carry out measurements with different Hydromx/water mixture ratios and is illustrated in charts. It is also important to determine Hydromx heat transfer performance interval according to different Reynolds (Re) and Prandtl (Pr) numbers.

Energy will be saved and energy costs will be reduced by using Hydromx within the higher efficient performance interval compared to water In terms of thermal performance. Reduction of equipment sizes will also decrease investment costs.