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APPENDICES

Appendix A

International standards of biodiesel (B100) (ASTMD 6751-02)

Property	ASTM method	Limits	Units
Flash point (closed cup)	D93	130.0 min.	°C
Water and sediment	D2709	0.050 max.	vol%
Kinematic viscosity, 40°C	D445	1.9-6.0	mm^2/s
Sulfated ash	D874	0.020 max.	mass%
Sulfur	D5453	0.05 max.	mass%
Copper strip corrosion	D 130	No. 3 max.	-
Cetane number	D613	47 min.	-
Cloud point	D2500	Report	°C
Carbon residue, 100% sample	D4530	0.050 max.	mass%
Acid number	D664	0.80 max.	mg KOH/g
Free glycerin	D6584	0.020 max.	mass%
Total glycerin	D6584	0.240 max.	mass%
Phosphorus content	D4951	0.001 max.	mass%
Distillation temperature, atmospheric equivalent temperature, 90% recovered	D 1160	360 max.	°C

Appendix B

Estimation of height and diameter of the reactor unit

Liquid volume of the reactor	= 50 liters
Volume of the conical section	= 3.239 liters
Volume of electric heaters	= 0.400 liters
Liquid volume in cylindrical section	= 50 – (3.239 – 0.400) liters
	= 47.161 liters

Height:diameter ratio of the reactor unit was taken as 1.5.

$$\frac{\pi D^2 h}{4} = 47.161 \text{ liters}$$

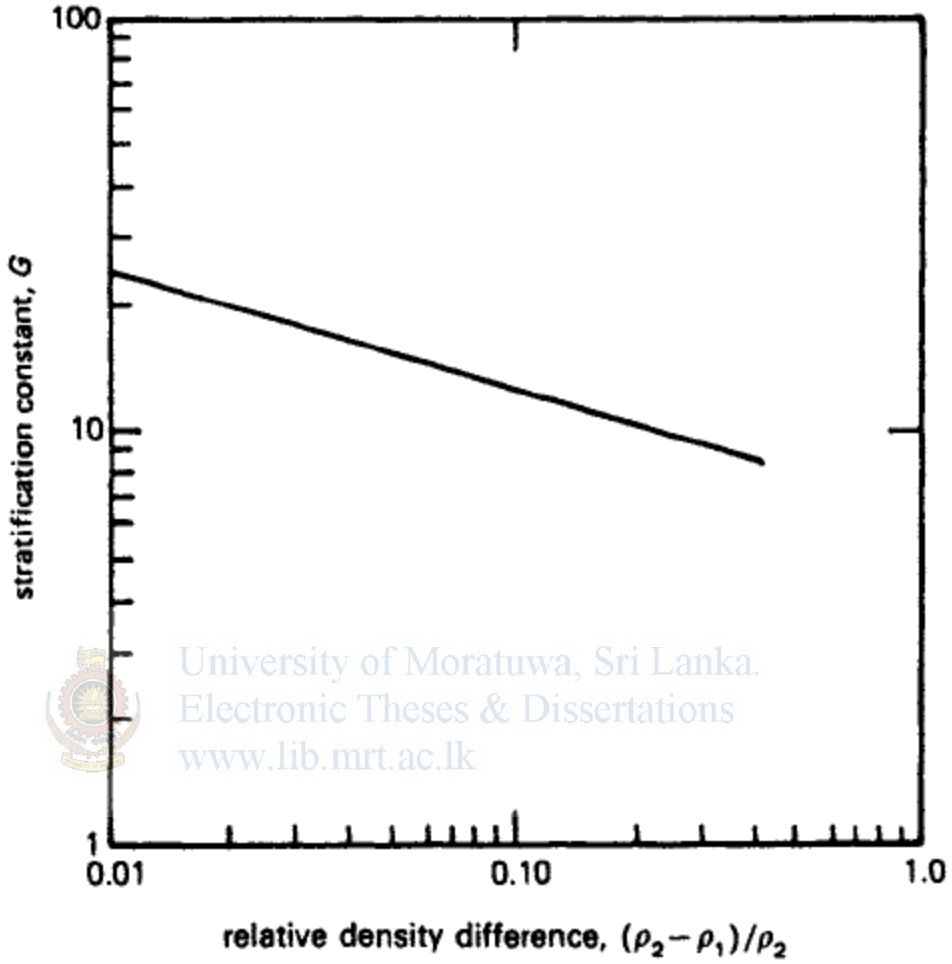
$$\frac{\pi D^2 \times 1.5D}{4} = 0.047161 \text{ m}^3$$

$$D = 342 \text{ mm}$$

Therefore 350 mm is selected as the diameter of the reactor vessel. The resulted liquid height for 50 litre liquid volume is 490 mm.

Appendix C

Stratification data for jet mixing



SOURCE - Nienow, A. W., Harnby, N. & Edwards, M. F. (1997) Mixing in the Process Industries: Second Edition, Butterworth-Heinemann, page 173.

Appendix D

Details of the process equipments used in the biodiesel pilot-plant

Centrifugal pump

Pipe diameter	Inlet 1.25″, Outlet 1″
Power	0.05 HP / 0.37 kW
Current	2.6 A
Voltage	230 V, 50 Hz
Speed	2,800 RPM
Suction head	7.8 m
Total head	17 m
Max. capacity	67 l/min
Impeller material	Stainless steel
Manufacturer	Arpico (Sri Lanka)

Mixing motor and gear box

Motor	
Model	4IK25GN-AWU
Type	Induction
Power	25 W
Current	0.55 A
Voltage	100 VAC, 50 Hz
Speed	1,250 RPM
Manufacturer	Oriental Motor Co. Ltd. (Japan)
Gear Head	
Model	4GN12.5-D1
Gear Ratio	12.5:1
Manufacturer	Oriental Motor Co. Ltd. (Japan)

Solenoid valves

Model	SUW-20
Pipe size	0.75″
Voltage	220 V, 50/60 Hz
Max. Temperature	80°C
Manufacturer	miT-UNiD-cns (Taiwan)

Electric heaters

Power	2000 W × 3
Current	26.1 A
Voltage	230 V, 50 Hz
Material	Stainless Steel
Manufacturer	Mega Heaters (Sri Lanka)

Pressure gauge

Model	K1.1.6
Range	0 – 100 mBar
Make	JAKO (Nederland)

Thermometer

Range	0 – 250°C
Make	–

Appendix E

Typical design stresses for plate

The appropriate material standards should be consulted for particular grades and plate thicknesses

Material	Tensile Strength (N/mm^2)	Design stress at temperature °C (N/mm2)									
		0 to 50	100	150	200	250	300	350	400	450	500
Carbon steel (semi-killed or silicon killed)	360	135	125	115	105	95	85	80	70		
Carbon-manganese steel (semi-killed or silicon killed)	460	180	170	150	140	130	115	105	100		
Carbon-molybdenum steel, 0.5per cent Mo	450	180	170	145	140	130	120	110	110		
Low alloy steel (Ni, Cr, Mo, V)	550	240	240	240	240	240	235	230	220	190	170
Stainless steel 18Cr/8Ni unstabilised (304)	510	165	145	130	115	110	105	100	100	95	90
Stainless steel 18Cr/8Ni Ti stabilised (321)	540	165	150	140	135	130	130	125	120	120	115
Stainless steel 18Cr/8Ni, Mo 2.5% (316)	520	175	150	135	120	115	110	105	105	100	95

SOURCE – Sinnott, R. K. (2005) Coulson & Richardson's Chemical Engineering Series, Volume-6, Elsevier Butterworth-Heinemann. page-812

Appendix F Complete biodiesel pilot plant

Appendix G Full schematic diagram of the PDS

Appendix H

Descriptions of the buttons used in CPI

Name	Mode selection switch
Switch type	Selector switch (Auto/Manual)
Limitation	No limitation – Function under both Auto and Manual modes
Description	Can be used to shift between Auto and Manual modes at any time Auto to Manual – System automatically load current status of the unit to manual mode and continue under Manual mode without any change. Manual to Auto – System stops and load next automatic mode (mode indicator light will indicate the loaded mode) and wait for operator's command to run under the new mode.

Name	Level selection switch
Switch type	Selector switch (Full/Half)
Limitation	No limitation – Function under both Auto and Manual modes
Description	Can be used to inform the system about operating liquid level of the reactor unit System will select the correct jet for mixing depend on the liquid level System avoid using incorrect jet valve under manual mode

Name	Reset switch
Switch type	Push button switch
Limitation	No limitation – Function under both Auto and Manual modes
Description	System switches off all the running equipments and reset it's memory.

Name	Permission switch
Switch type	Push button switch
Limitation	Function only under Automatic mode when system require permission to proceed a certain operation/process
Description	System will indicate the required permission through the display unit System waits until it receive permission

Name	Mode switches (Mode 1, Mode 2, Mode 3 and Mode 4)
Switch type	Push button switches
Limitation	Function only under Automatic mode
Description	Mode 1 – FFA reduction step Mode 2 – Layer separation of FFA reduction step Mode 3 – Biodiesel reduction step Mode 4 – Layer separation of biodiesel reduction step System will automatically shifted to next mode when one mode is complete

Name	Equipment control switches (6 Solenoid valves, Electric heaters, Electric pump and Electric motor)
Switch type	Push button switches
Limitation	Function only under Manual mode 3 heaters cannot be operated individually under Manual mode
Description	Can be use to control the equipments individually Can be change the status of a equipment by single press (Off to On or On to Off) System avoid using incorrect jet nozzle selection valve

Appendix I

Schematic diagram of the pilot-plant control system

Appendix J

Printed circuit board diagram of the pilot-plant control system

Appendix K

Printed circuit board diagram of the current amplifying circuit

Appendix L

Abstract of patent application I

Title:
Quantification of reactants required in the conversion of Free Fatty Acids (FFA) present in vegetable oils and animal fats into Fatty Acid Methyl Esters (FAME) based on the weight of the FFA content

Abstract:
A novel method to convert free fatty acids (FFAs) in triglycerides (i.e. vegetable oil and animal fat) to fatty acid methyl esters (FAMEs) is disclosed. In this method, the amounts of methanol and acid catalyst required to convert FFAs to FAMEs is estimated based on the weight of the FFA present in the oil. Oil, appropriate amounts of methanol and acid catalyst mixture is subjected to conditions that allow the fatty acid methyl esters (FAMEs) to form and then the reaction mixture is allowed to settle. The FFA reduced fat or oil is settled into a separate layer and can be separated from the rest of the reaction mixture. Then the FFA reduced oil/fat can be converted to triglycerides into fatty acid methyl esters (i.e. biodiesel). The method of present invention is especially useful for the production of biodiesel using vegetable oil and animal fat feedstocks that contain any level of free fatty acids.

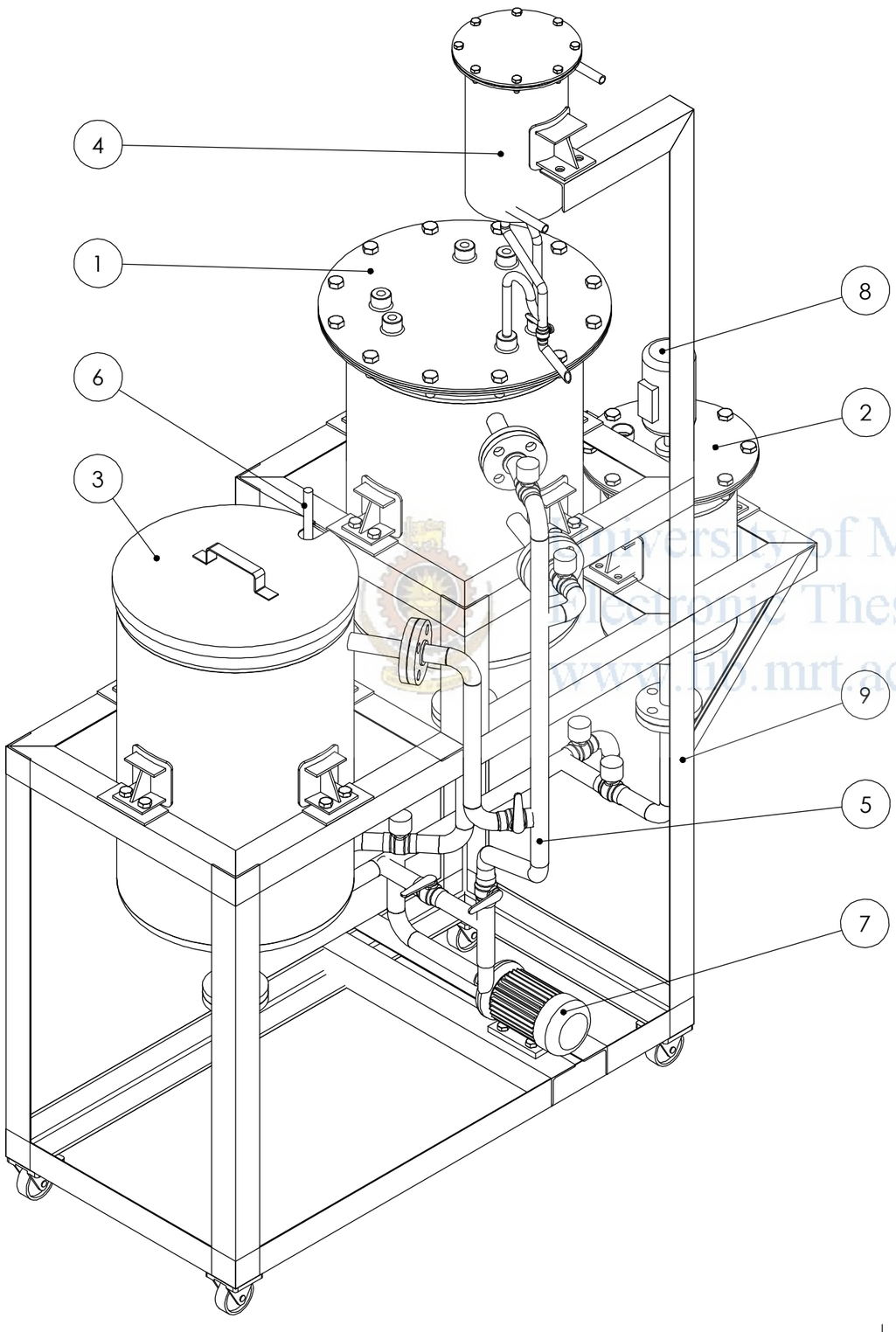
Appendix M

Abstract of patent application I

Title:
Method of converting free fatty acids to fatty acid methyl esters with extended settling

Abstract:
A novel method for converting free fatty acids (FFAs) in triglycerides (i.e. vegetable oil, animal fat and waste oi1) is disclosed. The method involves adding a appropriate amounts of methanol and acid catalyst, subjecting the mixture to conditions that allow the fatty acid methyl esters (FAMEs) to form and allowing the reaction mixture to be settled. The FFA reduced fat or oil is settled in to a separate layer and can be separated from rest of the reaction mixture. The remaining FFAs of the separated layer can be further reduced by allow for settling more time. The FFA reduced oil/fat then can be subjected to conditions suitable for converting the triglycerides into fatty acid methyl esters (i.e. biodiesel). The method of present invention is especially useful for a production of biodiesel using vegetable and animal oils and fats that contain a relatively high level of free fatty acids as the feedstock.

BIODIESEL PILOT-SCALE PLANT



	UNIT	MATERIAL
1.	REACTOR UNIT	STAINLESS STEEL 304
2.	MIXING UNIT	STAINLESS STEEL 304
3.	SETTLING UNIT	STAINLESS STEEL 304
4.	CONDENSER UNIT	STAINLESS STEEL 304
5.	PIPING SYSTEM	STAINLESS STEEL 304
6.	AIR BUBBLING SYSTEM	STAINLESS STEEL 304
7.	PUMP	STAINLESS STEEL 304
8.	ELECTRIC MOTOR	STAINLESS STEEL 304
9.	SUPPORTING STRUCTURE	LOW CARBON STEEL

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR: 2 MILLIMETERS
ANGULAR: 2 deg

FINISH:

DEBUR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING | REVISION

	NAME	SIGNATURE	DATE
DRAWN	D.R.S. HEWA WALPITA		09/08/2009
CHK'D1	DR. S.H.P GUNAWARDENA		09/08/2009
CHK'D2	DR. F.M. ISMAIL		09/08/2009
MFG			
Q.A			

MATERIAL: SS 304L & LOW CARBON STEEL

WEIGHT:

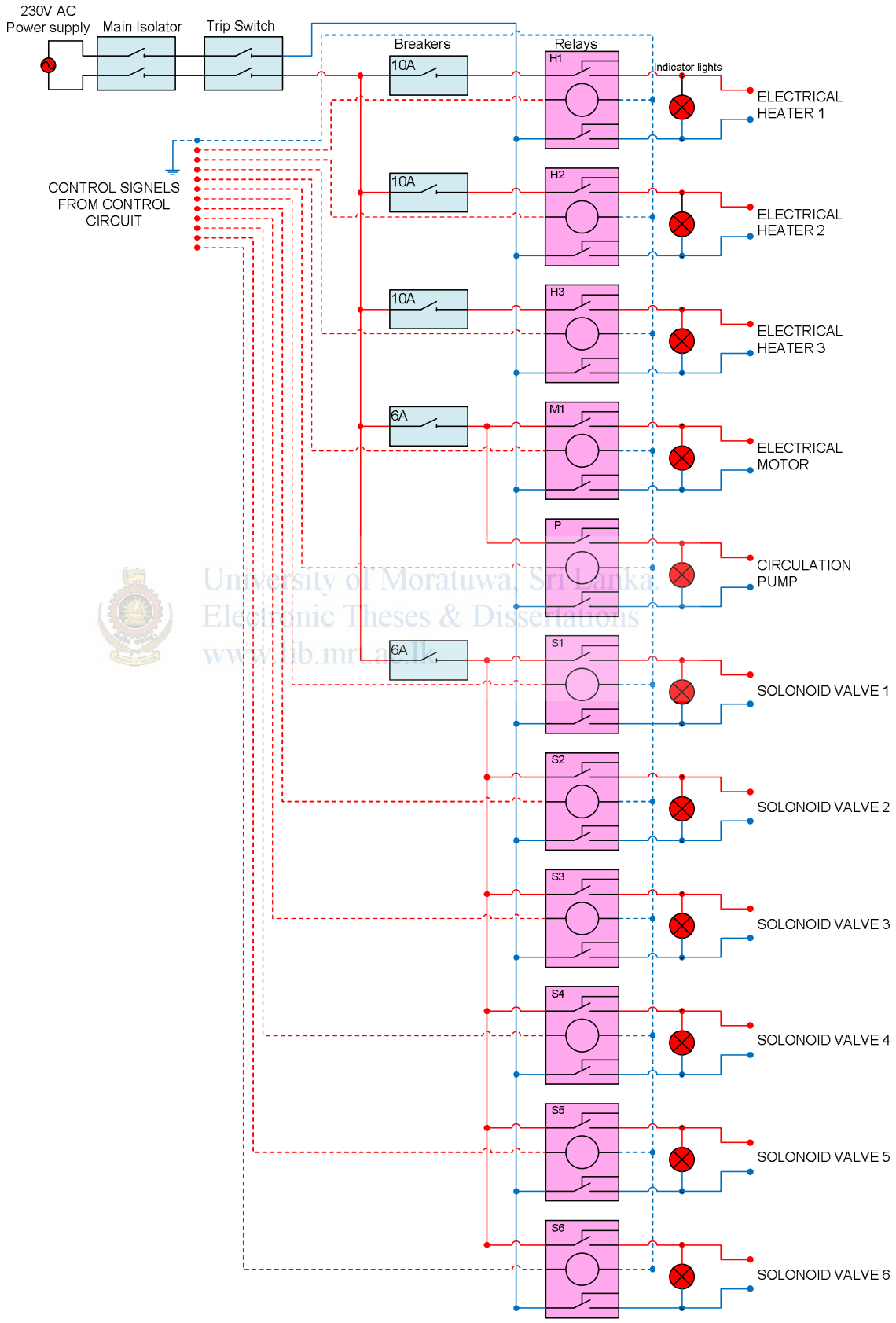
TITLE: BIODIESEL PILOT-SCALE PLANT

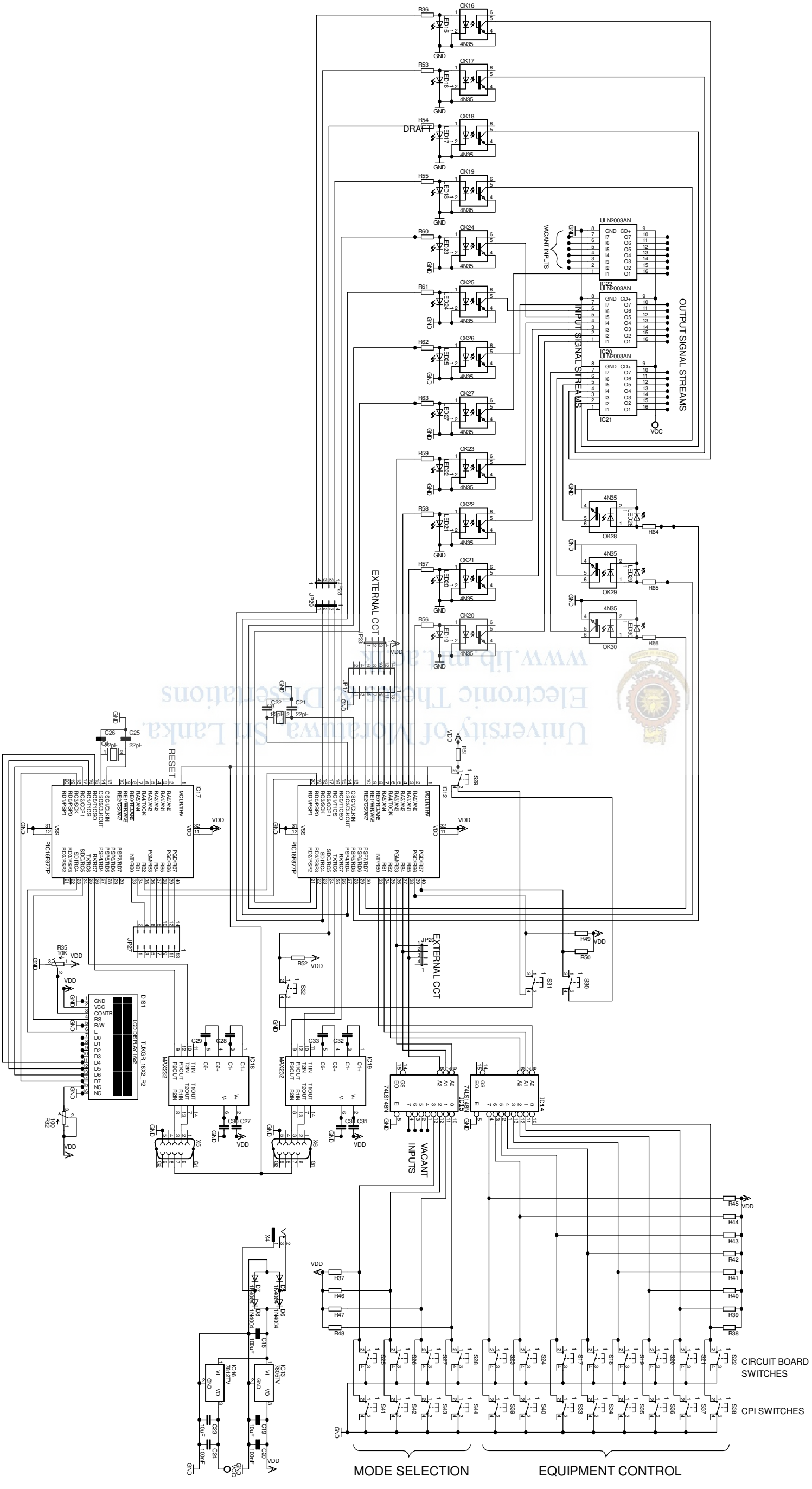
DWG NO. 01

A3

SCALE:1:8

SHEET 1 OF 9




OUTPUT SIGNAL STREAMS
INPUT SIGNAL STREAMS
EXTERNAL CCT
EXTERNAL CCT
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VACANT INPUTS
CIRCUIT BOARD SWITCHES
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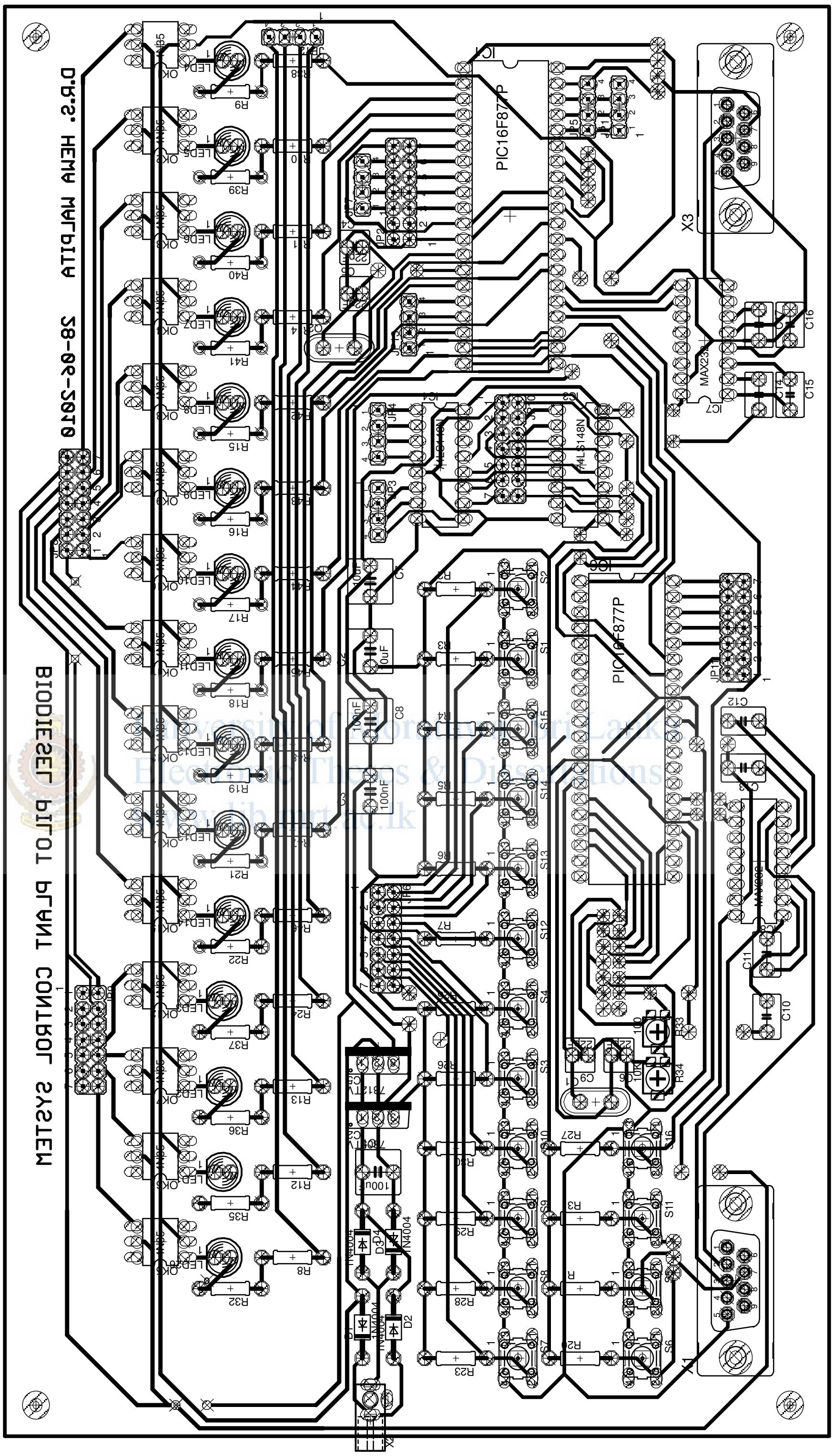
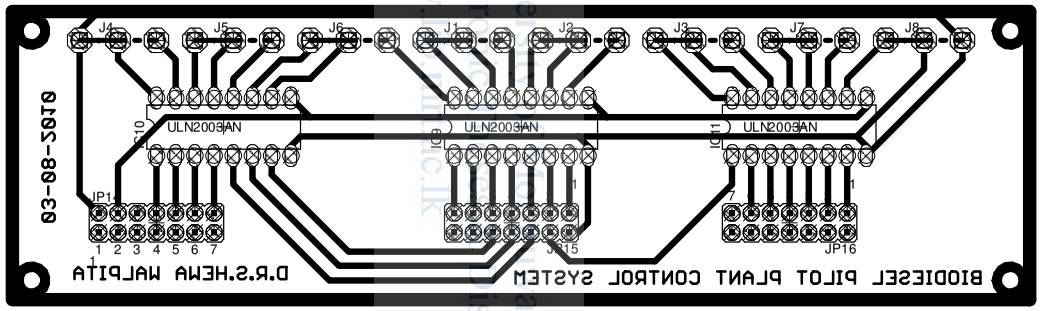
MODE SELECTION
EQUIPMENT CONTROL
RESET
ULN2003AN
PIC16F877P
MAX232
74LS148N
LCD DISPLAY 16x2
TUXGR_16X2_P2
4N35
VCC
VDD
GND
DRAFT

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BIODIESEL PILOT PLANT CONTROL SYSTEM
D.R.S.HEWA WALPITA
03-08-2010