PROCON

Level, Flow & Temperature Process Control Trainers

Reference Manual

38-001-3

Feedback

- e-learning
- Electricity & Electronics
- Control & Instrumentation
- Process Control
- Mechatronics
- Telecommunications
- Electrical Power & Machines
- Test & Measurement

Technology Training for tomorrow's world

PROCON

Level, Flow & Temperature Process Control Trainers Reference Manual

38-001-3

For use with:

Level/Flow Process Control	**38-001**
Temperature Process Control	**38-002**
Level/Flow & Temperature Process Control	**38-003**

Feedback
Feedback Instruments Limited

Feedback Instruments Ltd, Park Road, Crowborough, E. Sussex, TN6 2QR, UK.
Telephone: +44 (0) 1892 653322, Fax: +44 (0) 1892 663719.
email: feedback@fdbk.co.uk website: http://www.fbk.com

Manual: 38-001-3 Ed08 032006 *Printed in England by FI Ltd, Crowborough*

Feedback Part No. 1160–380013

Notes

THE HEALTH AND SAFETY AT WORK ACT 1974

We are required under the Health and Safety at Work Act 1974, to make available to users of this equipment certain information regarding its safe use.+

The equipment, when used in normal or prescribed applications within the parameters set for its mechanical and electrical performance, should not cause any danger or hazard to health or safety if normal engineering practices are observed and they are used in accordance with the instructions supplied.

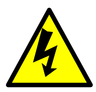
If, in specific cases, circumstances exist in which a potential hazard may be brought about by careless or improper use, these will be pointed out and the necessary precautions emphasised.

While we provide the fullest possible user information relating to the proper use of this equipment, if there is any doubt whatsoever about any aspect, the user should contact the Product Safety Officer at Feedback Instruments Limited, Crowborough.

This equipment should not be used by inexperienced users unless they are under supervision.

We are required by European Directives to indicate on our equipment panels certain areas and warnings that require attention by the user. These have been indicated in the specified way by yellow labels with black printing, the meaning of any labels that may be fixed to the instrument are shown below:

CAUTION -
RISK OF
DANGER



CAUTION -
RISK OF
ELECTRIC SHOCK

CAUTION -
ELECTROSTATIC
SENSITIVE DEVICE

Refer to accompanying documents

PRODUCT IMPROVEMENTS

We maintain a policy of continuous product improvement by incorporating the latest developments and components into our equipment, even up to the time of dispatch.

All major changes are incorporated into up-dated editions of our manuals and this manual was believed to be correct at the time of printing. However, some product changes which do not affect the instructional capability of the equipment, may not be included until it is necessary to incorporate other significant changes.

COMPONENT REPLACEMENT

Where components are of a ‘Safety Critical’ nature, i.e. all components involved with the supply or carrying of voltages at supply potential or higher, these must be replaced with components of equal international safety approval in order to maintain full equipment safety.

In order to maintain compliance with international directives, all replacement components should be identical to those originally supplied.

Any component may be ordered direct from Feedback or its agents by quoting the following information:

1. Equipment type	2. Component value
3. Component reference	4. Equipment serial number

Components can often be replaced by alternatives available locally, however we cannot therefore guarantee continued performance either to published specification or compliance with international standards.

OPERATING CONDITIONS

WARNING:

This equipment must not be used in conditions of condensing humidity.

This equipment is designed to operate under the following conditions:

Operating Temperature	10°C to 40°C (50°F to 104°F)
Humidity	10% to 90% (non-condensing)

CE DECLARATION CONCERNING ELECTROMAGNETIC COMPATIBILITY

Should this equipment be used outside the classroom, laboratory study area or similar such place for which it is designed and sold then Feedback Instruments Ltd hereby states that conformity with the protection requirements of the European Community Electromagnetic Compatibility Directive (89/336/EEC) may be invalidated and could lead to prosecution.

This equipment, when operated in accordance with the supplied documentation, does not cause electromagnetic disturbance outside its immediate electromagnetic environment.

COPYRIGHT NOTICE

ACKNOWLEDGEMENTS

Feedback Instruments Ltd acknowledge all trademarks.

IBM, IBM - PC are registered trademarks of International Business Machines.

MICROSOFT, WINDOWS XP, WINDOWS 2000, WINDOWS ME, WINDOWS 98, Internet Explorer are registered trademarks of Microsoft Corporation.

Foreword

This manual provides in Chapters 1 and 2 details of trainer installation and relevant setting-up procedures.

Chapter 3 provides details of the content of assignments found in 38-901-M. Additionally, answers to assignment questions are given.

Note:

Assignments for all three trainers, 38-001, 38-002 and 38-003, are provided in manual 38-901-M PROCON Process Control Trainer Level, Flow & Temperature.

Notes

TABLE OF CONTENTS

1 Installing 38-001 to 003 Process Control Trainers 1-1

1.1 Introduction 1-1

1.2 Installing the Hardware 1-1

1.2.1 Installing the Hardware Interface 1-1

1.3 Setting Up the Level/Flow Process Control Workstation (38-001) 1-3

1.3.1 Setting Up the Float Level Sensors 1-7

1.3.2 Calibrating The Pulse Flow Transmitter 1-8

1.3.3 Cleaning the Optical Pulse Flowmeter 1-9

1.4 Setting Up The Temperature Process Control part of Workstations 38-002 and 38-003 1-10

1.4.1 Filling the Temperature Process Rig Primary Flow Circuit 1-12

1.4.2 Testing the Primary Flow Circuit 1-13

1.4.3 Control Parameters 1-15

1.4.4 Setting up the Temperature Process Rig Secondary Flow Circuit 1-15

1.4.5 Temperature Calibration 1-16

1.4.6 Thermistor Checks 1-16

1.4.7 Dual Loop Control 1-16

1.4.8 Serial Controller Parameters 1-17

1.4.9 Controller Input Filter 1-17

1.5 Starting the Software 1-18

2 Using the 38-001 to 003 Process Control Trainers 2-1

3 Assignments 3-1

3.1 Introduction 3-1

3.2 Assignment Contents 3-4

3.2.1 Introduction to Procon Assignment 3-4

3.2.2	Flow/Level Rig Familiarisation Assignment	3-4
3.2.3	Flow/Level Rig Calibration Assignment	3-5
3.2.4	Interface Familiarisation Assignment	3-5
3.2.5	Interface Calibration Assignment	3-6
3.2.6	Controller Familiarisation Assignment	3-6
3.2.7	Controller Calibration Assignment	3-6
3.2.8	Float Level Transmitter Assignment	3-6
3.2.9	Pulse Flow Transmitter Assignment	3-7
3.2.10	On/Off Control Assignment	3-7
3.2.11	Proportional Control : Level Assignment	3-8
3.2.12	Proportional Control : Flow Assignment	3-8
3.2.13	PI and PID : Level Control Assignment	3-8
3.2.14	PI and PID : Flow Control Assignment	3-9
3.2.15	Tuning PID Controllers Assignment	3-9
3.2.16	Process Controller: Advanced Assignment	3-9
3.2.17	Temperature Rig Initialisation Assignment	3-10
3.2.18	Temperature Rig Familiarisation Assignment	3-10
3.2.19	Manual Flow Control Assignment	3-10
3.2.20	Temperature Process Control Assignment	3-11
3.2.21	P, PI and PID Temperature Control Assignment	3-11
3.2.22	Complex Control Loops Assignment	3-11
3.3	**Answers to Questions**	**3-12**
3.3.1	Flow/Level Rig Familiarisation Assignment	3-12
3.3.2	Flow/Level Rig Calibration Assignment	3-15
3.3.3	Interface Familiarisation Assignment	3-17
3.3.4	Interface Calibration Assignment	3-19
3.3.5	Controller Familiarisation Assignment	3-20
3.3.6	Controller Calibration Assignment	3-22
3.3.7	Float Level Transmitter Assignment	3-23
3.3.8	Pulse Flow Transmitter Assignment	3-25
3.3.9	On/Off Control Assignment	3-27
3.3.10	Proportional Control : Level Assignment	3-31

3.3.11 Proportional Control: Flow Assignment 3-33
3.3.12 PI and PID: Level Control Assignment 3-34
3.3.13 PI and PID : Flow Control Assignment 3-36
3.3.14 Tuning PID Controllers Assignment 3-37
3.3.15 Process Controller: Advanced Assignment 3-38
3.3.16 Temperature Rig Initialisation Assignment 3-39
3.3.17 Temperature Rig Familiarisation Assignment 3-40
3.3.18 Manual Flow Control Assignment 3-41
3.3.19 Temperature Process Control Assignment 3-43
3.3.20 P, PI and PID Temperature Control Assignment 3-44
3.3.21 Complex Control Loops Assignment 3-45

3.4 Answers To Questions Posed in Practical Work 3-47

3.4.1 Flow/Level Rig Familiarisation Assignment 3-47
3.4.2 Flow/Level Rig Calibration Assignment 3-47
3.4.3 Controller Familiarisation Assignment 3-48
3.4.4 On/Off Level Control Assignment 3-49
3.4.5 Temperature Rig Initialisation Assignment 3-49
3.4.6 Temperature Rig Familiarisation Assignment 3-49
3.4.7 Manual Flow Control Assignment 3-50
3.4.8 Temperature Process Control Assignment 3-50
3.4.9 Complex Control Loops Assignment 3-51

Notes

1 Installing 38-001 to 003 Process Control Trainers

1.1 Introduction

This chapter describes how to install and configure the hardware for the Level/Flow (38-001), Temperature (38-002) or Level/Flow & Temperature (38-003) Process Control Trainers. Instructions describing how to install the software can be found on the software distribution CD 38-901-M. For general information on how to install the software, refer to Feedback Manual – IMS Compatible Content, Installation and User Guide 93-IMS.

1.2 Installing the Hardware

1.2.1 Installing the Hardware Interface

This product uses a Serial interface to allow the Computer to control and interrogate single or multiple Process Controllers (38-300). The hardware should be connected to the workstation computer as described below.

1.2.1.1 Connecting a Single 38-300 Controller

Use the multiway cable terminated in a 25-way 'D' type connector, supplied with the accessories, to connect from the RS232 socket on the rear of the 38-300 to the PC Serial port 'COM1' or 'COM2'. Note that a 25-way connection is required at the PC. Set the 'connection' switch to 'on' and the 'termination' switch to 'on'. The serial page parameters must be set up correctly using the manual setting method before reliable computer control can be established.

Particular attention should be paid to the setting up of the controller identity. When a single controller is in use the Modbus Address should be set to '1'. See the section on Serial Controller Parameters at the end of this chapter for details.

1.2.1.2 Connecting Two 38-300 Controllers

Use the multiway cable terminated in a 25-way 'D' type connector to connect to the RS232 socket on the rear of the 38-300 to the PC Serial port 'COM1' or 'COM2'. Note that a 25-way connection is required at the PC. Set the 38-300 'connection' switch to 'on' and the 'termination' switch to 'off'.

The RS485 serial cable should then be used to connect between the RS485 connection on the rear of the first controller to the RS485 connection on the rear of the second controller. The 'connection' switch on the second controller should be set to 'off' and the 'termination' switch should be set to 'on'.

Figure 1-1 shows clearly the connections to be made and the required switch positions.

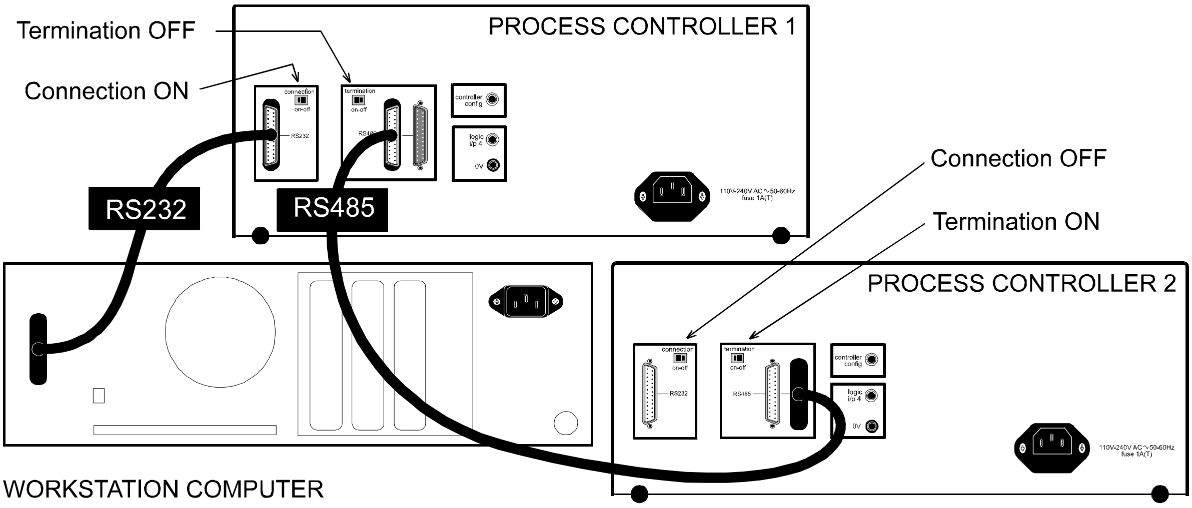


Figure1-1: Dual Controller Communication Connections

Again, particular attention should be paid to the setting up of the controller identities. The identity of the Process Controller 1 should be set to '1'. The Modbus Address of Process Controller 2 should be set to '2'. Successful communications cannot take place unless these addresses are correctly set. See the section on Serial Controller Parameters at the end of this chapter for further details.

IMPORTANT:

The RS232 cable supplied with this equipment is **non-standard**; the Transmit/Receive wires are not crossed within it. This is not a problem as the hardware is designed for this. If you require to utilise your own standard RS232 cables and/or socket adapters the following adjustments must be made inside the Process Controller connected to the computer. These instructions apply to both single and dual controller situations.

Remove the fixing screws from the case of the Process Controller and lift-off the cover. Position the controller so that the inside-rear of the case can be clearly seen. A circuit board will be seen on the right hand-side. This board contains a set of jumpers labelled 'GEN'. It is these jumpers that determine the RS232 transmission characteristics.

These jumpers are factory set across JP6 and JP7. They should be carefully moved to connect across JP5 and JP8. The diagram below shows the jumper settings before and after adjustment.

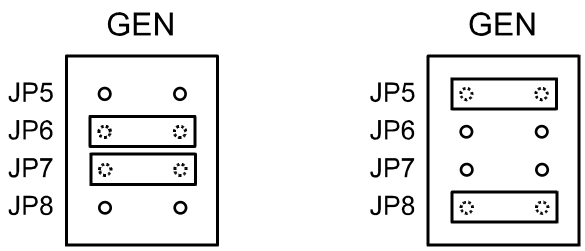


Figure 1-2: RS232 Jumper Settings

After adjustment of the jumpers the controller cover should be put back into position and the screws replaced and tightened.

The following sections describe simple installation tests which can be applied to the various items in the Feedback 38-001 to 003 PROCON range of equipment. Omit items not applicable to the options you have chosen.

1.3 Setting Up the Level/Flow Process Control Workstation (38-001)

This section covers the following items from the 38 Series:

- 38-100 Basic Process Rig
- 38-200 Process Interface
- 38-300 Process Controller
- 38-400 Level Sensor Pack
- 38-420 Flow Sensor Pack
- 38-490 Digital Display Module

Unpack the relevant items and proceed with the installation tests as follows:

Close the system drain valve and fill the sump at least three-quarters full with clean distilled water.

> **IMPORTANT**
>
> If possible, distilled water should always be used with the Process Rigs to avoid build-up of algae within the system. Boiled water can be used as a satisfactory substitute if distilled water is not available. Using normal tap water will not damage the system, but will slightly increase the level of maintenance required.

Make sure the power is switched off at the main supply and connect the equipment as shown in Figure 1-3.

Check that both switches on the Process Interface are UP.

Set up the Float Level Sensor, from the Level Sensor Pack 38-400, as described below.

Check that the orange bung is in place.

Set the manual drain valve to about half open and all other manual valves open (except the system drain valve).

Switch on the power and then the pump. Press the ‘Auto/Manual’  switch once if the manual control LED (M) is lit. After a few minutes the system should settle with about 50% level in the process tank. The Process Controller lower display should show about ‘30’. The actual value will depend very much on the exact setting of the manual drain valve.

IMPORTANT

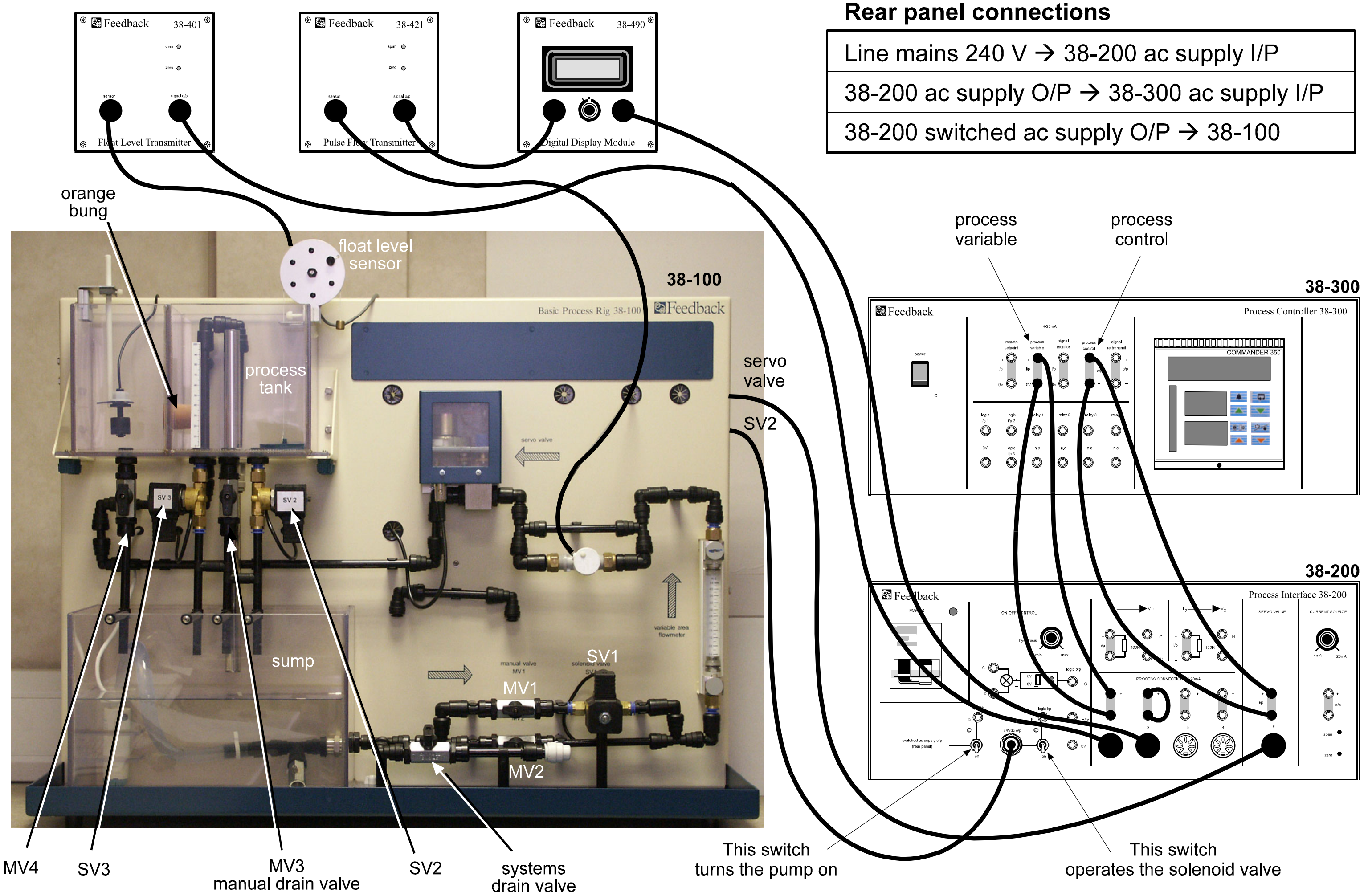
The pump should not be run without water. The rotor bearings use water lubrication and will be permanently damaged without it.

Observe that the float in the visual flowmeter is indicating the flow-rate. Also observe that the digital display is indicating the output from the pulse flow transmitter, if fitted.

Introduce a step function by switching on the extra drain valve (SV2). Observe the change in the flow-rate indicators.

Check that the other solenoid valves function correctly by moving the connection on the side of the rig to energise them in turn. Note that the two drain solenoid valves have different flow rates.

Close the manual bypass valve, MV2, and check that the flow can be stopped and started using SV1.



Rear panel connections

Line mains 240 V → 38-200 ac supply I/P	
38-200 ac supply O/P → 38-300 ac supply I/P	
38-200 switched ac supply O/P → 38-100	

Figure 1-3: Basic Process Rig Test Connections

Notes:

1. 38-490 Digital Display Module can be fitted in-line with any of the signal cables which have a 7-pin DIN connection. It can, for example, be used to monitor float level, pulse flow or valve control signals.

2. The controller remembers its previous settings at power on. Factory settings are to operate level control with P + I terms (no derivative). After the equipment is correctly set up, all that should be necessary is to switch the power on.

3. There are many control settings which can be altered but not all are relevant to this set up.

   For stable control only Proportional + Integral terms are required, with:

Proportional band = 10%	This gives a full swing in o/p from the controller for only a 10% change in the error. To increase prop. gain, prop. band must be reduced.
Integral action time = 15 secs	Decreasing this number increases the speed of response of the integral term.

4 38-300 Upper display, PV = process variable

Middle display, SP = set point

See COMMANDER 350 Operating Instructions.

5 The 38-421 is not used for control in this set-up, it is included only for test purposes.

6 BARGRAPH

This is a visual indication of the error. The green bar only = no error. Each red bar represents 5% error, positive or negative.

7 To get back to the standard display press [alarm acknowledge] 
then [parameter advance] .

8 The controller is switched between auto/manual modes with the front panel button, status is shown by the M LED, on = manual. The control will not function if this is on.

To restore normal operation press [auto/manual] 

1.3.1 Setting Up the Float Level Sensors

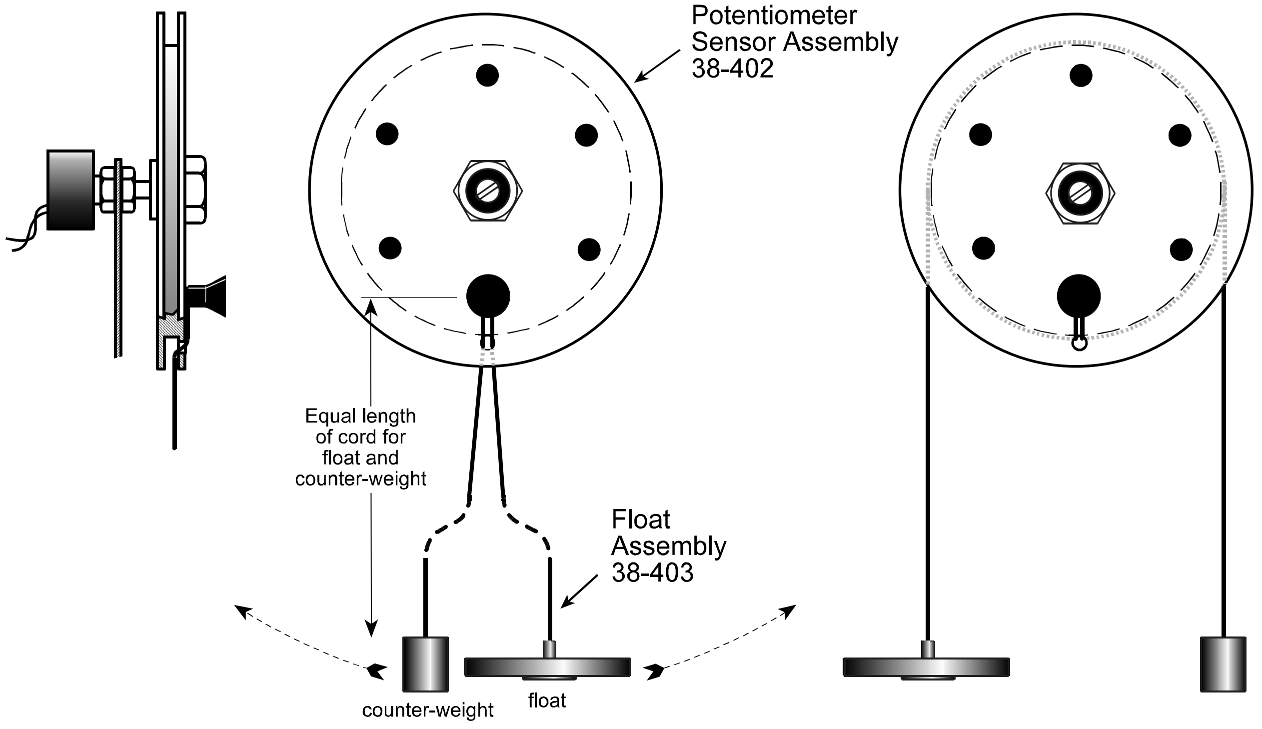


Figure 1-4: Threading the Float Level Sensor Cord

There are two adjustments which are required, potentiometer position with reference to. pulley and electrical span/zero adjustment. The pot/pulley position must be set first.

1 Fold the cord in half and secure the loop around the large plastic rivet see Figure 1-4. Wrap the cord twice around the pulley and check that the cord is not wound over itself and that the pulley turns freely.

2 Attach the level sensor to the Process Tank and make the electrical connections as shown in Figure 1-3, but temporarily connect the output signal from the Float Level Transmitter (38-401) to the Digital Display Module (38-490) then switch the power on. Do not run the pump so that the Process tank remains empty.

3 On the 38-490 set the switch to 'mA'.

4 If the sensor is correctly set-up there will be a reading of 3.8 to 4.0 mA with the float level with the ‘zero’ marked on the front of the tank. If adjustment is needed, continue, if not go to 7.

5 Using a small screwdriver adjust 'zero' on 38-401, until the above reading is obtained, if satisfactory then go to 7, if not continue.

6 Disconnect the potentiometer sensor input plug and set the 'zero' adjuster on the 38-401 to give a reading of 4.0 mA. Re-connect the input plug then, with the float at the minimum level, hold the pulley still with one hand and using a screwdriver, turn the potentiometer shaft anticlockwise until the reading can be seen to progress from a high value, down to approximately 4.0 mA. This method avoids the possibility of error which might occur if the potentiometer wiper is set off the end of its resistive track. Now repeat 5.

7 Raise the float up to the '100' level on the tank and adjust span on 38-401 for a reading of between 19 to 21 mA.

8 Set-up is now complete so re-connect the units as per Figure 4-6. The 38-300 displays its measured variable (large upper display) as a percentage, 0% indicates an empty tank and 100% a full tank. The float sensor is only used in the practicals to take readings in the region between the maximum and minimum marks. This is due to the inaccuracies introduced by the proximity of inflow and outflow disturbances.

Note that a similar procedure could be used to calibrate different levels to 0 and 100%.

1.3.2 Calibrating The Pulse Flow Transmitter

The 38-100 Basic Process Rig and 38-600 Temperature Process Rig are both equipped with an Optical Pulse Flowmeter. The output of this device is a pulsed signal whose 'frequency' alters in proportion to the rate of liquid flow past its rotating impeller. The output signal is fed into the Pulse Flow Transmitter which converts the pulses into a 4 mA to 20 mA standard control format.

A zero flow condition should produce a 4 mA output from the Pulse Flow Transmitter; a maximum flow condition should produce a 20 mA output.

The Pulse Flow Transmitter can be calibrated by following the steps below:

1 Connect the transducer, Pulse Flow Transmitter and Digital Display Module as shown in Figure 1-3.

2 Ensure that the pump is switched off. There should be zero flow.

3 Adjust the 'zero' control on the PFT until the DDM reads 4 mA. This represents zero flow.

4 Ensure that all valves are fully opened.

5 Switch on the pump. There should be maximum flow.

6 Adjust the ‘span’ control on the PFT until the DDM reads 20 mA. This represents maximum flow.

1.3.3 Cleaning the Optical Pulse Flowmeter

The Optical Pulse Flowmeter supplied as part of the Temperature Process Rig and Basic Process Rig may need occasional cleaning to remove scale from the internal LED detector mechanism. If a deterioration in performance is noted, the following cleaning procedure should be followed:

1 Drain the system.

2 Gently pull the front cover from the flow transducer.

3 Unscrew the main body and detach.

4 Using a small screwdriver gently remove the impeller from inside the case.

5 Clean any scale from the impeller and flow channel.

6 Re-assemble the unit, taking care to position the impeller correctly.

If poor performance is still apparent after cleaning, see the later section entitled ‘Controller Input Filter’ for further measures.

1.4 Setting Up The Temperature Process Control part of Workstations 38-002 and 38-003

This section covers the following items from the 38 Series:-

- 38-600 Temperature Process Rig
- 38-200 Process Interface
- 38-300 Process Controller
- 38-440 Temperature Sensor Pack
- 38-480 Temperature Auxiliary Control Pack
- 38-490 Digital Display Module

The Temperature Rig has two isolated water circuits. The primary circuit, which is normally used as a heat source, comprises; a heater, a circulation pump, a servo-valve for flow control, a pulse flowmeter, a header tank and a heat exchanger. The secondary circuit contains a heat exchanger and a cooler.

The primary circuit is self contained and has to be filled before the system is used. The secondary circuit is normally supplied, via flexible hoses, from the Basic Control Rig which is set up to provide a controlled flow. An alternative arrangement is to use a Temperature Auxiliary Control Pack 38-480 to provide a controlled flow from a mains water tap.

Warning:

This Rig has many pipes and surfaces which will reach temperatures of up to **70°C**.

Connect the equipment as shown in Figure 1-5.

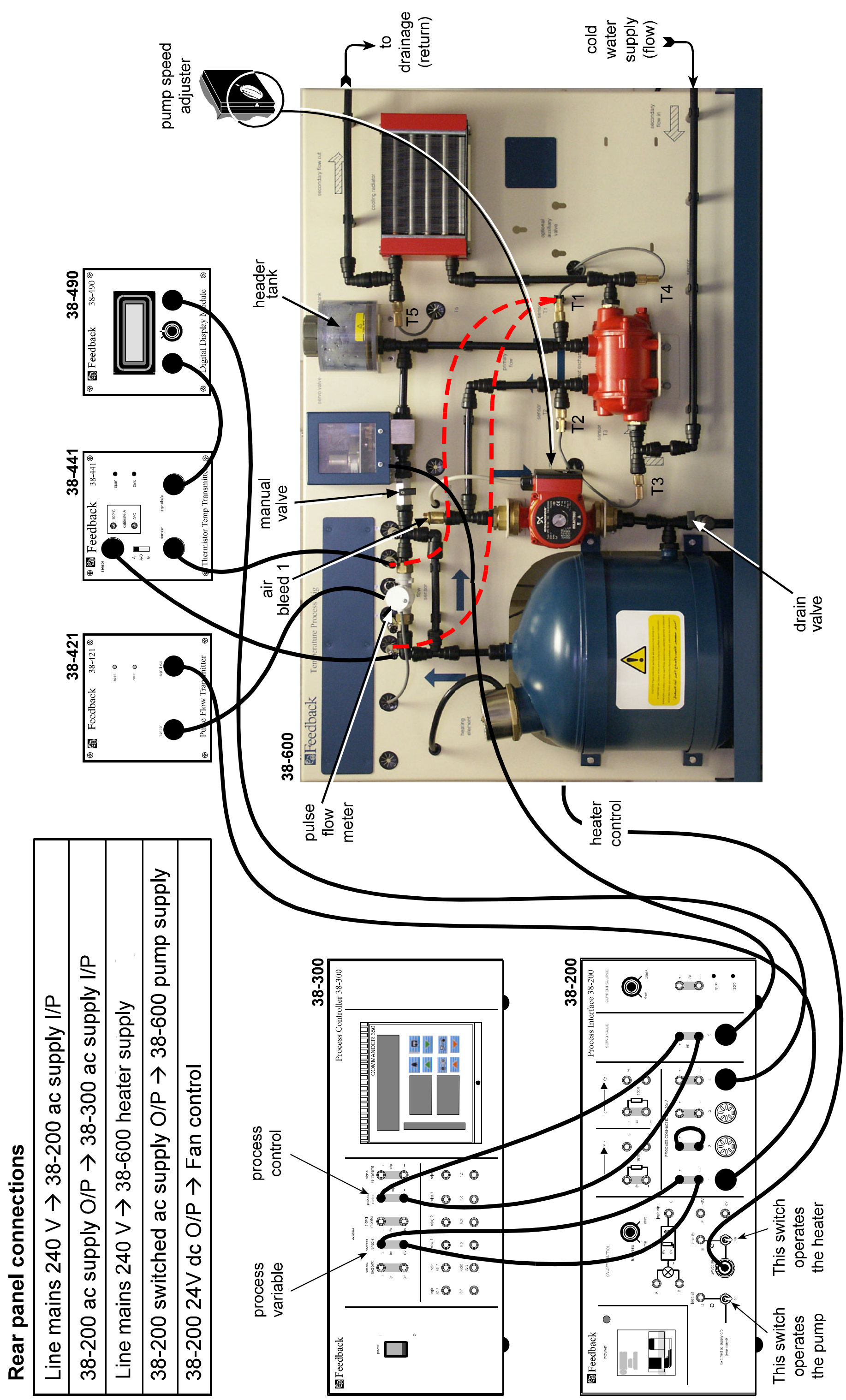


Figure 1-5: Temperature Process Rig Test Connections

Check that both switches on the Process Interface are UP, the pump speed setting (on the pump body) is at (2) and the appropriate manual valves are open.

Switch on the Process Interface and Controller and fill the temperature rig as described below.

The cooling fan behind the cooling radiator should be running.

Important:

The Pump and Heater must not be run without water in the primary circuit.

1.4.1 Filling the Temperature Process Rig Primary Flow Circuit

1 Open the manual valve.

2 Fully open the servo valve by setting the controller to manual and entering op=100. (Refer to the notes below and the Operating Instructions for COMMANDER 350 if you do not know how to do this).

3 Check that the drain valve is shut.

4 Remove the header tank cover and start to fill the system with clean distilled water, if available. The use of distilled water in the system reduces fungal build-up. Switch on the pump to clear the initial air-locks.

Important:

The header tank should not be filled beyond the maximum level marked. If extra water is added whilst the rig is at ambient room temperature overflow will occur during the heating process.

NOTE If the pump appears not to work, it may be necessary to free the shaft. This is carried out by removing the vent plug and inserting a small screwdriver (3 mm) into the end of the shaft, pushing gently and rotating the shaft several times to ensure it is free. This is particularly important for pumps which have not been used for some time.

5 Continue to introduce clean water until the header tank remains at the ‘max level’ mark. Switch off the pump, wait for 1 minute, then open 'air bleed 1' to release any trapped air.

6 Switch on the pump and repeat step 5 until no air escapes when 'air bleed 1' is opened.

7 Replace the header tank cover.

Once this procedure has been completed the water flow in the primary circuit should be ‘solid’ and free of air. A good indication of flow quality can be obtained from the flow transducer. A steady reading on the DDM is usually produced by a flow free of air. If any air remains in the system, a further procedure can be attempted.

1 Ensure the manual valve is closed.

2 Run the pump and release air from the system with ‘air bleed 1’ valve until flow begins. This can usually be heard.

3 Fill the header tank to its maximum level if required.

4 Open the manual valve in stages; after each stage run the pump and add extra water as required.

5 Repeat the process until all air has been removed from the system.

1.4.2 Testing the Primary Flow Circuit

Switch on the heater. Approximately 10 minutes is required for water in the primary flow circuit to reach maximum temperature. This is limited by a thermostat to 70°C.

Set controller parameters as listed below (refer to Operating Instructions COMMANDER 350 Universal Process Controller).

The primary circuit pump is capable of pressurising the system to a pressure of 11 bar, however the maximum working pressure for the secondary flow is 5 bar. This is equivalent to approximately 70 psi.

Notes on Process Controller settings

1 For stable control of flow only PROPORTIONAL PLUS INTEGRAL terms are required with:

Proportional band = 200 %	This means we get a full swing in o/p from the controller for a 200% change in the error. To increase prop. gain, prop. band must be reduced.
Integral action time = 2 secs	Decreasing this number increases the speed of response of the integral term.

With this flow control loop the 'process' to be controlled is in fact the valve itself, which we can explain as follows:

The transfer function relating valve position to flow is straightforward. Since the pump provides a continuous pressure differential across the valve, flow is simply proportional to valve position.

However when the controller output signal changes suddenly there is a delay before the valve reaches its new position which is due both to motor inertia and the high gear ratio used (it takes a few seconds to fully open or close the valve). So in fact it is the valve transfer function which dominates the 'process'.

For this installation example control parameters are chosen to give little or no overshoot in response to sudden changes in flow demand.

The set point should always be in the range 5 - 95%. This is a note to remember for other practicals, the control will be non-linear and may be unpredictable if the measured variable reaches its high or low limit. Adjust the setpoint using the [up] and [down] buttons

2 38-300 Upper display, PV = process variable

Middle display, SP = set point

See Operating Instructions for COMMANDER 350.

3 SECURITY CODE

There are security codes that restrict access to different sets of parameters. They should not be set, unless you wish access to the controller to be restricted.

4 BARGRAPH

This is a visual indication of the error. Green bar only = no error. Each red bar represents 5% error, positive or negative.

5 To get back to the standard display from anywhere press [alarm acknowledge]  then [parameter advance] .

6 The controller is switched between auto/manual modes with the front panel button, status is shown by the M LED, on = manual. The control will not function if this is on.

To restore normal operation press [auto/manual] .

1.4.3 Control Parameters

Check that the following parameters are set. Refer to the Operating Instructions given in the COMMANDER 350 Process Controller manual.

Operator Level	`A-tne`	`OFF`	Self tune
Level 2	`Pb-1`	`200`	Proportional band %
	`IAt.1`	`2`	integral action time
	`drV.1`	`OFF`	derivative action time

Now switch on the pump.

Observe that the rate of flow is controlled and will change when the setpoint is adjusted.

1.4.4 Setting up the Temperature Process Rig Secondary Flow Circuit

1.4.4.1 Workstation 38-003 (Level / Flow and Temperature)

Water for the secondary flow circuit may be obtained from the Basic Process Rig 38-100, which should be located on the bench to the right of the Temperature Process Rig. Make sure the Basic Rig pump is switched off and the water is all drained down into the sump. Remove the double elbow link on the left hand side, making sure to pull it evenly and keeping the locking rings in with your thumb and fore-finger.

Use the short lengths of plastic hose provided to connect the flow output (lower pipe) to the heat exchanger input and the return input (upper pipe) to the cooler output. The plastic pipes have push fit terminations which can be removed as described above. You may also need to use the adaptors provided to adjust for pipe diameter.

When the connections are made switch on the Basic rig pump and adjust the flow to approximately 2 litres/min.

1.4.4.2 Workstation 38-002 (Temperature only)

Secondary flow is controlled by the Auxiliary control unit 38-480.

Secure the 38-480 in the place marked on the rig. Connect the drain pipe onto the pipe leaving the cooling radiator and the supply pipe to the input of the 38-480. Attach the supply pipe to a mains water supply which can deliver at least 4 litres/minute. The mains water supply should have a pressure of nominally 1.5 bar, with a maximum of 2 bar. If your mains supply is of greater pressure, a pressure reducer must be used to bring it to the 1.5 bar nominal value. Such a reducer is available from Feedback, with details on request.

Water for the secondary is obtained from this supply; ensure the servo valve is fully open by setting the controller to manual and entering op=100, now turn on the mains water supply and set the flow to 25% using the manual valve located on the 38-480.

1.4.5 Temperature Calibration

Switch the Digital Display Module 38-490 to show %.

Switch the Thermistor Temperature Transmitter 38-441 to sensor A. Press the 25°C calibrate button and adjust ‘zero’ to give a ‘25’ display on the 38-490.

Press 80°C calibrate button and adjust ‘span’ to give an ‘80’ display on 38-441.

The display now indicates temperature directly in °C.

1.4.6 Thermistor Checks

The Temperature Process Rig is normally supplied with the five temperature sensing thermistors fitted. The thermistor units are fragile and should not be removed unless absolutely necessary. The Thermistor Temperature Transmitter 38-441 is designed to accept inputs from two thermistors and a switch is provided to select the required one.

Set both the Primary and Secondary flow circuits going.

Check the various components are functioning by making the following temperature comparisons:

1 T2 should be less than T1; Heat being transferred from Primary to Secondary.

2 T3 should be less than T4; Cold water being heated in the Heat Exchanger.

3 T5 should be less than T4; Heated water being cooled before returning.

Completing these tests will check that the main components are all functioning.

1.4.7 Dual Loop Control

Dual loop control is concerned with the final assignment and can only be carried out if a full set of Level / Flow (38-100) and Temperature (38-600) hardware is available (Workstation 38-003). The two rigs should be connected together as described previously.

Manually set the Basic Process Rig controller to ‘ident 1’ and the Temperature Process Rig controller to ‘ident 2’ (see below). You will need the RS485 lead from the PROCON accessories to physically connect the two controllers together. Connect one end of the cable to the RS485 connection on one of the controllers and the other to the RS485 connection on the other controller. On the Basic Process Rig controller, which should have the RS232 connection to the computer in place, set the 'connection' switch to ON and the' termination' switch to OFF. On the Temperature Process Rig controller set the 'connection' switch to OFF and the 'termination' switch to ON.

Please refer to the earlier section for more detailed information regarding connection of two controllers.

1.4.8 Serial Controller Parameters

The controller serial page must be set up as shown to allow communication with the Discovery Software. Refer to the Operating Instructions given in the COMMANDER 350 User Guide, Page 67.

The settings should be:

`Level D`	Serial Comms
`Serial Config`	4
`Parity`	None

Modbus Addresses

`Single 38-300`	1
`Second 38-300`	2

1.4.9 Controller Input Filter

The Process Controller incorporates the facility to filter the process variable input. This function is intended for use as a 'smoothing' stage for stepped input signals. It may also be more usefully used in this case to clean 'noisy' signals to a certain degree.

The output from the pulse flow sensor can in some cases be extremely noisy. This is not a fault with the hardware, rather a characteristic of the flow detector type. This noise can sometimes be amplified to an unacceptable degree if presented to the Process Controller in a high-gain state.

The Programmable Filter can be set by accessing Level 9. The parameter FLt.1 (Input Filter Time Constant) should be accessed and set.

The filter time represents the time a step in the input takes to change the displayed process variable from 10 to 90% of the step. The time can be set between 0 to 60 seconds in 1 second increments.

A Programmable Filter setting of 3 seconds is recommended.

1.5 Starting the Software

When both the hardware and the software installation has been completed, you can then start the stand alone environment by double-clicking on the ***Discovery*** icon that the environment installation program created on your computers desktop.

2 Using the 38-001 to 003 Process Control Trainers

The software package for the 'Level and Flow' can be accessed by double-clicking the 'Process Control' top-level menu, followed by 'PROCON Process Control Trainers'. Here, software can be initiated for a number of assignments that contains Theory, Background and practical information.

Double-clicking on an assignment reveals a number of *practicals*. Double clicking on a practical will 'launch' an Applet which provides access to the signals produced by a process rig.

When a practical starts, you will be presented with the warning message. This is to remind you that problems may arise if the Controller is turned off while your PC is preparing to receive data.

When the practical has started, the Controller automatically configures the process rig, allowing particular components of the rig to be studied.

If you begin a practical before the Controller has been turned on, an error message is displayed:

If this occurs, you should exit the practical page by changing to a non-practical page (such as background, theory or question pages). When on pages other than a practical page, turn the Controller on and reselect the required practical. This will re-initialise the Controller.

Note:

Always remember to wait a moment before selecting the practical after turning on the power to the Controller. The computer needs time to initialise the Controller so that its interface can be configured.

Do not overload the system by trying to open one practical before the last practical has finished. Although protection has been built into the software to prevent problems arising, the hardware may become confused, causing problems with the running of the software.

Always ensure that other applications that may be running simultaneously, such as word processors or e-mail packages are closed. The Level and Flow software has been designed as 'real-time' as possible. Other applications may interfere the with displaying of signals from the process rig. Similarly, ensure that no other copies of the Internet Explorer browser program are running.

When you have to change process rigs, you should exit a practical to a non-practical page, such as the background or theory pages, then power down.

Although powering down during the operation of a practical will not usually cause difficulties, your computer may be left waiting for data from the Controller.

Note:

Always ensure that you leave a practical page before you power down the Controller when you change process rigs**.**

The software performs checks before a process rig is configured. If an incorrect process rig is connected, an error message is displayed.

When this occurs, leave the current practical page by selecting non-practical page, power down the Controller, select plug in the required process rig, power up the Controller and select your required practical.

3 Assignments

3.1 Introduction

The Procon 38 Series Process Control Trainer is a complete package dealing with all aspects of Process Control, and includes many industry standard features. It includes the relevant hardware process control rigs, monitoring and interface devices, and an industry standard controller. With a high degree of modularity, the system is very flexible and many different methods of process control can be demonstrated.

Operating the hardware with the software package provides a series of practical assignments which demonstrate each type of process control, and allow the student to explore the strengths and weaknesses of a particular type. The software package also provides theory, objectives and questions relating to each practical to increase the breadth of the subject covered. The hardware will operate under the automatic control of the PC running the software, with the exact nature of operation controlled by the student.

By using the software package, PC based Virtual Instrumentation is available, which provides measurement and graphical display of results in real time, and automatic control of the process when required.

This chapter describes in section 3.1 the Procon Level/Flow and Temperature Process Control systems which introduce all aspects of modern industrial control, and allow different control algorithms to be constructed. Additionally, this chapter provides details of assignment contents (section 3.2) and assignment answers (section 3.3).

A Procon 38-001 Level/Flow Process Control System comprises:

- One 38-100 Basic Level/Flow Process Rig consisting of a self contained pumped water circuit and associated solenoid, manual and servo valves.
- One 38-200 Process Interface providing all necessary power outlets for the Basic Level/Flow Process Rig and its sensors.
- One 38-300 Industry Standard Process Controller which can provide a range of control functions.
- One 38-400 Level Sensor Pack comprising a Float Level Transmitter 38-401, a Float Level Sensor and a Float Switch.
- One 38-420 Flow Sensor Pack comprising a Pulse Flow Transmitter 38-421 and Sensor.
- One 38-490 Digital Display Module displaying signal current or signal percentage.

- One set of PROCON Accessories.
- One 38-901-M Software Pack for Level/Flow and Temperature (includes 38-801 RS485 Serial Cable).
- Reference Manual 38-001-3 (this manual) and Student Manuals 38-901-M.
- Feedback IMS Compatible Content, Installation and User Guide 93-IMS.

A Procon 38-002 Temperature Process Control System comprises:

- One 38-600 Basic Temperature Process Rig with a self contained pumped and electrically heated water circuit and a second cold water process circuit
- One 38-480 Temperature Auxiliary Control Pack
- One 38-200 Process Interface providing all necessary power outlets for the Basic Level/Flow Process Rig and its sensors
- One 38-300 Industry Standard Process Controller which can provide a range of control functions
- One 38-440 Temperature Sensor Pack comprising a Thermistor Temperature Transmitter 38-441 and Sensors. (Note the 5 sensors are permanently fitted to the 38-600 rig).
- One 38-490 Digital Display Module displaying signal current or signal percentage
- One set of PROCON Accessories
- One 38-901-M Software Pack for Level/Flow and Temperature (includes 38-801 RS485 Serial Cable).
- Reference Manual 38-001-3 (this manual) and Student Manuals 38-901-M.
- Feedback IMS Compatible Content, Installation and User Guide 93-IMS.

A Procon 38-003 Level/Flow and Temperature Process Control System comprises:

- One 38-100 Basic Level/Flow Process Rig consisting of a self contained pumped water circuit and associated solenoid, manual and servo valves
- Two 38-200 Process Interfaces providing all necessary power outlets for the Basic Level/Flow Process Rig and its sensors
- Two 38-300 Industry Standard Process Controllers which can provide a range of control functions

- One 38-400 Level Sensor Pack comprising a Float Level Transmitter 38-401, a Float Level Sensor and a Float Switch
- Two 38-420 Flow Sensor Pack comprising a Pulse Flow Transmitter 38-421 and Sensor
- One 38-440 Temperature Sensor Pack comprising a Thermistor Temperature Transmitter 38-441 and Sensors
- Two 38-490 Digital Display Module displaying signal current or signal percentage
- One 38-600 Basic Temperature Process Rig with a self contained pumped and electrically heated water circuit and a second cold water process circuit
- Two sets of PROCON Accessories
- One 38-901-M Software Pack for Level/Flow and Temperature (includes 38-801 RS485 Serial Cable).
- Reference Manual 38-001-3 (this manual) and Student Manuals 38-901-M.
- Feedback IMS Compatible Content, Installation and User Guide 93-IMS.

3.2 Assignment Contents

Introduction to Procon
Flow/Level Rig Familiarisation
Flow/Level Rig Calibration
Interface Familiarisation
Interface Calibration
Controller Familiarisation
Controller Calibration
Float Level Transmitter
Pulse Flow Transmitter
On/Off Level Control
Proportional Control: Level
Proportional Control: Flow
PI & PID: Level Control
PI & PID: Flow Control
Tuning PID Controllers
Process Controller: Advanced Features
Temperature Rig Initialisation
Temperature Rig Familiarisation
Manual Flow Control
Temperature Process Control
P, PI and PID Temperature Control
Complex Control Loops

3.2.1 Introduction to Procon Assignment

This assignment contains no practicals. It is an introduction to Procon, and describes the subject that is to be covered; Process Control.

3.2.2 Flow/Level Rig Familiarisation Assignment

Required hardware is the Basic Level/Flow Process Rig 38-100, the Process Interface 38-200, a Digital dc milliammeter (0 – 20 mA) and a Tape Measure

Practicals

1 The Centrifugal Pump

2 The Manual Valves and the Flow Gauge

3 The Servo Valve

4 The Solenoid Valves

3.2.3 Flow/Level Rig Calibration Assignment

Required hardware is the Basic Level/Flow Process Rig 38-100, the Process Interface 38-200, the Digital Display Module 38-490 and a Tape Measure.

Practicals

1 A Level - Volume Correspondence

2 Flow Meter Calibration

3 Servo Valve Calibration

4 Solenoid Valve Calibration

3.2.4 Interface Familiarisation Assignment

Required hardware is the Basic Level/Flow Process Rig 38-100, the Process Interface 38-200, the Digital Display Module 38-490 and a dc Voltmeter (0- 2 V).

Practicals

1 Circuit Breaker, and Circuit Loop Connections

2 The Servo Valve

3 The Current - Voltage Converters

3.2.5 Interface Calibration Assignment

Required hardware is the Basic Level/Flow Process Rig 38-100, the Process Interface 38-200, and the Digital Display Module 38-490. This assignment contains only one practical, but it does discuss other areas of the Process Interface that are used in later assignments.

Practicals

1 Current Source Calibration

3.2.6 Controller Familiarisation Assignment

Required hardware is the Process Controller 38-300, the Basic Level/Flow Process Rig 38-100, the Process Interface 38-200, and the Digital Display Module 38-490

Practicals

1 Serial Communication

2 Navigating the 38-300

3 Using the 38-300

3.2.7 Controller Calibration Assignment

Required hardware is the Process Controller 38-300, the Basic Level/Flow Process Rig 38-100, the Process Interface 38-200, and the Digital Display Module 38-490.

Practicals

1 38-300 Calibration

2 38-300 Relays

3 Reading the 38-300

3.2.8 Float Level Transmitter Assignment

Required hardware is the Process Controller 38-300, the Basic Level/Flow Process Rig 38-100, the Process Interface 38-200, the Float Level Transmitter 38-401, the Float Level Sensor, and the Digital Display Module 38-490.

Practicals

1 The Float Level Transmitter (FLT)

2 Calibrating the FLT

3 A Level Control Demonstration

3.2.9 Pulse Flow Transmitter Assignment

Required hardware is the Process Controller 38-300, the Basic Level/Flow Process Rig 38-100, the Process Interface 38-200, the Pulse Flow Transmitter 38-421, the Pulse Flow Sensor and the Digital Display Module 38-490.

Practicals

1 The Pulse Flow Transmitter(PFT)

2 Calibrating the PFT

3 A Flow Control Demonstration

3.2.10 On/Off Control Assignment

Required hardware is the Process Controller 38-300, the Basic Level/Flow Process Rig 38-100, the Process Interface 38-200, the Float Level Transmitter 38-401, the Float Level Sensor, the Float Level Switch, and the Digital Display Module 38-490.

Practical

1 On/Off Pump Control

2 On/Off Solenoid Control

3 The Float Switch

4 38-300 On/Off Control

3.2.11 Proportional Control : Level Assignment

Required hardware is the Process Controller 38-300, the Basic Level/Flow Process Rig 38-100, the Process Interface 38-200, the Float Level Transmitter 38-401, the Float Level Sensor, and the Digital Display Module 38-490.

Practicals

1 Simulation

2 Proportional Control of Level

3 Proportional Control and Offset

4 Proportional Band

3.2.12 Proportional Control : Flow Assignment

Required hardware is the Process Controller 38-300, the Basic Level/Flow Process Rig 38-100, the Process Interface 38-200, the Pulse Flow Transmitter 38-421, the Pulse Flow Sensor and the Digital Display Module 38-490.

Practical

1 Servo Proportional Control

2 Proportional Control Offset

3.2.13 PI and PID : Level Control Assignment

Required hardware is the Process Controller 38-300, the Basic Level/Flow Process Rig 38-100, the Process Interface 38-200, the Float Level Transmitter 38-401, the Float Level Sensor, and the Digital Display Module 38-490.

Practicals

1 PI Control of Level

2 Limitations of PI Control

3 PID Control of Level

3.2.14 PI and PID : Flow Control Assignment

Required hardware is the Process Controller 38-300, the Basic Level/Flow Process Rig 38-100, the Process Interface 38-200, the Pulse Flow Transmitter 38-421, the Pulse Flow Sensor and the Digital Display Module 38-490.

Practicals

1 PI Control of Flow

2 PID Control of Flow

3.2.15 Tuning PID Controllers Assignment

Required hardware is the Process Controller 38-300, the Basic Level/Flow Process Rig 38-100, the Process Interface 38-200, the Float Level Transmitter 38-401, the Float Level Sensor, and the Digital Display Module 38-490.

Practicals

1 Zeigler-Nichols Tuning

2 Self-Tuning

3.2.16 Process Controller: Advanced Assignment

Required hardware is the Process Controller 38-300, the Basic Level/Flow Process Rig 38-100, the Process Interface 38-200, the Float Level Transmitter 38-401, the Float Level Sensor, and the Digital Display Module 38-490.

Practicals

1 Remote Set Point

2 Profile Programming

3 Time Proportioned Output

3.2.17 Temperature Rig Initialisation Assignment

Required hardware is the Process Controller 38-300, the Temperature Process Rig 38-600, the Process Interface 38-200, the Thermistor Temperature Transmitter 38-441, and the Digital Display Module 38-490. The Basic Level/Flow Process Rig 38-100 is optional for the completion of the assignment.

Practicals

1 Calibration of the Temperature Thermistor Transmitter

2 Thermistors

3 Bleeding the Secondary Flow

3.2.18 Temperature Rig Familiarisation Assignment

Required hardware is the Process Controller 38-300, the Temperature Process Rig 38-600, the Process Interface 38-200, the Thermistor Temperature Transmitter 38-441, and the Digital Display Module 38-490. The Basic Level/Flow Process Rig 38-100 is optional for the completion of the assignment.

1 On/Off Heater Control

2 Operation of the Heat Exchanger

3 Operation of the Cooler

3.2.19 Manual Flow Control Assignment

Required hardware is the Temperature Process Rig 38-600, the Process Interface 38-200, the Thermistor Temperature Transmitter 38-441, and the Digital Display Module 38-490. The Basic Level/Flow Process Rig 38-100 is optional for the completion of the assignment.

Practicals

1 Simulation

2 Primary Flow Control

3 Secondary Flow Control

3.2.20 Temperature Process Control Assignment

Required hardware is the Process Controller 38-300, the Temperature Process Rig 38-600, the Process Interface 38-200, the Thermistor Temperature Transmitter 38-441, and the Digital Display Module 38-490. The Basic Level/Flow Process Rig 38-100 is optional for the completion of the assignment..

Practicals

1 Single Loop Control Demonstration

2 Industrial Process Control

3 Automatic On/Off Control

3.2.21 P, PI and PID Temperature Control Assignment

Required hardware is the Process Controller 38-300, the Temperature Process Rig 38-600, the Process Interface 38-200, the Thermistor Temperature Transmitter 38-441, and the Digital Display Module 38-490. The Basic Level/Flow Process Rig 38-100 is optional for the completion of the assignment.

Practicals

1 Proportional Control of Temperature

2 PI Control of Temperature

3 PID Control of Temperature

3.2.22 Complex Control Loops Assignment

Required hardware is two Process Controllers 38-300, the Basic Level/Flow Process Rig 38-100, the Temperature Process Rig 38-600, two Process Interfaces 38-200, the Thermistor Temperature Transmitter 38-441, two Digital Display Modules 38-490, the Float Level Transmitter 38-401, the Float Level Sensor and the Pulse Flow Sensor.

Practicals

1 Flow Ratio Control

2 Dual Loop Temperature and Flow Control

3 Dual Loop Temperature and Level Control

3.3 Answers to Questions

Note:

These are not necessarily definitive answers to the questions in 38-901-M, but are rather guide lines covering the main points that should be included in a student's solution.

3.3.1 Flow/Level Rig Familiarisation Assignment

Questions for Practical 1

1 *What are the special features and principle of operation of the centrifugal pump? Explain how the pump is used in this practical. What is the purpose of the overflow pipe?*

Pump features: submersible, ignition protected, non-airlocking, water cooled. Pump pushes water from lower to upper tank. Water enters (low pressure) at centre of pump, travels radially and exits with pressure and kinetic energy increase. Overflow pipe prevents flooding.

2 *If initially the upper tank is empty, how long does it take from the time you switch on the pump, until overflow occurs? What is the volume of the water at overflow? Hence, calculate the rate of flow.*

Approximately: 45 seconds to overflow.

volume: 110 mm x 155 mm x 180 mm = 3069 cm^3 = 3069 ml ≅ 3.07 L

this is 4.09 L/min = 25 L/hr

3 *Why is the flow through the piping network less than the full flow capability of the pump?*

Pipe dimensions, pipe resistance.

Questions for Practical 2 (Manual valves & Flow-gauge)

1 *What is process control and how does it differ from servo control? How do you think the Basic Process Rig fits into process control? What instruments are used in a process control system? What are the characteristics of those instruments, that are of interest to a control engineer?*

Process control - disturbance rejection (regulator)

Servo control - output follows input

BPR is small, industrial process, controlling water around fluid circuit.

Instruments - measuring devices, transmitters.

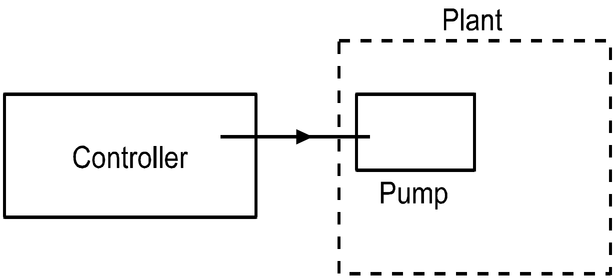
Static characteristics - accuracy, tolerance, precision, range, bias, linearity, sensitivity, drift, hysteresis, resolution.

Dynamic characteristics - time constants, sensitivity, undamped natural frequency, damping ratio, steady state error.

2 *What are the principles of operation of the manual valve and the visual flowmeter? How would you classify these instruments from a control engineering point of view?*

Manual valves cut off flow and are controlled by the user. Visual flow meter is displacement type and gives approximate flow. Both are passive instruments, not applicable to automatic control.

3 *Visualise the process control system of Practical 2 and sketch a block diagram of it, identifying each element. Is this control system manual or automatic? Is it an open loop or a closed loop system?*



- Manual, Open Loop System.

4 *What process variables are being controlled? Are these variables interrelated? Can you control both variables simultaneously?*

- Controlling level and flow, these are interrelated, cannot control flow with out changing level, and vice versa.

Questions for Practical 3 (The Servo Valve)

1 *What is the principle of operation and the physical structure of the servo valve? Why is it called a servo valve? How is the servo valve controlled and what is its response?*

Servo valve is a gate lowered and raised on demand. 100% open to 100% closed. It is a servo system where output (position) follows input (current). Controlled by the 4-20 mA current signal produced by the Process Controller and response is approximately linear.

2 *Compare the servo valve with the manual valve, listing similarities, differences, advantages and disadvantages?*

Both control flow, but servo allows automatic control. Manual is simple, but its position is approximate. Servo position is totally variable and can be known precisely.

3 *What should you not forget to do before switching off the servo valve, so that no future practical is affected by the state of the servo valve?*

Servo should be opened fully when a practical is complete.

Questions for Practical 4 (Solenoid Valves)

1 *Describe the physical structure and principle of operation of the solenoid valve. What is the normal state of the solenoid valve?*

Solenoid is on/off binary device, with electrical solenoid coil that opens when current is passed through it. Normal state is closed.

2 *Compare the solenoid valve with the servo valve, listing the advantages, disadvantages and control applications.*

Solenoid is binary, only two positions, simple, well suited to on/off control.

3 *What is the significance of the valve size in process control? Having repeated Practical 4 using SV3 in place of the SV2, what do you deduce about the size of SV3?*

Valve size controls maximum flow (and so proportion of maximum flow). SV3 is smaller than SV2

4 *The two solenoid valves SV1 and SV2 used in the practical are the same size. Why then, when both valves are open, does the water level in the upper tank not remain constant at an intermediate level, and adjustments to the manual valve MV1 are necessary to keep the input and output flows equal?*

Resistance of pipes that water is passing through, head of water, gravity.

3.3.2 Flow/Level Rig Calibration Assignment

Questions for Practical 1 (Level - Volume correspondence)

1 *Define the term 'calibration'. Why is calibration important? List the calibration procedures applicable to measurement instruments. How is calibration affected?*

Calibration compares output of instrument with output of instrument of known accuracy and adjusts accordingly. Measurements from a calibrated instrument can be relied upon. Calibration is affected by environmental conditions.

2 *What kind of human errors are important when measuring dimensions and what rules should be followed in order to avoid them?*

Random errors are removed by averaging. Systematic errors are avoided by careful operation of measuring devices (parallax error).

3 *What is the length and width of the upper right hand tank? What is the mathematical expression relating volume and level for this part of the tank? What is the expression for the whole tank?*

length 180 mm, width 110 mm, area 19800 mm^2 (19.8 cm^2). Volume = area x level (or depth) so...

Volume = 19.8 x level. Area will be larger for the whole tank.

4 *Compare the two expressions. What is the significance of the level to volume correspondence?*

Volume can be calculated very quickly. Obvious how the volume will be greater in a large tank at the same level as that in a smaller tank.

Questions for Practical 2 (Visual Flow-meter calibration)

1 *What are the two main types of measurement error? What are the sources of these errors? How can these errors be reduced to a minimum?*

Random and Systematic

Random - often human error, averaging reduces error

Systematic - error in output reading, reduced by better instrument design.

2 *How is flow measurement performed in this experiment and what factors should be considered? Why do you have to take the average value of the flow rates measured? (Relate this to question one). Can you now appreciate the level to volume correspondence?*

Visual flow meter is used. Averaging reduces random error.

3 *How is the calibration of the variable area flow meter performed? How inaccurate is the flow meter and what is its resolution?*

Flow meter is calibrated against level-volume correspondence, not very accurate, resolution 0.2 l/min.

Questions for Practical 3 (Servo Valve calibration)

1 *Why are measurement errors impossible to eliminate? How are signal processing techniques used to improve the quality of the measurement signal? Give some examples.*

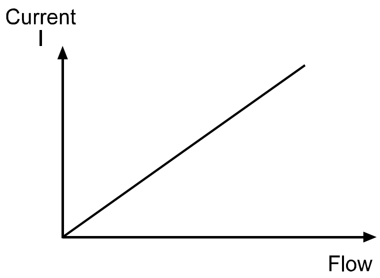
Errors are inherent in instruments, environmental conditions cannot be controlled. Digital Signal Processing can amplify, linearise, attenuate, filter and remove bias. Home stereo system amplifies signals before outputting.

2 *What are the differences between analogue and digital signal processing? What are the advantages and disadvantages of Digital Signal Processing (DSP) over analogue signal processing?*

Analogue is simple and straight forward, digital is complex but is very accurate, digital requires slightly longer processing time and will also involve analogue to digital (A/D) conversion.

3 *Plot the graph of flow rate against current. Is the graph linear or non-linear? Why should the graph be linear?*

The graph is linear. The position of the servo valve is directly proportional to the current supplied to it, so the flow through the servo should also be linear to the current.



4 *Considering your answer to question 3, what are you doing by calibrating the servo valve?*

Ensuring that the servo is as linear as possible.

Questions for Practical 4 (Solenoid Valves Calibration)

1 *What is the significance of the valve size in process control? Having repeated Practical 4 using SV3 in place of the SV2, what do you deduce about the size of SV3?*

The size of the solenoid valve is controlling the flow through that valve. SV3 is smaller than SV2.

2 *Having calculated the size coefficients of SV2 and SV3, compare them to the manufacturer's figures reproduced below. How do they compare?*

Manufacturer's figures for the valves: SV2 6 mm hole size and flow coefficient of 0.6 gives a size coefficient of 3.6. SV3 3 mm size hole and flow coefficient of 0.3 gives a size coefficient of 0.9. Experimental results should compare approximately with these.

3 *What does calibrating a solenoid valve actually mean?*

Calibrating a solenoid valve will ensure its size coefficient is suitable for the system.

3.3.3 Interface Familiarisation Assignment

Questions for Practical 1 (Breaker, Loop, Connections)

1 *What is the use of the circuit breaker? How does it operate? How would you test its operation?*

Circuit breaker is a protection device, temporarily breaking a circuit to protect against short-circuit and overload current. There is a test button to simulate a short circuit condition.

2 *Which parts of the PI have you dealt with in this practical and how are they used?*

Power section, current source, process connections. The power section provides power for the Process Controller, Pumps, Heater and Transmitters. The current source can be used to directly open and close the servo valve. It produces a 4-20 mA current control signal. The process connections are used to make power, control and signal connections for the control of the processes.

3 *How and why is a current loop used in process control? What type of current source is incorporated in the PI and what are its advantages and disadvantages over the other type?*

Current loop allows long distance signalling and standard communication formats to be used (4-20 mA). The PI contains a transmitter as a current source, which is independent of line resistance, but requires a separate supply and has no fail safe.

4 *What is the general purpose of the Digital Display Module (DDM) and how is it used in this practical? What is the significance of the mA / % switch?*

DDM is a milliammeter displaying loop current, either in mA or as a % of 4-20 mA signal.

Questions for Practical 2 (Servo Valve)

1 *What are the input and output terminals in this practical?*

Servo valve supply socket is input and servo DIN on PI is the output.

2 *What is the effect of a change in the loop current on the DDM and variable area flowmeter?*

Changing loop current is displayed on the DDM, and will change servo position, changing flow and so changing visual flow meter.

3 *What are the signals that are carried by the 7-pin DIN socket of the servo valve process connection 5?*

DIN carries 4-20 mA signal to servo.

4 *How is the state of the servo valve opening described with reference to the DDM, and why is this way generally preferable in process control?*

Servo is % open. This is a non-dimensional representation.

Questions for Practical 3 (I-V Converters)

1 *What is the use of the I-V converters, particularly in process control, and how do they operate?*

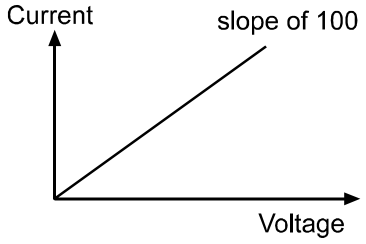
Converts current signal to a voltage across a 100 Ohm resistor. Voltage can be used with voltage controlled devices (solenoids).

2 *How is I_1-V_1 converter incorporated in this practical? How else can the I-V converters be used with the rest of the equipment?*

Returning current signal from plant is converted. Voltage signals allow logic control to be implemented.

3 *Plot a graph of the voltage across terminals G and 0V against the current in the loop, as the current source output is varied. What is the approximate shape of the graph plotted? What is the error involved and where does it come from?*

Should be straight line graph. Errors will be introduced by the voltmeter, possibly random and systematic, and also from the tolerances in the resistor, and environmental conditions.



4 *What is the gradient of the line and what should it be theoretically?*

Slope is value of resistor, 100R.

3.3.4 Interface Calibration Assignment

Questions for Practical 1 (Current Source Calibration)

1 *What is meant by calibration? Why is calibration so important? What are the critical issues in calibration?*

Calibration compares instrument output with a known instrument's output and corrects any deviation. Ensures reliable measurement. Important to keep dedicated calibrating instruments, and to be able to chain back to calibration standards.

2 *What are the two controls associated with the current source calibration and how are they used?*

Zero - to calibrate zero reading.

Span - to calibrate maximum range value.

3 *How would you calibrate the current source if high accuracy was required?*

Instruments calibrated to a much higher standard of accuracy (highly specialised instruments).

Questions for Practical 2 (PI Comparator)

1 *What is a comparator? What are the different types of comparator that exist? Describe the one included in the Process Interface.*

Non-linear circuit based on Op Amps which produces two discrete outputs dependent on input level. Inverting or non-inverting, positive feedback creates a Schmitt trigger, included in the PI.

2 *What is hysteresis and how is it associated with a Schmitt trigger? What is the effect of varying the hysteresis on the operation of the Schmitt trigger?*

Hysteresis is non-coincidence of transition curves of output (high to low, low to high) of Schmitt trigger. Varying hysteresis controls switching level of Schmitt trigger.

3 *What are the benefits of taking care when choosing the threshold voltage V_t? What can occur if V_t is chosen incorrectly?*

Minimise noise at the switching levels. Too large degrades crossover point.

3.3.5 Controller Familiarisation Assignment

Questions for Practical 1 (Serial Communication)

1 *Why is it vital that this practical is completed before any others that involve the Process Controller (38-300) and a personal computer?*

Computer and 38-300 controller cannot communicate without it.

2 *The first two steps deal with the physical link between the 38-300 and a computer, what does the third deal with? What would be the effect of incorrectly completing this step?*

Serial parameters. Without, there would still be no communication.

Questions for Practical 2 (Navigating The Controller)

1 *When controlling the PI, of what type are the process inputs and outputs of the Process Controller (38-300)? What input signals does the 38-300 accept?*

4-20 mA signals. Thermocouple, voltage/current, resistance, temperature transmitter.

2 *What is the major restriction when using the 38-300 in terms of monitoring process variables? What sort of control can be implemented using this controller, and so how many variables can be controlled?*

Only one process variable can be controlled. Single loop control.

3 *Considering the operations carried out before the parameters on the Control and Set Point pages were recorded, and the information given in the background to this practical on computer initialisation, what do you suggest is the reason for the differences in the two sets of parameter values recorded? As well as saving time and effort, what is another advantage of using a computer to initialise the 38-300 before attempting a practical?*

Different initialisation files. The controller is placed in a known state.

Questions for Practical 3 (Using The Controller)

1 *Hysteresis, with regard to the 38-300 alarms, is the difference between the switch-on level and the switch-off level of the variable assigned to the alarm. Did you find your experimental results were the same as the values set up in the controller by your personal computer (these can be found by observing the 'SEtUP ALAr_S' page)? When is hysteresis operational, and when using it what can be said about the variable as it moves inside the trip level?*

Hysteresis is operational when alarm is active. Shows how far inside the trip level variable travels.

2 *When transferring between modes of the 38-300, what is a 'bump' and what are the conditions that would cause a bump? What steps should be carried out to prevent bumps, and what facility is available on modern controllers to prevent bumps? What is the anomalous situation that can occur if care is not taken when transferring modes in a modern controller?*

A bump is difference between set point and operating (measured) point when changing mode. Equating these will remove bump. Automatic bumpless transfer can produce deviation between operating point and set point.

3 *Considering what you have learnt in this and previous assignments about automatic and manual control systems, split the following into Automatic Control and Manual Control:*

A heater with a thermostat.	auto
A refrigerator.	auto
Filling a bath tub.	manual
A burglar alarm which has been armed.	auto
Traffic lights at a road junction.	auto
A pedestrian crossing with traffic lights.	manual
A washing machine once it is turned on.	auto
A petrol-driven lawnmower once it has been turned on.	manual

3.3.6 Controller Calibration Assignment

Questions for Practical 1 (The Calibration Check)

1 *What are the four steps that make up the 38-300 pre-practical set-up procedure? (Clue: three were met in the previous assignment)*

Physical link, Termination, Parameters, Scale adjust

2 *Why is it unnecessary to calibrate the 38-300 in the same way that the current source on the Process Interface was calibrated? What devices would be needed to calibrate the 38-300 to an accuracy level greater than the one it has already been calibrated to?*

Already calibrated to a very high accuracy. To calibrate to a greater accuracy would require instruments of a very high accuracy.

Questions for Practical 2 (The Relays)

1 *What is a relay? What are the different types of relay available in the 38-300 controller? What type of control are they well suited to?*

Relays - Voltage controlled switches, normally open / normally closed, positive action / negative action. Suited to On / Off control.

2 *Describe the operation of the process in this practical. What types of relays were used, how do they differ?*

Controlling flow manually by increasing/decreasing output of the 38-300 to the servo, and controlling flow using the solenoids and alarm/relay combination. The relays are n/o and n/c, one is the inverse of the other (open/closed).

3 *What are the trip levels and hysteresis values of the alarms that are controlling the relays, as found experimentally by investigating the full range of output?*

alarm A trip 80%, hyst 5%

alarm B trip 60%, hyst 5%

4 *By assigning relays to alarms, what do the relays inherit, and how does it affect the way in which they operate?*

Relays inherit hysteresis, and switching is voltage direction dependent.

Questions for Practical 3 (Reading the 38-300)

1 *What is the difference between a READ command and a WRITE command as sent by your computer to the 38-300?*

READ contains no parameter value since it is asking for one to be returned.

2 *In this practical you have met two virtual instruments that are used when controlling a process with your computer. Briefly outline the different facilities that a computer offers to process control; include which direction communication is passing, and between whom.*

Control bars - write to and read from the controller to the computer.

Computer initialisation - write to and read from the controller to the computer.

Chart recorder - reads the controller only.

3 *What type of controller is the 38-300, and what is the nature of the subservient relationship between controller and computer.*

Automatic controller. Master - slave arrangement.

4 *Why are there steps in the curve being drawn by the chart recorder? What are these steps dependent on? How could the size of the steps be reduced, how could the curve be made smoother?*

Sampling rate of the computer. Step size dependent on sampling frequency f_S. Sample quicker, or use interpolation techniques.

3.3.7 Float Level Transmitter Assignment

Questions for Practical 1 (Float Level Transmitter)

1 *Why are the signals from the Float Level Sensor converted to the 4-20 mA format by the Float Level Transmitter?*

Signals from the sensor could be in any form, so converted to a standard form. Also long distance communication is possible.

2 *What is the Float Level Transmitter providing to the controller, and how does this enable feedback control to be carried out?*

Providing information on level, so providing information on process state, which is feedback.

3 *Considering what you have already learnt about using instruments, and what must be done to them before they can be relied upon in a measurement situation, why is it possible that the Float Level Sensor and Transmitter combination is not producing a 4-20 mA signal proportional to the level of water in the tank?*

Transmitter is not calibrated for sensor.

Questions for Practical 2 (Calibrating the FLT)

1 *Consider the following instruments in turn; Does each one have to be calibrated regularly if its readings are to be relied on absolutely?*

- A Float Level Sensor and Transmitter
- A Current Source
- A Digital Multimeter
- A Tyre Pressure Gauge
- A Weighing Machine
- A Geiger Counter
- A Digital Watch
- A Thermostat

(think carefully about what calibration is before answering)

λ ALL MUST BE CALIBRATED

Questions for Practical 3 (Level Control Demo)

1 *Identify the following:*

1.a) *Items of Hardware*

the measurement instrument	float level sensor
the measured variable	level
the feedback path	sensor, transmitter, DDM, PI, 38-300
the 'master' and the 'slave' controller	master - computer, slave - 38-300
the actuator	servo

1.b) *On The 38-300 Display*

the measured (or process) variable	top display
the control effort	output, bottom display
the desired level (or set point)	bottom display

1.c) *Displayed On Screen*

the measured (or process) variable	chart recorder
the desired level (or set point) both places	chart recorder, control bar
the difference (or error)	chart recorder

3.3.8 Pulse Flow Transmitter Assignment

Questions for Practical 1 (Pulse Flow Transmitter)

1 *What type of signal is the Pulse Flow Sensor producing, and what is done to make this suitable for transmission to other instruments around the process system?*

Pulse flow sensor produces a pulse train, which is converted to 4-20 mA signal by the pulse flow transmitter.

2 *What is also being controlled by limiting the flow around the system?*

Level.

3 *Considering what you have already learnt about using instruments, and what must be done to them before they can be relied upon in a measurement situation, why is it possible that the Pulse Flow Sensor and Transmitter combination is not producing a 4-20 mA signal proportional to the rate of flow through the pipe network?*

Transmitter is not calibrated for the sensor.

Questions for Practical 2 (Calibrating the PFT)

1 *How often should the pulse flow transmitter be calibrated?*

As often as possible, before every practical at least.

2 *What can we now do reliably and accurately, and what does it provide for the system? What can be constructed with either this, or the previous assignment's instruments?*

Measure flow, providing information on the state of the process. A feedback loop can be constructed.

3 *Why use different transmitters if the outputs from both the float level transmitter and the pulse flow transmitter are 4-20 mA signals? Could you reliably use the same transmitter for two seemingly identical pulse flow sensors without adjustment?*

The inputs to the transmitters from the sensors are different. Must be calibrated, two devices should not be considered identical.

Questions for Practical 3 (Flow Control Demo)

1 *Identify the following:*

the measurement instrument	pulse flow sensor
the measured variable	flow
the feedback path	sensor, transmitter, DDM, PI, 38-300
the actuator	servo

2 *What is happening to the measured value that makes proportional control unsuitable for flow rate control without any modification or improvement?*

Oscillation

3 *Explain exactly what is occurring to the system, as the effect from question 2 is exhibited. What is the 38-300 trying to do, and what happens when it applies a control effort to the system?*

Flow is fluctuating back and forth. 38-300 is trying to set flow by controlling servo position, but control effort is too large for system and sends process in opposite direction.

3.3.9 On/Off Control Assignment

Questions for Practical 1 (On/Off Pump Control)

1 *What is on/off control and why is it sometimes preferable to other types of control? What are the disadvantages of on/off control?*

On/Off control is two state binary control, only using extremes. Simple and cheap. Oscillation often occurs, it will cure deviation when it occurs rather than prevent deviation.

2 *How is on/off control used in this practical to control the level of the water in the upper tank? Which pieces of equipment are involved?*

Signal from float level sensor converted to current signal from transmitter, converted to voltage level by I-V_1. Current source current converted to voltage level by I-V_2. Two voltages are inputs to Schmitt trigger, they are compared and output switches pump on/off dependent on deviation.

3 *What are the meanings of the following terms: reference value, measured value, and deviation? What do they represent in this practical, how are they produced, and how are they used?*

Reference value - current source converted to voltage.

Measured value - float level sensor, transmitter output converted to voltage.

Deviation - difference between two.

4 *What is the significance of manual valve MV3 connected to the upper tank, with reference to the operation of the on/off level control and how should it be set for correct operation?*

MV3 controls rise and fall times of upper tank (outflow rate). Must be such that level increases with pump on, decreases when pump off.

Questions for Practical 2 (On/Off Solenoid Control)

1 *Why is on/off control of the pump avoided and a solenoid valve used instead?*

Pump not designed to be switched repeatedly and indefinitely, but solenoid is.

2 *Describe the different actions that can be produced from the comparator and Schmitt trigger arrangement, depending where the reference voltage is connected.*

Inverting action - if difference between inputs is negative, output is positive.

Non-inverting action - if difference between inputs is negative, output is negative.

3 *What is being imitated when the water is swished around in the upper tank? How does the hysteresis level affect this, how does it control disturbance rejection?*

Disturbance. Hysteresis controls trip levels, and large hysteresis value has wide trip levels so disturbance rejection.

4 *Sketch a hysteresis loop for a V_t value of 1V, with output switching between 0V and 5V. What would be output of the Schmitt trigger if;*

a) the reference voltage is 2.5 V connected to the inverting input of the comparator, and the measured value is i) 1 V, ii) 4 V, and is connected to the non-inverting input of the comparator.

b) the reference voltage is 2.5 V connected to the non-inverting input of the comparator, and the measured value is i) 0.5 V, ii) 3 V, and is connected to the inverting input of the comparator.

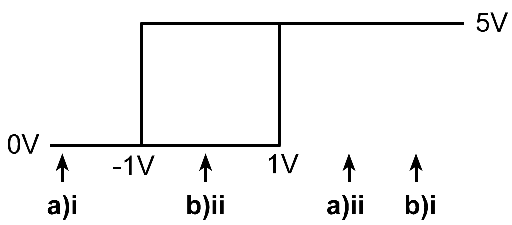
What else must be known about b) ii) before an output level can be specified?

a)i, 1 V - 2.5 V = -1.5 V at this point output is 0 V.

a)ii, 4 V - 2.5 V = 1.5 V at this point output is 5 V.

b)i, 2.5 V - 0.5 V = 2 V at this point output is 5 V.

b)ii, 2.5 V – 3 V = -0.5 V state of output cannot be decided since direction of voltage change will determine level.



Questions for Practical 3 (The Float Switch)

1 *Why was it necessary to recalibrate the FLT before beginning this practical?*

New sensing instrument (float switch).

2 *Describe the operation of the whole process during this practical. Split it into the following stages:*

- FIlling up the tank
- Passing the desired level
- Triggering the state change

- Emptying the tank
- Passing the desired level
- Triggering the state change

For each stage identify the values of:

- Deviation between measured and reference values
- Schmitt trigger output
- Position of the solenoid valve
- Output of the float switch

Filling -measured value < reference, Schmitt trigger output = 5 V, solenoid is open, float switch output is low.

Passing level - measured value = reference, float switch output is high.

Triggering - measured value > reference, Schmitt trigger output = 0 V, solenoid is closed.

Emptying - no state changes until........

Passing - measured value = reference, float switch output is low.

Triggering - measured value < reference, Schmitt trigger output = 5 V, solenoid is open.

3 *The measured value is now only a 4 mA signal or a 20 mA signal since the measuring device is the float switch. How does this affect deviation? Will hysteresis determine switching in the same way as the first two practicals? What should happen when hysteresis is greater than maximum deviation?*

Deviation is binary, positive or negative. Hysteresis will no longer determine switching as before. If hysteresis is greater than maximum deviation, nothing will ever switch.

4 *How does varying the current source (and so the reference voltage) affect this process?*

Varies set point.

5 *What is happening when the upper tank is shaken?*

Disturbance.

Questions for Practical 4 (38-300 On/Off Control)

1 *Which type of relay is being used on the 38-300? Why is this? What sort of control action is being produced, inverting or non-inverting?*

SV2 is controlled with normally closed, positive action relay. It needs to be closed when deviation is negative. This is non-inverting action.

2 *What does the 38-300 allow us to do, that the single PI did not?*

Set up more than one trip level/action. Each tripping/ hysteresis/ control action would require a separate PI.

3 *Describe the operation of the process for each of the following stages:*

- tank level increasing
- reaching desired level
- switching state
- tank level decreasing
- passing hysteresis value
- switching state

For each stage consider alarm status, relay status, actuator logic input and measured level with respect to desired level.

Increasing - alarm off, relay closed, logic level low, measured level < desired level.

Reaching - measured level = desired level.

Switching - alarm on, relay open, logic level high.

Decreasing - measured level < desired level.

Passing and switching - alarm off, relay closed, logic level low.

4 *When using the 38-300, the trip level and hysteresis value of the alarm are available to the user, to determine how the system will operate. What are the equivalent of these two variables when the PI is used as the controller?*

Trip level - reference from current source.

Alarm hysteresis - variable hysteresis setting of Schmitt trigger.

3.3.10 Proportional Control : Level Assignment

Questions for Practical 1 (Simulation)

1 *What benefits might the use of a mimic diagram have in an industrial environment?*

Mimic diagrams provide ‘user friendly’ instrumentation and control displays, concentration of information in a single location and central error reporting. These can all be of great benefit in industrial situations.

2 *Discuss briefly the effect of an increase in proportional band on a simple control system.*

Proportional band represents the change in a measured variable that will generate a 100% change in control effort. Therefore an increase in the proportional band width will reduce the gain of the control system and reduce the observed reaction to process variable changes.

Questions for Practical 2 (Proportional Control of Level)

1 *As the measured variable approaches the set point on the chart recorder, its rate of approach decreases (the curve becomes more horizontal). Why is this so?*

Control action decreases as deviation decreases.

2 *What does the quiescent point correspond to in a practical process control situation? What is the significance of this quiescent point?*

Desired operating point, set point.

3 *If the control law was such that the measured value approached the set point by half the error for every time step, should the measured value ever reach the set point?*

Theoretically, they should never be equal, but the deviation will become negligible, and the actuator has a resolution, a minimum movement.

Questions for Practical 3 (Proportional Control and Offset)

1 *Why is an error (or offset) always present when using proportional control, and how can it be reduced? What must you be aware of when attempting to reduce offset?*

Control effort is proportional to deviation, so with no error there will be no control effort. Deviation is decreased by increasing controller gain, but make gain too large and oscillation will occur.

2 *For the four examples of process input below, decide if each is manual control, proportional control, or neither. Compare each case to the general form of the proportionally controlled input, met in the proportional control theory.*

process input: U   process output: C   time (in seconds): t

2.a) U = 10	manual
2.b) U = 10 + (2 x t x C)	neither
2.c) U = 10 + (0.5 x C)	proportional
2.d) U = t x C	neither

Questions for Practical 4 (Proportional Band)

1 *What is the relationship between system gain and proportional band? Why is proportional band given as a percentage?*

System gain is inversely proportional to proportional band. A percentage is non-dimensional.

2 *Considering the equations given in the theory section on Proportional Band, and then those given in the theory section on Proportional Control, explain the operation of the system when the proportional band is varied. How are the following changing; PB, K, U, Uc, Um, e?*

If proportional band is increased, gain K decreases, total effort U decreases, control effort Uc decreases, manual effort Um unchanged, deviation e increases.

3 *What is the value of proportional band that caused the measured value to begin oscillating? Was is possible to completely remove offset without triggering oscillations?*

Approximate PB 4% beginnings of instability. There will always be some offset present.

3.3.11 Proportional Control: Flow Assignment

Questions for Practical 1 (Servo P-Control)

1 *Why are measuring/controlling flow and measuring/controlling level so different? In terms of control effort, what should you be aware of when choosing the type of control to be implemented?*

Flow is dynamically much quicker than level. Control effort should be reduced accordingly to avoid overcompensation and oscillation.

2 *Describe qualitatively the terms Uc, PB and K, when using proportional control. What are the two expressions that link all three, and one other variable? What is A, the constant of proportionality?*

Uc - proportional control effort

PB - proportional band, determines contribution of proportional control term. It is percentage change in measured value that will generate 100% change in control effort.

K - controller gain.

Expressions   Uc = K e   PB = A/K   A = output span / measurement span

3 *The combination of the 38-300 reading the process variable, your personal computer reading the 38-300, and the chart recorder drawing the variables has produced a curve made up of small steps. If the sample rate of both devices was fast enough to be considered 'continuous', what would be the resulting shape of the smoothed curve?*

Sinewave.

Questions for Practical 2 (P-Control Oscillation)

1 *What is the value of proportional band that caused the measured value to stop oscillating? As proportional band was decreased, did the oscillatory behaviour increase linearly? What else occurred?*

Approximate PB 8% begins instability. As PB decreases offset decreases. Instability cannot be considered linear by implication.

2 *Recalling the value of proportional band that caused oscillation in the last practical of Assignment 11, why are the two different? What are the corresponding system gain values, with respect to each other?*

Different because of system dynamics. Flow is dynamically quicker than flow, so PB must be higher for system to reach steady state.

3 *When the proportional band was at a level high enough for there to be no oscillation, there was the variable offset as met in the last assignment. How does it compare with the offset found when controlling level?*

Offset should be much higher.

4 *Why are the two values of offset (when controlling level, and when controlling flow) different?*

Proportional Bands are very different.

3.3.12 PI and PID: Level Control Assignment

Questions for Practical 1 (PI Control: Level)

1 *Explain the behaviour of the parameter Proportional Band, and describe how it affects the process characteristics? (You should have a pretty good idea about PB from this and the two previous assignments)*

PB controls proportional control term contribution and gain, so determines control effort, and so offset/response/oscillation/steady state.

2 *Discuss integral action, and the differences between Proportional and Proportional + Integral control. What part does the reset time T_r play and how does it determine the contribution of the reset component?*

Integral action is control term which is integral of error, (so area under error against time curve) and it will be present until error is zero, removing offset. T_r controls length of time integral is taken over so determines contribution of integral action.

3 *Can you now reduce the offset produced by Proportional control to zero?*

Yes

4 *How readily did the system oscillate when the integral action was turned on?*

Should be necessary to reduce T_r very small to trigger oscillation.

Questions for Practical 2 (PI Control Limitations)

1 *How does Proportional Band affect the response time of the controller? (Consider what PB is and how it influences the control effort)*

PB influences total size of control effort whatever algorithm is being applied, since it is a function of gain. Smaller PB, larger gain, larger control effort, faster response.

2 *Recall the simple equations met in earlier theory sections, and explain how PB and T_r can be traded off against each other to produce a desired control action?*

PB will control oscillation but will introduce an offset, T_r will reduce offset, so PB can be large to reduce any chances of oscillation and T_r can be small to reduce offset.

3 *Why must the integral action be large if PB is large (explain each step linking these two parameters)?*

A large integral action is produced by a small T_r. PB large, so small control effort, so large offset, so small T_r for large integral action to decrease offset.

Questions for Practical 3 (PID Control: Level)

1 *Discuss the effect of derivative action, both theoretically and experimentally. What will it do to a process plant and controller?*

Derivative action is contribution which is proportional to the rate of change of deviation. It should increase control effort when deviation is increasing and exhibit a braking effect when measured value is approaching set point.

2 *How do the three control effort parameters determine the response of the controller? Are their values critical, or could a particular controller responses be provided by a range of parameters?*

PB is directly proportional to error, T_r controls offset, T_d controls rate of change of deviation. Different parameter values could produce similar responses (parameters not wildly different obviously, but they are not critical).

3 *Can you foresee any possible problems with PID control, in particular the derivative element of the control effort, that would become apparent when controlling a dynamically fast system? (Consider this question carefully but do not worry if you are unable to answer it as this will be considered in the next assignment)*

With a dynamically quicker system, a change in deviation will produce a much greater control effort than before, because of the derivative action. Large control efforts encourage oscillation.

3.3.13 PI and PID : Flow Control Assignment

Questions for Practical 1 (PI Control of Flow)

1 *What is the main difference between controlling flow and controlling level, in terms of the process variables themselves?*

Flow is so much quicker than level in its response to a control effort.

2 *Fill in the missing words:*

- 'Integral action decreases as T_r **increases**'
- 'Proportional Band and system gain are **inversely** proportional'
- 'A large PB value corresponds to a **small** gain value and a **small** control effort for a deviation between **measured** value and **set point**'
- 'Using proportional control, an **offset** will always be present because control effort is proportional to **error**, without this there would be no control effort'
- 'The integral of a curve is a measure of the **area under** that curve'
- 'Integral or reset action will remove **offset** by applying a control effort until the **error** is zero'

Questions for Practical 2 (PID Control of Flow)

1 *What is the reason for any oscillation when the measured value is increasing towards the set point? Does this increase in severity as T_d increases? (Consider rate of change of error) Would you consider this process variable (flow) suitable for PID control?*

Error changes very fast and so control effort is very large to compensate, too large for system and oscillation is the result. This will increase as T_d increases. Flow is not really suitable for PID control.

2 *Fill in the missing words:*

- 'Derivative action decreases as T_d **decreases**'
- 'If there is a large change in a process output for a small change in process input, the process is considered to have a **large** gain'
- 'The derivative of deviation between measured value and set point is the **rate of change** of that deviation'

- 'While deviation is increasing, derivative action will **increase** control effort to compensate. While deviation is decreasing it will exhibit a **braking action** due to the deviation contribution.'

3.3.14 Tuning PID Controllers Assignment

Questions for Practical 1 (Zeigler-Nichols Tuning)

1 *Using the table of recommended settings met in the background to this practical, and reproduced below, calculate all parameters for P, PI and PID control of your process plant.*

Continuous Cycling Zeigler-Nicholls Tuning

Control Algorithm	Controller PB	T_r	T_d
P	$2PB_U$	-	-
PI	$2.\ 2PB_U$	$\frac{T_U}{1.2}$	-
PID	$1.7PB_U$	$\frac{T_U}{2}$	$\frac{T_U}{8}$

Do these parameters appear reasonable, considering your previous work on instability and parameter values?

Example results: PB_u = 2%, T_u = 17 secs

Questions for Practical 2 (Controller Self Tuning)

1 *Was the controller able to automatically tune itself to the process and put forward values that settled down oscillation?*

Should be yes.

2 *Were these values similar to the values produced manually in the last two practicals? (The parameters are not expected to be identical, but they should all be of a similar magnitude)*

Yes, they should all be of a similar scale.

3.3.15 Process Controller: Advanced Assignment

Questions for Practical 1 (Remote Set Point)

1 *Describe how the Remote Set Point facility is used by the controller, both in this practical and generally in a real industrial situation.*

Remote set point uses another measured variable to control the set point (actually providing the set point) for a process.

2 *What are you pretending to be by manually varying the current source of the PI to change the remote set point?*

Another process variable.

Questions for Practical 2 (Profile Programming)

1 *Discuss how the different control algorithms coped with a changing set point.*

This will be affected by the system and the control algorithm, but there are general points which have already been explored: PID should control deviation, but if it is very quick the control effort may be too great - overshoot, P control may appear slow but there should be no overshoot, the responses should exhibit behavioural characteristics that have been discussed previously.

2 *Which control method could best follow the set point profile?*

This will depend on the set point profile programmed.

Questions for Practical 3 (Time Proportioned Output)

1 *Discuss the differences between conventional On/Off control and Time Proportioned Output control.*

On/Off control switches the state of the control effort as deviation changes sign. Time Proportioned Output control is essentially a pulse train, where the periods of high and low control effort are determined by the deviation (with no deviation, T.P.O should output a square wave).

2 *What is the characteristic of On/Off control that Time Proportioned Output control helps to avoid?*

Conventional On/Off control will always force a system in one direction and then compensate accordingly (oscillate), but T.P.O. control will hope to maintain a system’s operating point by switching the control effort as a square wave.

3 *Why could conventional On/Off control still be chosen for a process plant even though Time Proportioned Output control will limit oscillation?*

Conventional On/Off control is very simple and cheap to implement.

3.3.16 Temperature Rig Initialisation Assignment

Questions for Practical 1 (Calibration of the TTT)

1 *Consider the following instruments in turn; Does each one have to be calibrated regularly if its readings are to be relied on absolutely?*

Thermistor Temperature Transmitter	Yes
Current Source	Yes
Digital Multimeter	Yes
Mechanical Tyre Pressure Gauge	Yes
Digital Weighing Machine	Yes
Geiger Counter	Yes
Digital Watch	Yes
Thermostat	Yes

Questions for Practical 2 (Thermistors)

1 *Explain the differences between NTC and PTC thermistors ?*

NTC thermistors have a negative temperature coefficient. The resistance of an NTC thermistor decreases with an increase in body temperature. The opposite is true for PTC thermistors.

2 *Why do you think the power dissipated in a thermistor is such an important consideration?*

Power is dissipated in a thermistor in the form of heat. This heat raises the temperature of the component body above that of the surrounding environment.

Questions for Practical 3 (Bleeding the Secondary Flow)

1 *Describe how the presence of air in a radiator reduces its efficiency.?*

The conduction of heat through air is less efficient than through water. The subject is covered at length in the theory and background to this assignment.

2 *Imagine a situation where large quantities of air became trapped in an industrial process much like the temperature rig. What problems do you imagine would arise?*

Problems with inefficient heat transfer, overheating and vibration would occur. Other problems would also occur dependent on the process involved.

3.3.17 Temperature Rig Familiarisation Assignment

Questions for Practical 1 (On/Off Heater Control)

1 *What are the advantages and disadvantages of on/off control?*

Advantage-It can provide the required control with the minimum initial cost and outlay.

Disadvantage-Due to system lags the measured value can oscillate. The actuators are driven to the two outer process limits.

2 *When using on/off control with the TPR what prevents the potential temperature from being reached instantaneously?*

The system lags.

Questions for Practical 2 (Operation of the Heat Exchanger)

1 *Explain with the aid of a diagram the operation of the heat exchanger.*

This is covered at length in the background to this assignment.

2 *Why are the signals from the thermistors converted to the 4-20mA format by the Thermistor Temperature Transmitter?*

This is an industry standard control signal format accepted and understood by most process control equipment. It allows longer transmission lines.

3 *What is the Thermistor Temperature Transmitter providing to the controller, and how does this enable feedback control to be carried out?.*

The TTT provides a standard control representation of the temperature at the thermistor. This provides the controller sufficient information to switch the heater on/off or increase/decrease the flow, depending on the controlled process. In other words, the TTT is closing the feedback loop.

Questions for Practical 3 (Operation of the Cooler)

1 *From the following list of systems, identify and explain the types of cooling used:*

i)	A car engine.	Water cooled - cooling radiator.
ii)	A small motorcycle engine.	Air cooled - cooling fins
iii)	A marine engine	Water cooled - heat exchanger.

2 *Define the areas of lag associated with the Temperature Process Rig.*

Distance Velocity Lag - This is the time taken for the primary flow (heating fluid) to travel from the valve (heating reservoir) to the heat exchanger.

Transfer lag between primary and secondary flows of the heat exchanger. Due to supply capacity, time is required following a change in valve position for the secondary flow to heat up or cool down.

3.3.18 Manual Flow Control Assignment

Questions for Practical 1 (Simulation)

1 *Explain the benefit of realistic simulations to the process control industry?*

This question can be answered with reference to the theory section of this assignment.

2 *'The temperature rig simulation is a digital representation of an analogue system' What does this statement mean?*

The temperature rig is an analogue system. This means that the parameters within it (ie, temperature and flow) are infinitely variable. This means that they can be at any value. The hands on the face of an analogue clock can occupy any position. The simulation allows the parameters only to move in discrete steps; the analogue variables are being represented by discrete digital values.

Questions for Practical 2 (Primary Flow Control)

1 *Describe a verbal algorithm of the control effort required to maintain a given temperature set point?*

The primary flow must remain in ratio with the secondary flow. However if the secondary flow is held constant, the primary flow should remain constant, except for the fact that the secondary flow heats up. This has the effect of reducing the heat transfer effectively, hence as the secondary heats up, the primary flow must increase. This is true until such a point as the secondary flow has reached the same temperature as the system set point. At such a point the temperature of the secondary continues to increase and the system becomes unstable.

2 *Explain in detail the effect of the secondary flow temperature on the efficiency of the heat exchanger?*

See above.

Questions for Practical 3 (Secondary Flow Control)

1 *Explain the differences between open and closed loop systems?*

Open loop - no feedback, Closed loop - feedback.

2 *Explain why less control effort is required once the system `settles down'?*

Once the system as settled down the temperature fluctuations are very small, hence minimal control effort is required.

3 *What would be observed if the system was left running for a long period of time?*

The system would become unstable, as the secondary flow temperature rose above the system set point.

3.3.19 Temperature Process Control Assignment

Questions for Practical 1 (Single Loop Control Demonstration)

1 *Identify the following:*

a) Items of Hardware

the measurement instrument	thermistor
the measured variable	temperature
the feedback path	thermistor, TTT, DDM, PI, 38-300
the 'master' and the 'slave' controller	master - computer, slave - 38-300
the actuator	servo

b) On The 38-300 Display

the measured (or process) variable	top display
the control effort	output lower display
the desired level (or set point)	lower display

c) Displayed On Screen

the measured (or process) variable	chart recorder
the desired level (or set point) ....both places	chart recorder, control bar
the difference (or error)	chart recorder

Questions for Practical 2 (Industrial Process Control)

1 *What are the advantages of using mimic diagrams in an industrial plant situation?*

The major advantages are more user friendly instrumentation and control, the concentration of all instrumentation to one convenient location, global system and error reporting, etc.

2 *In an industrial plant would you replace all real instrumentation by virtual instrumentation in the form of mimic diagrams? Why?*

The relative merits of mimic diagrams and virtual instrumentation are discussed in the theory associated with this assignment.

Questions for Practical 3 (Automatic On/Off Control)

1 *What is on/off control, and why is it sometimes preferable to other types of control?*

On/Off control allows only two states for the controlling device. This can be open or closed, on or off, depending on the device. The greatest advantage is the simplicity of implementation this method of control allows.

2 *Explain the meaning of the hysteresis value when applied to on/off control. What effect does the level of hysteresis have on the performance of a system?*

The hysteresis level defines the difference between the on/off switching levels when the variable is moving up of down. A small hysteresis level can lead to oscillation, while a large hysteresis level can lead to an un-responsive system.

3.3.20 P, PI and PID Temperature Control Assignment

Questions for Practical 1 (P-Control of Temperature)

1 *Why is there always an offset present when using proportional control and how can it be reduced ?*

Offset will always be present in a proportional control application because the control effort is a function of error, for there to be a control effort there must also be an error. The error can be reduced by increasing the system gain (achieved by reducing the proportional band value), producing a larger control action for the error present.

2 *What are the effects of a narrow proportional band and what would result if the proportional band was increased 50%?*

Small offset due to any load changes. Offset increases dramatically such that control would be insufficient.

Questions for Practical 2 (PI Control of Temperature)

1 *What is the main advantage of using PI control as opposed to P only?*

λ It reduces offset.

2 *Name two disadvantages of PI control?*

The system generally takes longer to stabilise than with proportional control only.

For negative deviation, integral action shifts the whole proportional band above the set point until the controlled condition reaches it. This means that the correcting element does not start to close until it is too late to prevent overshoot.

Questions for Practical 3 (PID Control of Temperature)

1 *What type of control processes does PID most suit ?*

Control process having large distance velocity and transfer lags. Also where load changes may be sudden and/or sustained.

2 *What is the effect of derivative action on control processes ?*

It improves the response of the controller to rapidly changing loads and provides a braking effect when the measured variable approaches the set point.

3.3.21 Complex Control Loops Assignment

Questions for Practical 1 (Flow Ratio Control)

1 *Explain with the aid of a diagram, a system for automatically proportioning the flow of liquid in two separate pipelines.*

The system to achieve this task is known as ratio flow control and is covered in detail in the theory section of this assignment.

2 *Why is it necessary, in some instances to use more than one controller?*

In some cases dual loop control (two controllers) has to be carried out in order to achieve satisfactory control, which would have been unattainable with only single loop control.

Questions for Practical 2 (Dual Loop Temperature and Flow Control)

1 *What is the effect of increasing and decreasing the flow set point ?*

If the secondary flow is increased, the temperature at T5 decreases, hence the primary flow increases, similarly if the secondary flow decreases the primary flow decreases.

2 *Name two industrial applications where flow and temperature has to be controlled ?*

Any typical industrial application, such as paint manufacture, petro-chemical industry, fertiliser manufacture, etc.

Questions for Practical 3 (Dual Loop Temperature and Level Control)

1 *Discuss the effect of changing the level set point on the rest of the system.*

If the level set point was increased, the secondary flow would have to increase to attain the new level, which subsequently results in the primary flow increasing to maintain the temperature set point. opposite is true if the level set point was decreased.

2 *What are the major advantages of virtual instrumentation and control?*

The major advantages are user friendly instrumentation and control, the concentration of all instrumentation in one location, global system and error reporting, etc.

3.4 Answers To Questions Posed in Practical Work

3.4.1 Flow/Level Rig Familiarisation Assignment

Question for Practical 1

"Calculate the volume of water in the tank at overflow and hence calculate the rate of flow through the pipes from lower to upper tank"

Volume of tank / Time to fill tank from empty to overflow = Rate of flow

Questions for Practical 2

"What do you deduce about the input and output flow-rates?"

They are equal; hence the level of water in the tank remains constant.

"What happens to the water level in the upper tank now?"

The level will begin to reduce as the inflow rate reduces.

Questions for Practical 4

"Switch on the PI and the switched AC supply. What do you notice?"

There is no flow through the pipes.

"What happens now?"

The flow rate through the pipes increases.

3.4.2 Flow/Level Rig Calibration Assignment

Question for Practical 1

"Estimate the measurement accuracy"

The curved surface of the water (meniscus) should be considered.

Also, the accuracy of the final volume calculation can only be as good as the accuracy of the measurements used to perform the calculation.

Question for Practical 2

"What is the accuracy and resolution of the visual flow meter?"

The markings on the visual flow meter are in 0.2 litre/minute graduations. Readings taken from the meter are to this accuracy at best. The problems associated with taking visual readings in-general should also be considered.

Question for Practical 4

"Calculate the size coefficient (Cv) of the solenoid valve SV2"

The information contained within the Background for this practical should be consulted.

The following equation should be used in the solution:

$f = ka\,[2g\,(h_1 - h_2)]^{0.5}$

Where:

f = flow rate (l/s).

a = area of control valve port (m^2).

g = acceleration due to gravity (m/s^2).

$(h_1 - h_2)$ = difference between upstream and downstream levels (m).

3.4.3 Controller Familiarisation Assignment

Questions for Practical 3

"What is the DDM showing?"

The DDM is showing the control output from the 38-300 Process Controller.

"What are the units of the output?"

The DDM is displaying the output in percentage (%) units.

3.4.4 On/Off Level Control Assignment

Question for Practical 2

"What is happening? Why?"

Rapid on/off switching occurs as the level rapidly changes. As the hysteresis level is altered so the switching alters.

Question for Practical 4

"What occurs? Why?"

Rapid on/off switching occurs due to the small hysteresis level.

3.4.5 Temperature Rig Initialisation Assignment

Question for Practical 1

"What do you observe and why?"

The temperature indicated by the DDM should increase as the heat from the hand is conducted through the piping to the thermistor T1.

3.4.6 Temperature Rig Familiarisation Assignment

Questions for Practical 2

"Why is there only a small difference being displayed?"

Only a small amount of heat is being conducted away from the primary flow via conduction into the body of the heat exchanger and into the stationary secondary flow.

"What is the result and why?"

The heat exchanger is now passing both the primary and secondary flows. Thus greater heat transfer takes place.

Questions for Practical 3

"Why is there a difference being displayed?"

Even without the fan, a certain degree of cooling occurs across the radiator.

"What do you notice, and why?"

The fan is now operating, and a greater heat loss is occurring across the radiator. The radiator is functioning as it should.

3.4.7 Manual Flow Control Assignment

Questions for Practical 1

"Why is there a drop in temperature across the heat exchanger when secondary flow is zero?"

See answer provided for Assignment 18, Practical 2.

"What do you notice?"

The water entering is at a slightly higher temperature than that exiting.

"What happens if you turn off both primary and secondary flows. Why?"

The whole system slowly cools as heat is lost to the atmosphere.

"Why is there a difference in temperature between the water flowing into the rig to that flowing out of the rig.?

The water entering the rig has been cooled by the large volume of water contained in the sump tank. This situation is temporary as the water in the sump tank will eventually be heated to the same temperature as the primary flow.

Question for Practical 2

"Why does this control the temperature at T5?"

This controls the temperature at T5 because the primary flow rate determines how much heat is transferred to the secondary flow, and hence T5.

3.4.8 Temperature Process Control Assignment

Question for Practical 1

"As the secondary flow water temperature rises it becomes increasingly difficult to control the temperature set-point. Why?"

The cooling water temperature slowly rises towards that of the water it is cooling. As this happens the water loses its ability to cool.

3.4.9 Complex Control Loops Assignment

Question for Practical 1

"What is happening and why?"

The ratio between the two rates of flow is being maintained by controller 2. The changing set-point is being re-transmitted by controller 1 to controller 2.

Question for Practical 2

"What is happening and why?"

The temperature and flow within the primary and secondary circuits is being maintained independently.

Notes