Feedback

PROCON Pressure Control Trainer - Instruction Manual

38-714

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PROCON

PRESSURE CONTROL TRAINER

INSTRUCTION MANUAL

38-714

1160–38714

Feedback

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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.

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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.

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38-714 PRESSURE PROCESS RIG INTRODUCTION

The successful design and operation of industrial plant requires the optimum choices of instrumentation and control equipment together with the ability to commission, monitor and maintain such equipment. Technicians and engineers need to be trained in these skills, particularly in view of the rapid advances in the use of electronics and microcomputers in process control.

This range of specially designed equipment allows practical appreciation and understanding of the whole spectrum of process control technology from the characteristics of individual components to complex control loops operating on real processes

This manual describes the 38-714 Pressure Process Rig, which is part of the PROCON range of equipment designed to introduce and demonstrate the principles of process measurement and control.

The system includes those pneumatic control components of interest to the process industries. The design allows study of component operation and connection to electrical control devices through the use of pressure/current transducers.

The unit consists of a pipeline on which are mounted a Pneumatic Control Valve, Orifice Block, Flowmeter and pressure tappings. The flow discharges directly to atmosphere or via an Air Receiver to vary the 'process lag'. The Pneumatic Control Valve is operated from a Current/Pressure Converter, and sensors for direct and differential pressure facilitate measurement of pressure and flow respectively. Both sensors are provided with signal conditioning units.

The unit is designed to work with the 38-200 and 38-300 Process Interface and Controller, to configure closed loop control circuits. A supply of compressed air is required for both flow and control.

NOTES

38-714 PRESSURE PROCESS RIG DESCRIPTION

The front panel of the Pressure Control System incorporates a schematic diagram of the equipment which identifies the major components and relevant connections in standard pneumatic notation.

The unit consists of a pipeline on which are mounted a Pneumatic Control Valve, Orifice Block and pressure tappings. The flow discharges directly to atmosphere or via an Air Receiver to vary the 'process lag'. The valve is operated from a Current to Pressure Converter, and sensors for direct and differential pressure facilitates measurement of pressure and flow respectively.

The square root extraction facility of the 38-300 Process Controller is used with the latter to provide a linear signal. Both sensors are provided with conditioners. The pipework and fittings are mounted on a support frame which is designed to stand on a bench top. The unit is designed to operate with the 38-200 and 38-300 Process Interface and Controller to configure open or closed loop control circuits.

Compressed air for the pneumatic instrumentation and process is connected to a common inlet. Air for the instrumentation is regulated by a Regulator (R1) and the operating pressure in indicated on a Gauge (G1). Air for the process is regulated by a Regulator (R2) and the operating pressure is indicated on Gauge (G3).

The pneumatic instrumentation comprises a I/P Converter and Pneumatic Control Valve. The I/P Converter accepts a 4-2OmA control signal from the 38-200 Process Interface and converts this to a 3-l5psi pneumatic signal which operates the control valve.

The control valve comprises a diaphragm actuator which positions the stem of a plug type valve. An indicator on the valve stem shows the actual position of the valve. A Gauge (G2) indicates the pneumatic signal applied to the control valve by the I/P Converter. The 4-2OmA input to the I/P Converter can be connected to the 38-200 Process Connections or the Servo Valve connection.

The air flowing through the process pipe passes through the Pneumatic Control Valve and an Orifice Block assembly before discharging to atmosphere via a Diffuser.

A set of Valves (V1, V2 and V3) allow a rear-mounted Air Receiver to be connected in series or parallel with the process pipe to change the response of the system (to vary the process lag). The Air Receiver incorporates a Pressure Relief Valve.

Step changes may be applied to the process by bleeding air through an additional Diffuser by opening and closing the Valve (V4).

This accessory incorporates pneumatic control components of great interest to the process industries. The design allows study of component operation and connection of control devices through the use of current to pressure converters.

Two pressure signal conditioning units are supplied with the 38-714 Pressure Process Rig. The pressure conditioning module (38-461 Pressure Transmitter) is used in conjunction with the Pressure Sensor for measurement of static pressure in the process pipe. The Pressure Sensor is connected to the process pipe by a combination of rigid and flexible tube which includes the Pressure Gauge (G5).

The differential pressure conditioning module (38-462 Differential Pressure Transmitter) is used in conjunction with the Differential Pressure Sensor which measures the difference in pressure across the Orifice Block (this is used for measurement of flow). The Differential Pressure Sensor is housed in a box which incorporates the necessary electrical connections on the front panel. The two ports on the sensor are connected to the Orifice Block assembly by a combination of rigid and flexible tubes.

The Pressure and Differential Pressure Transmitters are designed for mounting on the magnetic panel. They allow the sensor outputs to be connected to the four Process Connections on the 38-200. Control and monitoring of the system is achieved in this way. The Pressure Sensors are connected to the signal conditioners using the 5 pin DIN leads which are supplied with the 38-714.

When despatched, the Pressure Transmitter is set up to give an operating range of 0-10psi. The Differential Pressure Transmitter is set up to suit the maximum flow rate through the system of 24L/min. The 4-20mA output from the Transmitters must be calibrated prior to them being used.

INSTALLATION REQUIREMENTS

The Pressure Process Rig 38-714 must be operated in conjunction with the 38-200 Process Interface and 38-300 Process Controller which provide the necessary signal conditioning and control circuits.

The Pressure Transmitter and Differential Pressure Transmitter are associated with the Pressure Sensor and Differential Pressure Sensor. They are signal conditioning units designed for connection to the 38-200 Process Interface.

The equipment is designed for bench mounting on a firm level surface and will require permanent connection to a supply of clean compressed air capable of providing 4 cubic metres per hour at a pressure of 40psi gauge.

Note: An air compressor can be noisy in operation. If using a portable compressor (not supplied) to provide the air for the instruments and process line on the 38-714, the compressor should be located as far from the equipment as possible to reduce disturbances to the operator.

Overall dimensions are:

Height	-	0.66m
Width	-	0.90m
Depth	-	0.40m

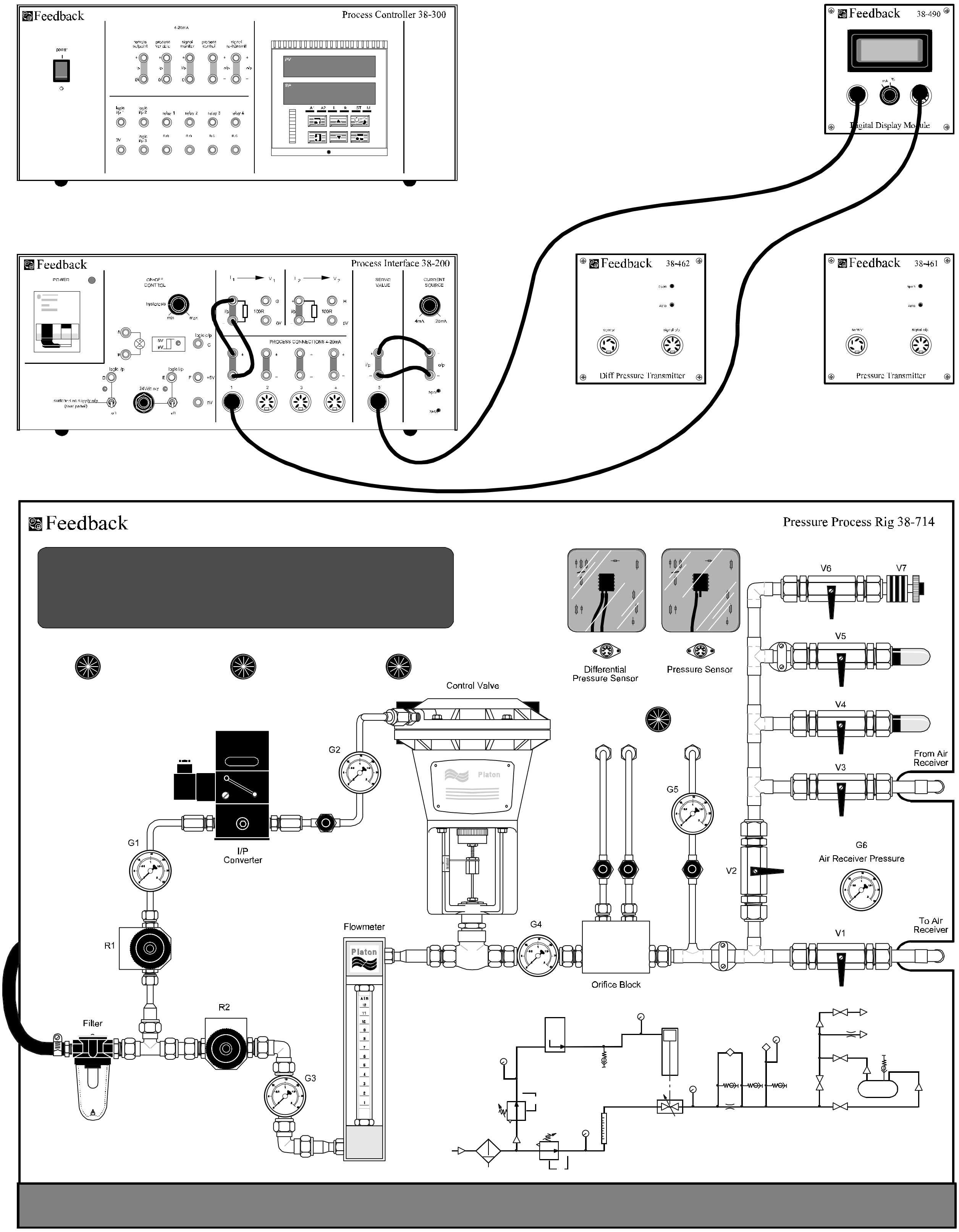

Fig 1 - Current Source Connection Diagram

COMMISSIONING

A 38-200 and 38-300 Process Interface and Controller will be required to commission the 38-714 Pressure Control System. A 38-490 Digital Display Module is used throughout this commissioning chapter, although this is an optional extra. It is not essential to use a 38-490 with the Pressure Process Rig.

It should also be remembered that the most thorough commissioning can only take place after full calibration of the instruments supplied as part of the package. It is suggested that this chapter is carefully read before continuing. Particular attention is drawn to the **WARNING** and **CAUTION** boxes.

The following instructions describe how to set-up the 38-714 Pressure Process Rig and its associated components in order to check for correct and safe operation.

1. Connect a supply of clean compressed air to the inlet using a reinforced air hose. The supply must be capable of providing the required volume of compressed air at the operating pressure, otherwise flow and pressure in the system will be inadequate for satisfactory demonstrations.

WARNING

The maximum supply pressure should not exceed **40psi**. Supply pressure should be adequately and reliably regulated prior to presentation to the Pressure Process Rig.

2. From Figure 1 identify all the relevant gauges and valves. Open valve V1, V3 and V4 adjacent to the air tank connection, close valves V2, V5 and V6.

3. Adjust instrumentation pressure regulator R1 to give 25psi at G1. Pull the collar out to adjust the regulator. Turn the collar clockwise to increase the downstream pressure and anticlockwise to reduce the pressure. Push the collar back into place after adjustment.

4. Adjust process pressure regulator R2 to give 10psi at G3. Air will flow through the system, pressurising the pipes and Air Receiver to 10 psi.

5. Calibrate the Process Interface 38-200 Current Source.

   Connect the Current Source to the Digital Display Module 38-490 as shown in Figure 1.

Turn the Current Source control fully anticlockwise to reduce the output to the minimum. The display should read 4mA or 0%. If it does not, adjust the zero control using a small screwdriver or trim tool until the display shows 4mA or 0%.

Turn the Current Source control fully clockwise to increase the output to the maximum. The display should read 20mA or 100%. If it does not, adjust the span control.

The Current Source is now calibrated.

6. Check operation of I/P Converter and Pneumatic Control Valve.

Note

If you have the 37-820 compressor unit, then connect the male union from the 38-714 to the female union on the 38-820.

If you do **not** have the 38-820 compressor, then remove the male fitting from the 38-714 and use your own fitting.

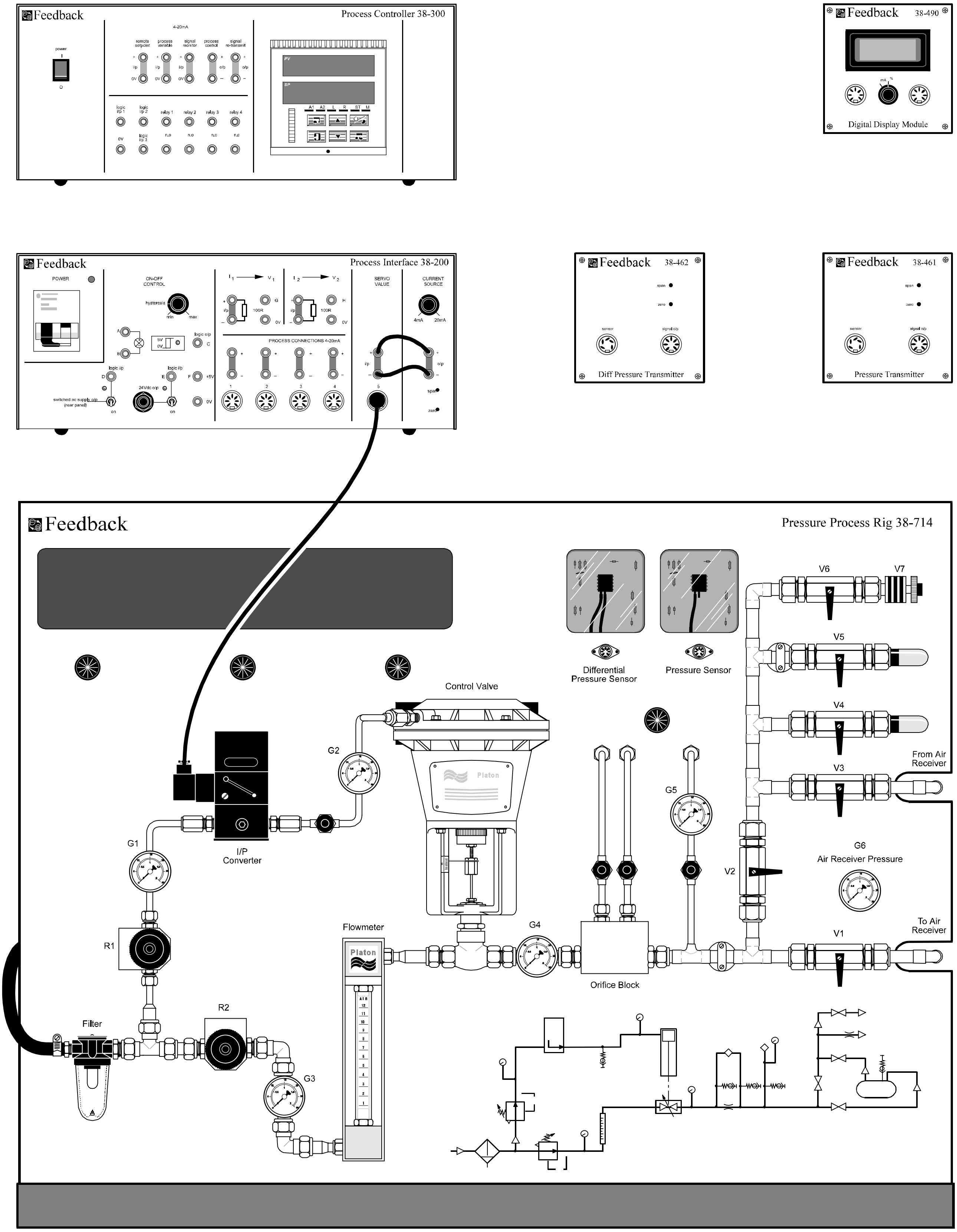

Fig 2 - I/P Converter Connection Diagram

CAUTION

The I/P Converter input pressure should not exceed 30psi. The instrument may be permanently damaged if this pressure is exceeded.

Connect the I/P Converter to the 38-200 4-20mA supply by making the connections shown in Figure 2.

Set the Current Source output to minimum (4mA) by turning the adjusting knob fully anticlockwise. Gauge G2 should indicate 3 psi with control valve fully open. The indicator on the valve stem should be in the raised position.

Set the current source output to maximum (20mA) by turning the adjusting knob fully clockwise. Gauge G2 should indicate 15 psi with control valve fully closed. The indicator on the valve stem should be in the lowered position.

Note that the indicator on the valve stem provides only an approximate indication of valve position.

Note: If the pressures indicated on G2 differ from the values stated above it will be necessary to recalibrate the I/P Converter. This procedure is detailed in Experiment 2.

CAUTION

The Pressure Sensors are very delicate instruments. They may be damaged if presented with differential pressures in excess of 30psi.

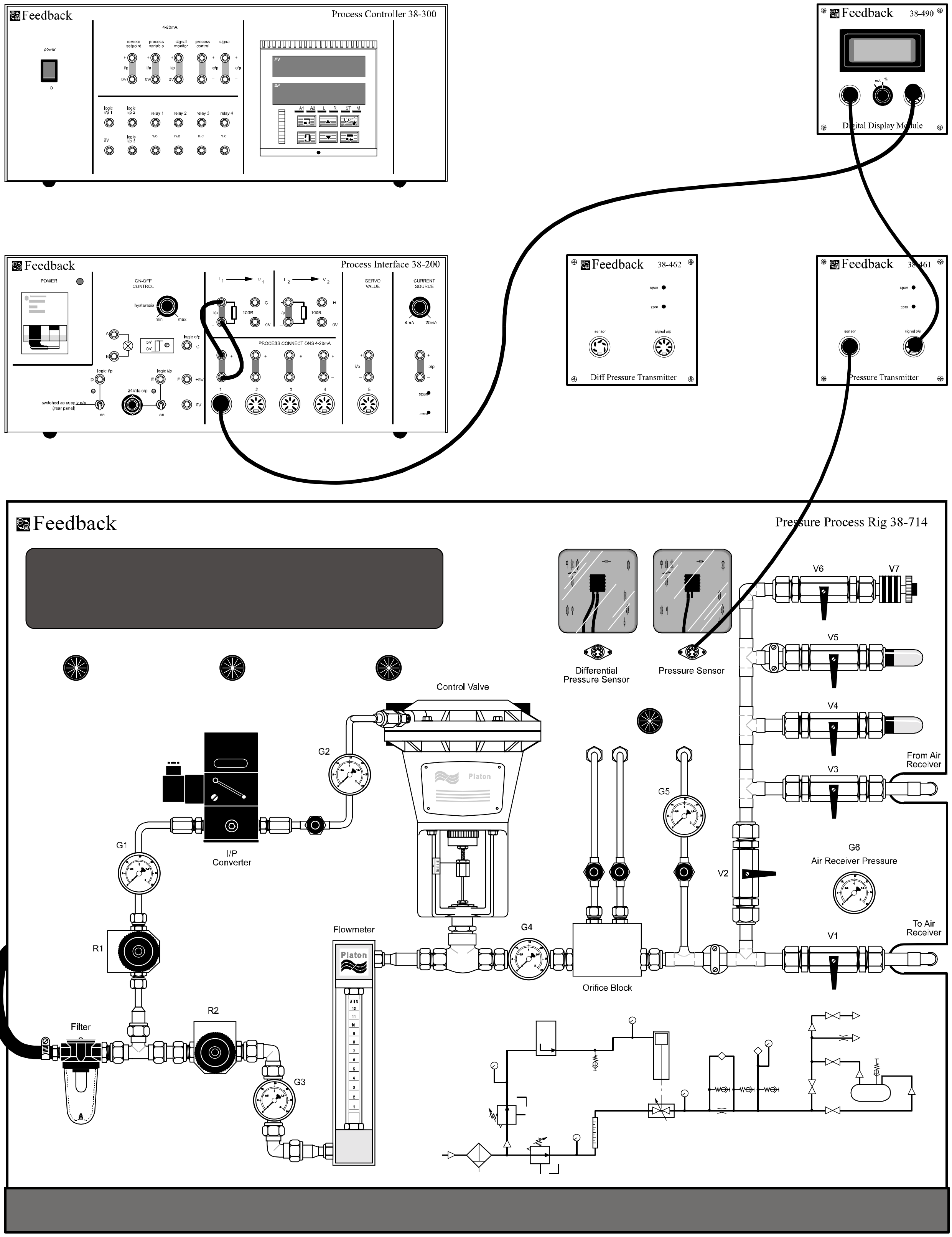

Fig 3 - Pressure Sensor Connection Diagram

7. **Check operation of the Pressure Sensor and Transmitter.**

Complete the connections shown in Figure 3.

Drain all pressure from the system by fully closing R2 and fully opening V2, V4 and V5. After a few moments the system will be at atmospheric pressure throughout. The Digital Display Module should show 4mA or 0%. If it does not, adjust the zero control until the desired reading is obtained.

Pressurise the Air Receiver by opening V1 and closing V2 then adjusting R2 to produce a reading 0.7 bar of 10psi on G3. After a few moments the Air Receiver pressure gauge will read 10psi.

The Digital Display Module should read 20mA or 100%. If it does not, adjust the span control until the desired reading is obtained. Repeat the above process checking readings of 0% at atmospheric pressure and 100% at 10psi.

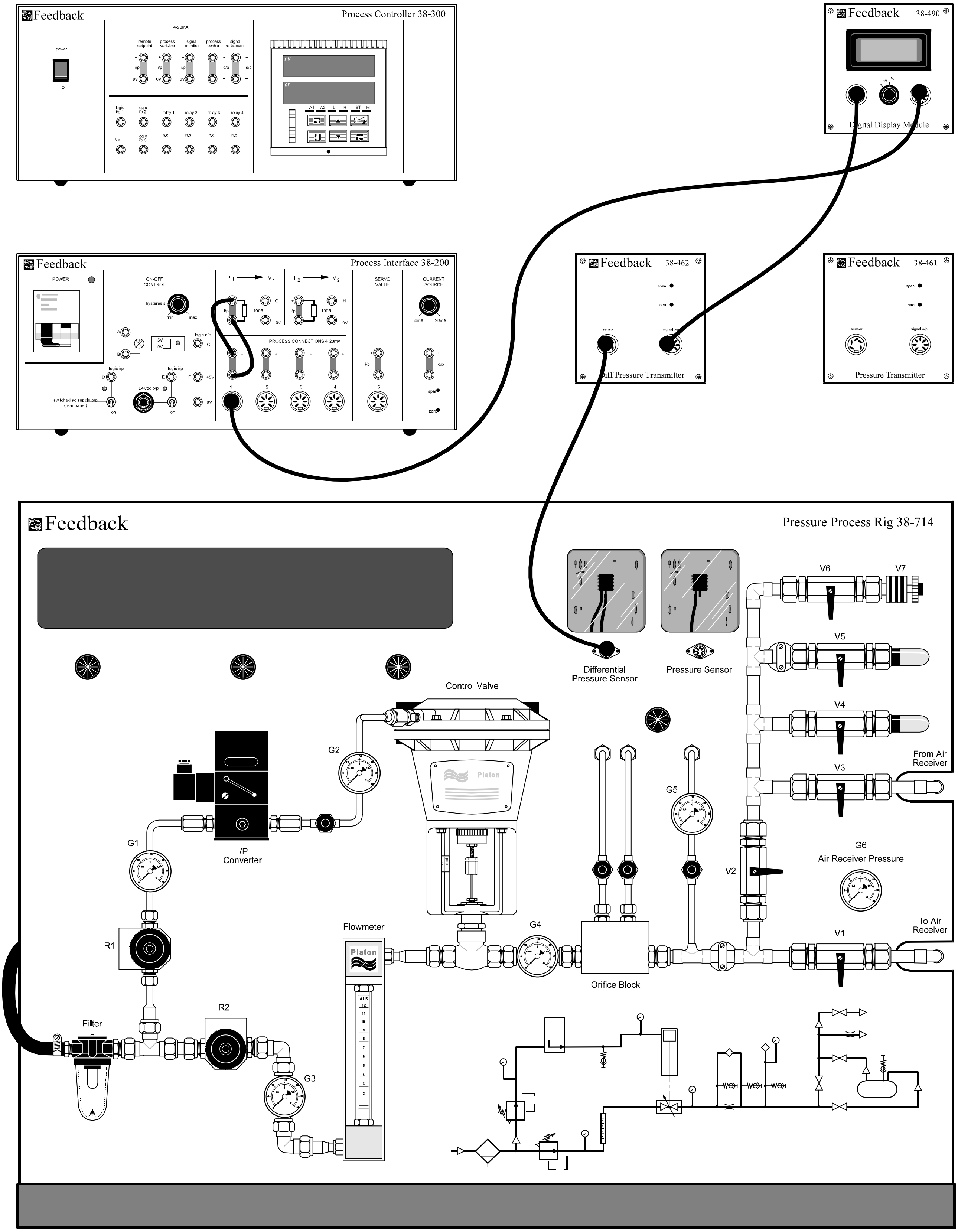

Fig 4 - Differential Pressure Sensor Connection Diagram

8. **Check operation of Differential Pressure Sensor and Transmitter.**

Complete the connections shown in Figure 4.

Open valves V2, V4, V5 V6 and V7. Close valves V1 and V3 (ensure V7 is fully open).

Drain all pressure from the system by fully closing R2 and fully opening V2. After a few moments the system will be at atmospheric pressure throughout. The Digital Display Module should show 4mA or 0% to indicate the zero flow condition. If it does not, adjust the zero control until the desired reading is obtained.

Create a full flow condition by adjusting R2 until a 10psi difference is shown between the reading on G4 and the reading on G5. This should easily be achieved. The Digital Display Module should show 20mA or 100%. If it does not, adjust the span control until the desired reading is obtained. When G4 indicates 10psi and G5 indicates zero the flow meter will show a flow of approx 24 litres/min.

EXPERIMENTAL INDEX

1 To Calibrate the Pressure Sensor and Transmitter and Investigate the Linearity and Hysteresis of the Sensor/Transmitter.

2 To Calibrate the Current to Pressure Converter to Operate the Pneumatic Control Valve and Investigate the Linearity and Hysteresis of the Converter.

3 To Demonstrate Manual Operation of the Pneumatic Control Valve and to Determine its Characteristics (Pressure/Position).

4 To Determine the System Response With and Without the Air Receiver by Manually Operating the Pneumatic Control Valve.

5 To Control Pressure in the Process Pipe using a Pressure Sensor and Three-Term Controller with Proportional Output to an I/P Converter and Pneumatic Control Valve.

Effect of Disturbances.

Changing the Set Point Remotely.

6 To Demonstrate the Characteristics of a (P) Proportional Only Process Controller and the Response to a Change in Set Point or a Disturbance to the Process.

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Effect of Changing the Set Point.

Effect of Changing the Proportional Band.

7 To Demonstrate the Characteristics of a (P+I) Proportional+Integral Action Process Controller and the Response to a Change in Set Point or a Disturbance to the Process.

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Effect of Changing the Integral Action Time.

Effect of Changing the Proportional Band.

8 Characteristics of a (P+D) Proportional + Derivative Action Process Controller and the Response to a Change in Set Point or a Disturbance to the Process.

Effect of Disturbances.

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Effect of Changing the Derivative Action time.

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Effect of Disturbances.

Changing the Set Point Remotely.

Repeat of Pressure Control Experiments.

EXPERIMENTS

EXPERIMENT 1

Object of Experiment:

To calibrate the pressure sensor and pressure transmitter and to investigate the linearity and hysteresis of the sensor/transmitter.

Equipment Required:

38-200	Process Interface
38-714	Pressure Process Rig
38-461	Pressure Transmitter
38-490	Digital Display Module

Note: The equipment requires a supply of clean compressed air.

Optional Equipment:

0.5 Metre Mercury Manometer or Digital Pressure Sensor (not supplied).

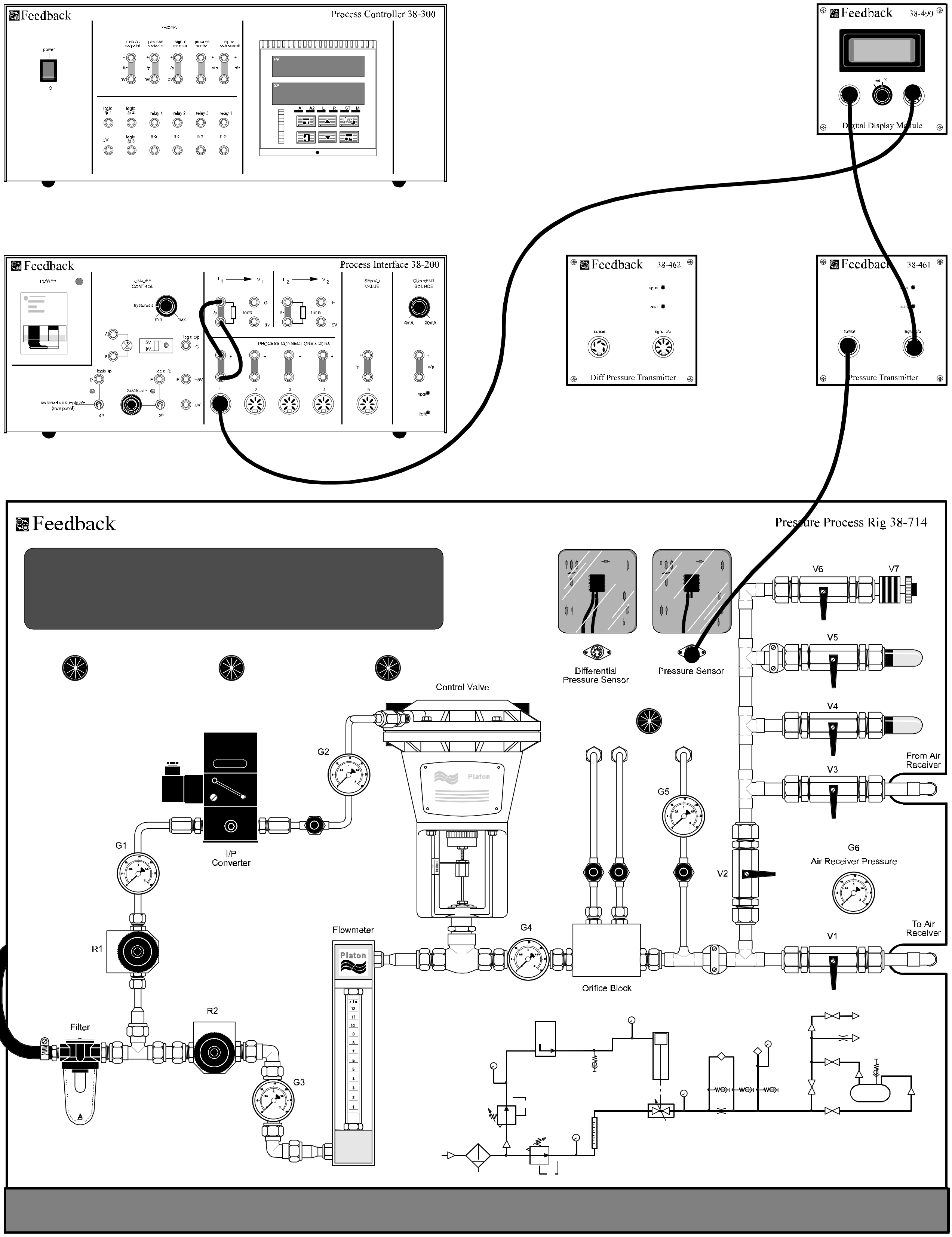

Fig 5 - Experiment 1 Connection Diagram

<u>Initial Settings</u>:

Complete the connections shown in Figure 5.

R1 & R2	Closed
V2	Open

(all other valves closed)

The Process Controller is not required for this experiment.

<u>Experimental Details</u>:

The aim of this experiment is to calibrate the Pressure Sensor and Transmitter to give the following conditions.

Minimum pressure = 0 psi = 4mA output from the Pressure Transmitter

Maximum pressure = 10psi = 20mA output from the Pressure Transmitter

Note: The Pneumatic Control Valve is designed to open with lack of air. With R1 closed and the I/P Converter disconnected, the valve will remain open.

If an accurate Manometer or Digital Pressure Gauge is available this may be connected underneath the Bourdon gauge (G5) to allow a more precise calibration to be performed. (Note that the connection is a $^1/_4$ inch push-fitting).

With R2 closed, the pressure in the system will be atmospheric (ie the minimum required, 0psi on gauge G5 or 0mm differential on the manometer). Use a small screwdriver or trim tool to adjust the zero control on the Pressure Transmitter to give a reading of 4mA or 0% on the Digital Display Module

Open valve V4. Set the pressure in the system to the maximum required (10.0psi on gauge G5 or 414mm on the manometer) by adjusting valve R2. When the pressure is steady, adjust the span control on the Pressure Transmitter to give a reading of 20mA or 100% on the Digital Display Module.

Repeat the minimum and maximum settings until no further adjustments of the zero and span controls is required.

Linearity and hysteresis

Having calibrated the Pressure Sensor and Transmitter, it is interesting to determine the linearity of the output over the operating range from minimum to maximum pressure.

Adjust the pressure in the system in steps of 2 psi from 0 psi to 10 psi indicated on gauge G5.

Alternatively, if using a Mercury Manometer, adjust the pressure in steps of 50mm from 0mm to 515mm differential reading on the manometer

Note: 1mmHg = 0.01934 psi

Record the pressure and corresponding output from the Pressure Transmitter at each step. Repeat for reducing pressure in the system to investigate the hysteresis in the sensor. Plot the pressure versus the output voltage to determine the linearity and hysteresis.

Typical Results:

Pressure (psi)	Rising Percentage	Falling Percentage
0	0	0.5
2	22	17
4	40	36
6	62	57
8	80	79
10	100	100

Note: The Bowden gauges fitted to the 38-714 are only 10% accurate therefore you may get some variation from these results.

Further Experiments:

Repeat the procedures outlined above for different minimum and maximum pressures in the system.

DO NOT EXCEED A READING OF 30PSI ON GAUGE G5 AS SENSOR DAMAGE COULD OCCUR. PLEASE REFER TO 'COMMISSIONING'.

Conclusions:

A Pressure Sensor may be used to give a remote reading of pressure in a system. This feature will be used in later experiments to enable the level to be controlled automatically.

It is necessary to calibrate an electrical sensor (with its conditioning circuit) before use to provide an output which is meaningful.

The Pressure Sensor may be calibrated to suit the operating range and datum required for a particular application.

The sensor supplied has an output which changes linearly with change in pressure, and hysteresis is small. Note that this characteristic will not apply to all Pressure Sensors used in process control.

Resolution of the Pressure Sensor is much finer than the Bourdon gauge which is designed for indication of approximate pressure only.

For accuracy in operation, a Pressure Sensor should be calibrated using a manometer or dead weight calibrator.

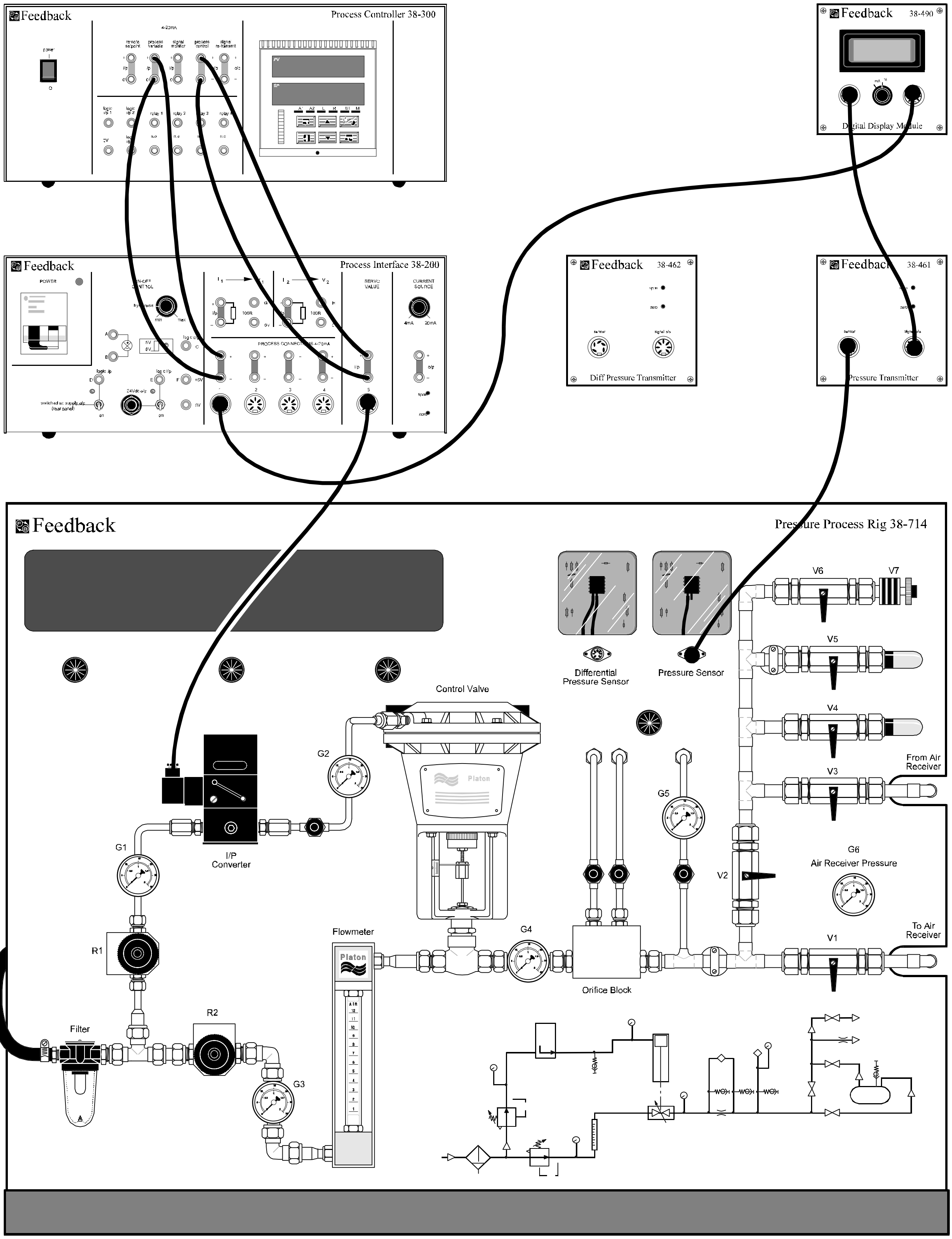

Fig 6 - Experiment 2 Connection Diagram

EXPERIMENT 2

Object of Experiment:

To calibrate the Current/Pressure (I/P) Converter to operate the Pneumatic Control Valve and investigate the linearity and hysteresis of the converter.

Equipment Required:

38-200 Process Interface

38-300 Process Controller

38-714 Pressure Process Rig

38-490 Digital Display Module

Note: The equipment requires a supply of clean compressed air.

Optional Equipment:

None.

Initial Settings:

Complete the connections shown in Figure 6.

R2, V 1, V3, V5 & V6 Closed

R1, V2 & V4 Open

Adjust R1 to give a reading of 25 psi on gauge G1.

For this set of demonstrations the 38-300 Process Controller will be used in Manual operation mode to operate the I/P Converter. Calibration of the controller is not required.

Switch-on the controller. The initial message ‘300 test’ will be seen. After a short time the display then begins to show the set-point (SP) and process variable (PV) ready for normal operation.

Experimental Details:

The aim of this experiment is to calibrate the I/P Converter to position the Pneumatic Control Valve with the following characteristics:

4mA to converter = 3 psi from converter (on G2) = Pneumatic Control Valve open

20mA to converter = 15 psi from converter (on G2) = Pneumatic Control Valve closed

Note: The Pneumatic Control Valve is designed to open with lack of air.

Connect the I/P Converter to the output of the Process Controller as shown in the set-up diagram.

Connect the compressed air supply to the inlet.

Ensure that gauge G1 reads 25psi. Adjust R1 if necessary.

Set the Process Controller to Manual operation by pressing the Auto/Manual button until the LED marked ‘M’ lights.

Remove the plastic stoppers which seal the zero and span adjusting controls on the I/P Converter. Note the span control on the I/P Converter is called 'Range'.

Press the Parameter Advance button once to display the control output in the lower screen. The screen should show ‘op 0.0’ to show a zero output effort. If it does not, press the Parameter Decrease button to reduce the value to zero.

Adjust the zero output on the I/P Converter to give a reading of 3 psi on gauge G2. The Pneumatic Control Valve should be just on the point of starting to close. This could be described as a ‘braced’ position.

Adjust the output from the Process Controller to 100% by pressing and holding the Parameter Increase button. The Process Controller output is now 20mA.

Adjust the span (range) control on the I/P Converter to give a reading of 15 psi on gauge G2. The Pneumatic Control Valve should be just fully closed.

Repeat the minimum and maximum settings until no further adjustments of the zero and span controls is required.

Replace the plastic stoppers on the zero and span controls.

Check the operation of the Pneumatic Control Valve.

With the output from the controller set to 0%, adjust valve R2 until a reading of 10 psi is indicated on gauge G5. Valve V2 should be open, all other valves should be closed.

Adjust the output from the Process Controller to 100%.

Observe that the pressure in the system falls to zero with the valve closed.

Note: The Pneumatic Control Valve is not designed to isolate totally when in the position. A small amount of air will leak past the valve seat and from the system. An Isolation or Stop Valve is required to completely remove leakage. The small amount of air bleeding through the valve causes the float in the flow meter to attempt to lift very slightly and a clicking noise can be heard from the flow meter.

Adjust the output from the controller to intermediate settings (e.g. 40% and 60%) and observe the change in valve position and the change in pressure on gauge G5.

Further Experiments:

To investigate the linearity and hysteresis of the I/P Converter

Close valve R2.

Adjust the controller output to 0% (4mA).

Confirm that the corresponding output from the I/P Converter is 3 psi on gauge G2.

Adjust the controller output from 0% to 100% in steps of 10% and record the corresponding pressure from the I/P Converter on gauge G2. Repeat for reducing inputs to the I/P Converter.

Plot the input versus the output for rising and falling inputs to determine the linearity and hysteresis of the I/P Converter.

Note that the pressure gauge used to perform this experiment has a stated accuracy of only ±3% of full scale.

Conclusions:

A Pneumatic Control Valve requires a current to pressure converter to change the electrical signal from the control circuit to a corresponding pressure which can actuate the valve.

It is necessary to calibrate a current to pressure converter before use to provide the appropriate output to a Pneumatic Control Valve.

In this pneumatic control system, the equivalent of the 4 to 20mA electronic signal is 3 psi to 15 psi.

The Pneumatic Control Valve should not be used in applications where total shut-off is required. An additional Isolating or Stop valve should be used. Note that this characteristic will apply to the majority of proportional control valves used in process control.

The I/P Converter provides a largely linear conversion from current input to pneumatic output. Hysteresis is small.

Control Valve Linearity

Typical Results:

Controller Output (%)	Increasing G2 psi	Decreasing G2 psi
0	3.0	3.0
10	3.5	4.0
20	5.0	5.0
30	6.0	6.5
40	7.3	7.8
50	8.5	9.0
60	10.0	10.0
70	11.0	11.5
80	12.5	13.0
90	13.7	14.0
100	15.0	15.0

NOTES

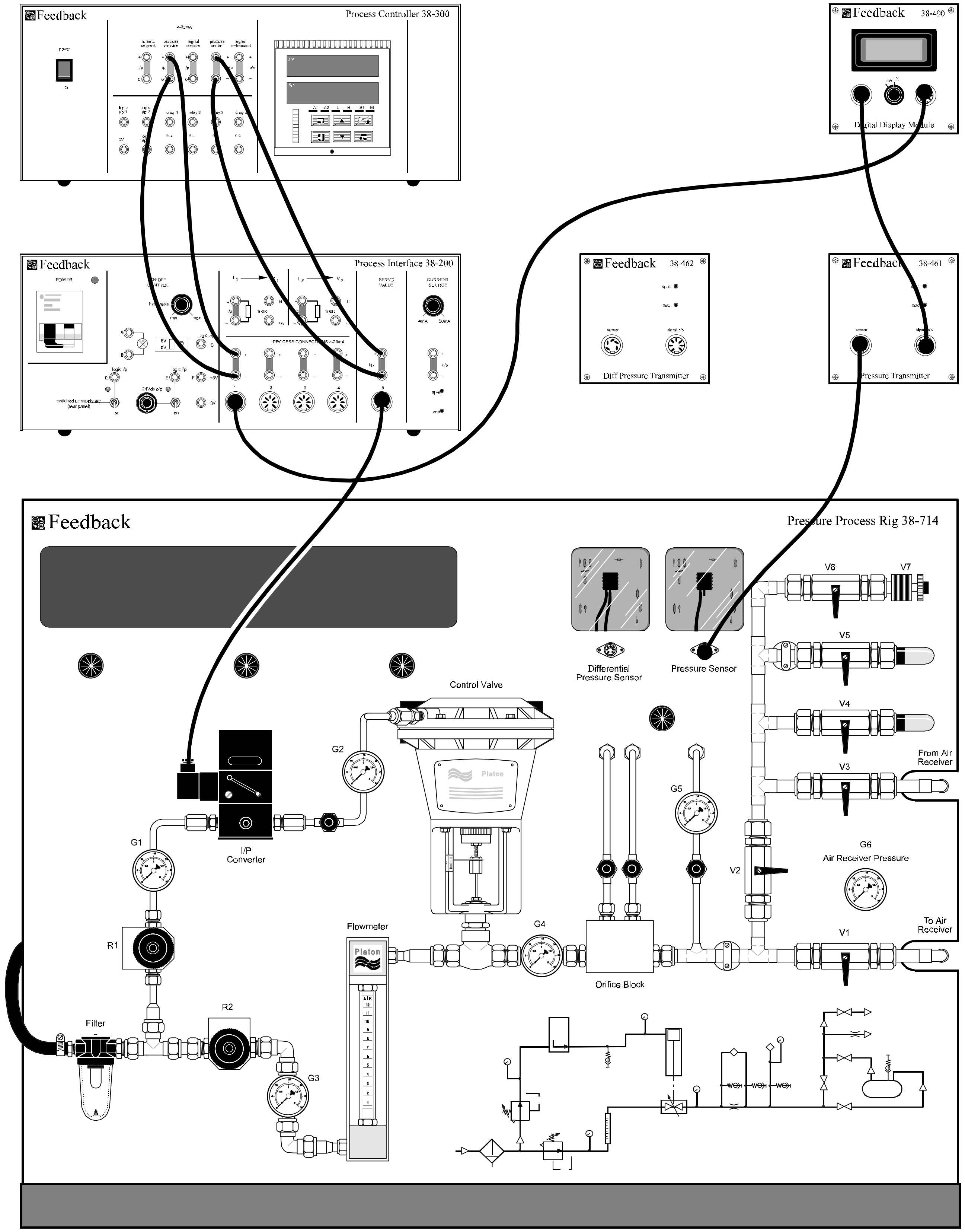

Fig 7 - Experiment 3 Connection Diagram

EXPERIMENT 3

Object of Experiment:

To demonstrate manual operation of the Pneumatic Control Valve and to determine its characteristics (pressure/position).

Equipment Required:

38-200 Process Interface

38-300 Process Controller

38-714 Pressure Process Rig

38-461 Pressure Transmitter

38-490 Digital Display Module

Note: The equipment requires a supply of clean compressed air.

Optional Equipment:

None.

Initial Settings:

Complete the connections shown in Figure 7.

V1, V3 & V6	Closed
R1, R2, V2, V4 & V5	Open

Adjust R1 to give 25psi on gauge G1.

Adjust R2 to give 10 psi on gauge G5 with the Pneumatic Control Valve open.

For this set of demonstrations the controller will be used in Manual operation mode to operate the I/P Converter.

Switch-on the controller. The initial message '300 test' will be seen. After a short time the display begins to show the set-point and process variable ready for normal operation.

The Process Controller is factory calibrated in the following way:

Span 100% represents 20mA input or output

Zero 0% represents 4mA input or output

The Pressure Sensor and Transmitter are calibrated in the following way:

0 psi at G5 produces 4mA from Pressure Transmitter, representing 0% of range

10 psi at G5 produces 20mA from Pressure Transmitter, representing 100% of range

Experimental Details:

The Pneumatic Control Valve comprises a plug type valve operated by a pneumatic actuator which receives a 3 to 15 psi pneumatic signal from a Current to Pressure Converter.

The most useful characteristic of the control valve is the relationship between current input to the I/P Converter and pressure in the process pipe downstream of the valve.

The relationship between current input and corresponding process variable is relevant in control applications.

The aim of this experiment is to demonstrate how the valve may be opened or closed to any intermediate position using a 4-20mA current and to obtain the characteristics of pressure versus position.

Connect the equipment as shown in the set-up diagram.

Set the Process Controller to Manual operation by pressing the Auto/Manual button until the LED marked 'M' lights.

Fully open the Pneumatic Control Valve by manually changing the Process Controller output in the following manner.

Press the Parameter Advance button once to display the control output in the lower screen. The screen should show '`op 0.0`' to show a zero output effort. If it does not, press the Parameter Decrease button to reduce the value to zero.

The Pneumatic Control Valve should now be fully open as the control output is 0%.

Check that the maximum pressure is 100% on the process variable display of the controller (10 psi on gauge G5). If not adjust R2.

Close the Pneumatic Control Valve by setting the controller output to 100% (20mA) by pressing and holding the Parameter Increase button. Check that the process variable falls to 0% (0 psi on gauge G5).

Using the Parameter Increase [▲] and Decrease [▼] buttons, adjust the position of the valve in steps of 10% from 0% to 100% by adjusting the controller output manually.

At each position of the valve record the corresponding pressure on the process variable display.

Repeat the procedure for the valve opening in steps of 10% to determine any hysteresis.

<u>Typical Results</u>:

Controller Output (%)	Process Variable (%)
0	100
10	98
20	95
30	89
40	81
50	71
60	57
70	37
80	21
90	7
100	0

<u>Further Experiments</u>:

To demonstrate the change in characteristic when operated over a different range of pressures

The Pressure Sensor may be recalibrated to operate over a different range, e.g. 0 to 12 psi. However, for the purpose of demonstration, the pressures may be read directly on gauge G5 to avoid the need for recalibration.

Adjust regulator R2 to give a reading of 12 psi on gauge G5 with the Pneumatic Control Valve fully open.

Repeat the above procedure but read the corresponding pressures directly on gauge G5.

Observe the change in characteristic noting that the change from 10 psi to 12 psi operating pressure is a relatively small change.

Conclusions:

The plug-type valve provides a fine adjustment of flow through the valve and is ideal for the purpose of pressure control.

A 4-20mA control signal may be used to open or close a valve to any intermediate position. This facility to operate a valve remotely allows a process to be controlled automatically when the valve is connected to an appropriate sensor and controller.

Although the Pneumatic Control Valve supplied does not have a truly linear characteristic, it is satisfactory for control purposes at the operating pressure suggested. As the pressure is increased, the relationship becomes less linear.

The control valve must be carefully selected to give the correct characteristics over the normal range of operation.

NOTES

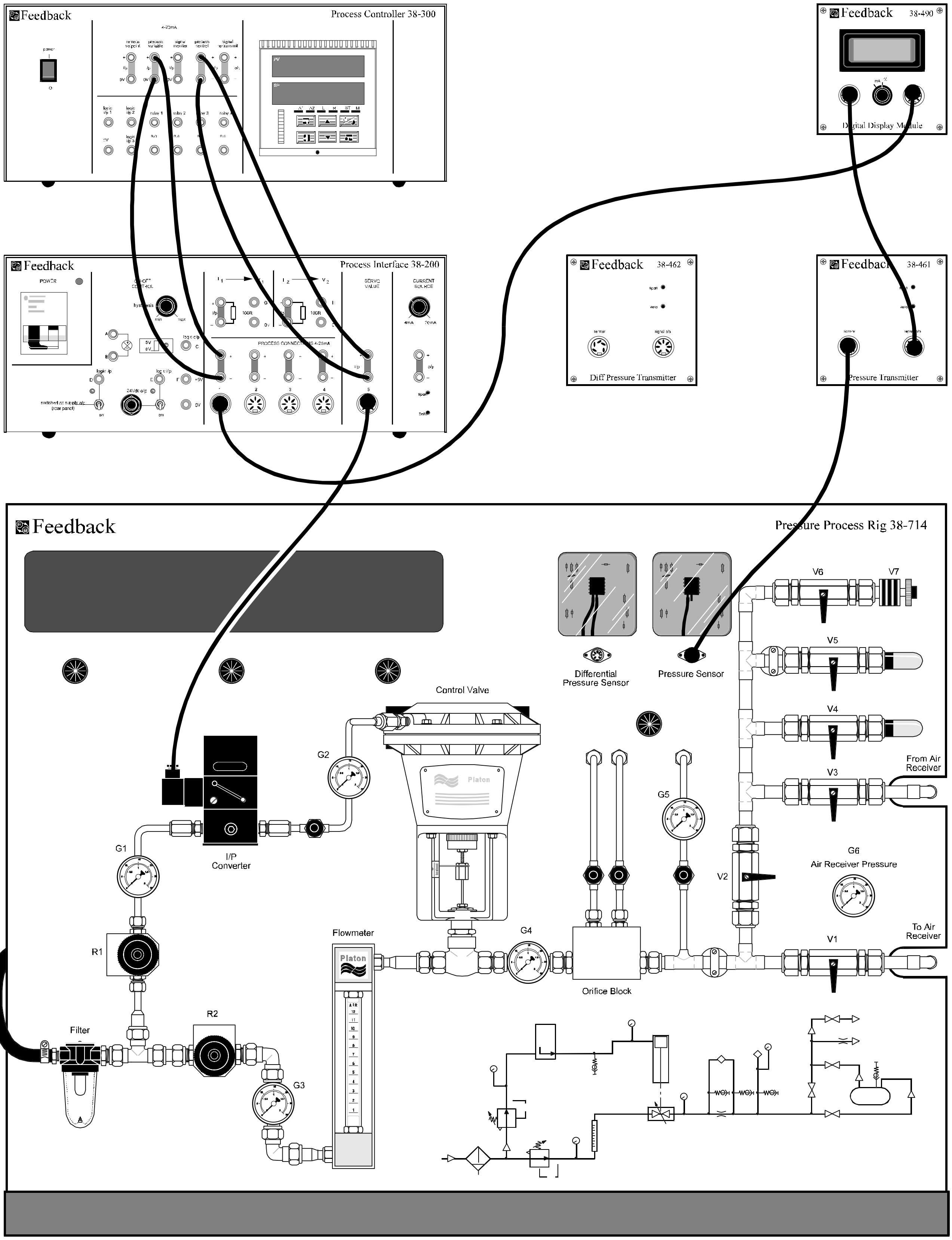

Fig 8 - Experiment 4 Connection Diagram

EXPERIMENT 4

Object of Experiment:

To determine the system response with and without the Air Receiver by manually operating the Pneumatic Control Valve.

Equipment Required:

38-200 Process Interface

38-300 Process Controller

38-714 Pressure Process Rig

38-461 Pressure Transmitter

38-490 Digital Display Module

Note: The equipment requires a supply of clean compressed air.

Optional Equipment:

None.

Initial Settings:

Complete the connections shown in Figure 8.

V1, V3, V5 & V6 Closed

R1, R2, V2 & V4 Open

Adjust R1 to give 25psi on gauge G1.

Adjust R2 to give 10 psi on gauge G5 with Pneumatic Control Valve open.

Switch-on the controller. The initial message '300 test' will be seen. After a short time the display begins to show the set-point and process variable ready for normal operation.

The Process Controller is factory calibrated in the following way:

Span	100% represents 20mA input or output
Zero	0% represents 4mA input or output

The Pressure Sensor and Transmitter are calibrated in the following way:

> 0 psi at G5 produces 4mA from Pressure Transmitter, representing 0% of range.
>
> 10 psi at G5 produces 20mA from Pressure Transmitter, representing 100% of range.

Experimental Details:

Connect the equipment as shown in the set-up diagram.

The current output from the Pressure Transmitter should be connected to the process variable input of the Process Controller to indicate the pressure in the process pipe as measured by the sensor. A chart recorder or the PROCON Discovery Software System 38-906 (if available) should be connected in the Pressure Transmitter output/Process Controller input 4-20mA loop to give a clear indication of the responses. The changes may best be observed by watching the pressure indicated on gauge G5 (the digital changes on the process variable display may be too rapid to observe).

The object of the demonstration is to maintain the pressure of the air in the process pipe at a preset value.

Operation without Air Receiver

Set the Process Controller to manual operation by pressing the Auto/Manual button.

Press the Parameter Advance button to show the controller output in the lower display.

Using the button, adjust the output from the controller to 50% (the lower display will show OP 50.0) and note the corresponding process variable (pressure in the process pipe) when the system has settled.

Change the output from the controller to 60%. Observe the change in process variable.

Change the output from the controller to 50%. Note that the process variable returns to the original value.

Adjust the position of the Pneumatic Control Valve to give a process variable reading of 50%. Note the output from the controller.

Open valve V5 to give additional outflow and observe the response of the process variable.

Readjust the output from the controller to return the process variable to 50%.

Close valve V5 and observe the response of the process variable. Adjust the controller output to its original value and observe that the process variable returns to 50%.

Operation with Air Receiver

Fully open valve V1, open V3 and close valve V2 so that the air leaving the process pipe travels through the Air Receiver before discharging.

Repeat the procedure outlined above and observe the slower changes in response with the Air Receiver in series with the process pipe.

Conclusions:

Proportional adjustment of flow into the process pipe gives a steady pressure at the required value provided the process characteristics remain constant, ie a change in conditions in the system necessitates a corresponding change in valve position to maintain the pressure.

The Pneumatic Control Valve provides proportional adjustment of flow into the process pipe by remote operation using a 3-15 psi control signal.

Without the Air Receiver, disturbances cause the process variable to change very quickly.

With the Air Receiver in series, changes in process variable are much less fast.

The Air Receiver has the effect of changing the response of the process (time constant).

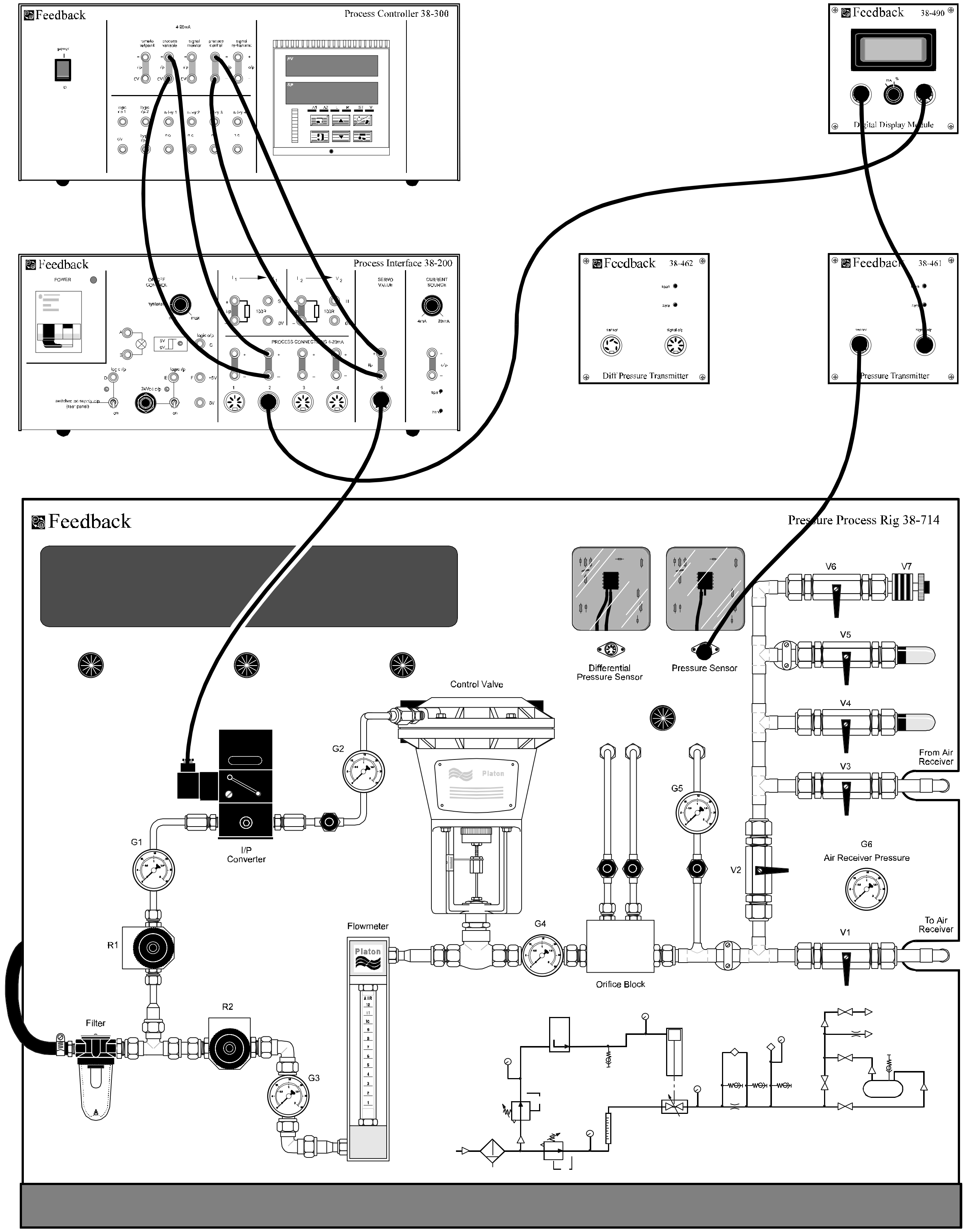

Fig 9 - Experiment 5 Connection Diagram

EXPERIMENT 5

Object of Experiment:

To control pressure in the process pipe using the Pressure Sensor and three-term Process Controller with 4-20mA proportional output to an I/P Converter and Pneumatic Control Valve.

Note: This experiment is intended to introduce and demonstrate the principle of using a proportioning valve. Experiments 6 to 8 introduce the for setting up a Process Controller.

Equipment Required:

38-200 Process Interface

38-300 Process Controller

38-714 Pressure Control Module

38-461 Pressure Transmitter

38-490 Digital Display Module

Note: The equipment requires a supply of clean compressed air.

Initial Settings:

Complete the connections shown in Figure 5.

V2, V5 & V6	Closed
R1, R2, V1, V3 & V4	Open

Adjust R1 to give 25psi on gauge G1.

Adjust R2 to give 10 psi on gauge G5 with Pneumatic Control Valve open. The Air Receiver pressure will begin to rise towards 10psi.

Switch-on the Process Controller. The initial message '300 test' will be seen. After a short time the display begins to show the set-point and process variable ready for normal operation.

This experiment requires that the Process Controller be configured for three-term control.

The following parameters should be set:

Controller Parameter	Setting	Units	
Set Point	50	%	
Proportional Band	300	%	
Integral Time	5	Secs	
Derivative Time	OFF	Secs	
Span	100	%	at 20mA input
Zero	0	%	at 4mA input

The set-point can be assigned by pressing the Up or Down buttons until the lower display shows '50.0'.

The proportional band is assigned by pressing the Page Advance button until the 'Contrl page' display is seen. Press the Parameter Advance button until the proportional band page is reached; 'prop' is shown in the upper display. Change the proportional band value to 300 by pressing the Up or Down buttons. Confirm the change by pressing the Enter button.

The integral time is assigned by pressing the Parameter Advance button whilst in the control page until 'intgrl' is shown in the upper display. Adjust the integral time using the Up or Down buttons until '5' is shown in the lower display. Confirm the change by pressing the Enter button.

The derivative time is assigned by pressing the Parameter Advance button whilst in the control page until 'deriv' is shown in the upper display. Adjust the derivative time using the Up or Down buttons until 'off' is shown in the lower display. Confirm the change by pressing the Enter button.

The span and zero parameters are preset and require no adjustment.

The Pressure Sensor and Transmitter are calibrated in the following way:

0 psi at G5 produces 4mA from Pressure Transmitter, representing 0% of range

10 psi at G5 produces 20mA from Pressure Transmitter, representing 100% of range

Experimental Details:

To maintain a steady pressure in the process pipe, the Pneumatic Control Valve must be opened to the appropriate position by the Process Controller and continually adjusted to compensate for changes upstream or downstream in the system.

The Air Receiver has been included in the circuit to give a slow response to the process. The object of the demonstration is to maintain the pressure at the set point (50% process variable on the controller corresponds to 5psi on gauge G5).

As the Pneumatic Control Valve is open when 4mA is applied to the I/P converter and a pressure below the set point requires the valve to be opened, the Process Controller is configured for DIRECT action. The control action can be checked, and altered if necessary, by pressing the Page Advance button until the display shows 'setup contrl'. Press the Parameter Advance button until the upper display shows 'action'. The lower display will toggle between 'rev' and 'dir' (the required setting) when pressing the Up and Down buttons. Press the Enter button to confirm any change.

Connect the equipment as shown in the set-up diagram.

A recorder may be connected to the Pressure Transmitter output/controller input and controller output/current to pressure converter input 4-20mA loops to provide a record of the response.

If the set-up is correct, air should be delivered to the process pipe and discharge at the outlet with the pressure remaining at 50% (process variable).

Observe that the pressure is controlled at the set point.

Effect of disturbances

Open valve V5 to give an additional outflow from the system.

Observe the response of the system. The Pneumatic Control Valve will open to give the required additional flow of air to maintain the pressure in the process pipe at the set point.

Close valve V5. Observe the response as the Pneumatic Control Valve closes to maintain the pressure.

Observe the changes in air flow on the flow meter.

Further Experiments:

Changing the set point remotely

In the basic set-up, the pressure was controlled about a mean value of 50% which corresponds to 5 psi on gauge G5.

Adjust the set point to 70% on the Process Controller by pressing the Up button.

Observe how the pressure changes to the required setting and the position of the Pneumatic Control Valve varies to suit the conditions.

Adjust the set point to 40% on the Process Controller, by pressing the Down  button.

Once again, observe the changes in the level and the valve operation.

<u>Conclusions</u>:

Pressure in the process pipe can be controlled using a Pressure Sensor and Process Controller configured for proportional output (4-20mA) to position a Pneumatic Control Valve as required.

Proportional control of the Pneumatic Control Valve allows the pressure to be held at the required set point despite changes in the upstream and downstream conditions.

The pressure in the system may be changed by setting an alternative set point on the controller. No adjustment to the process or sensor is required provided the inlet and outlet conditions are compatible with the new setting.

NOTES

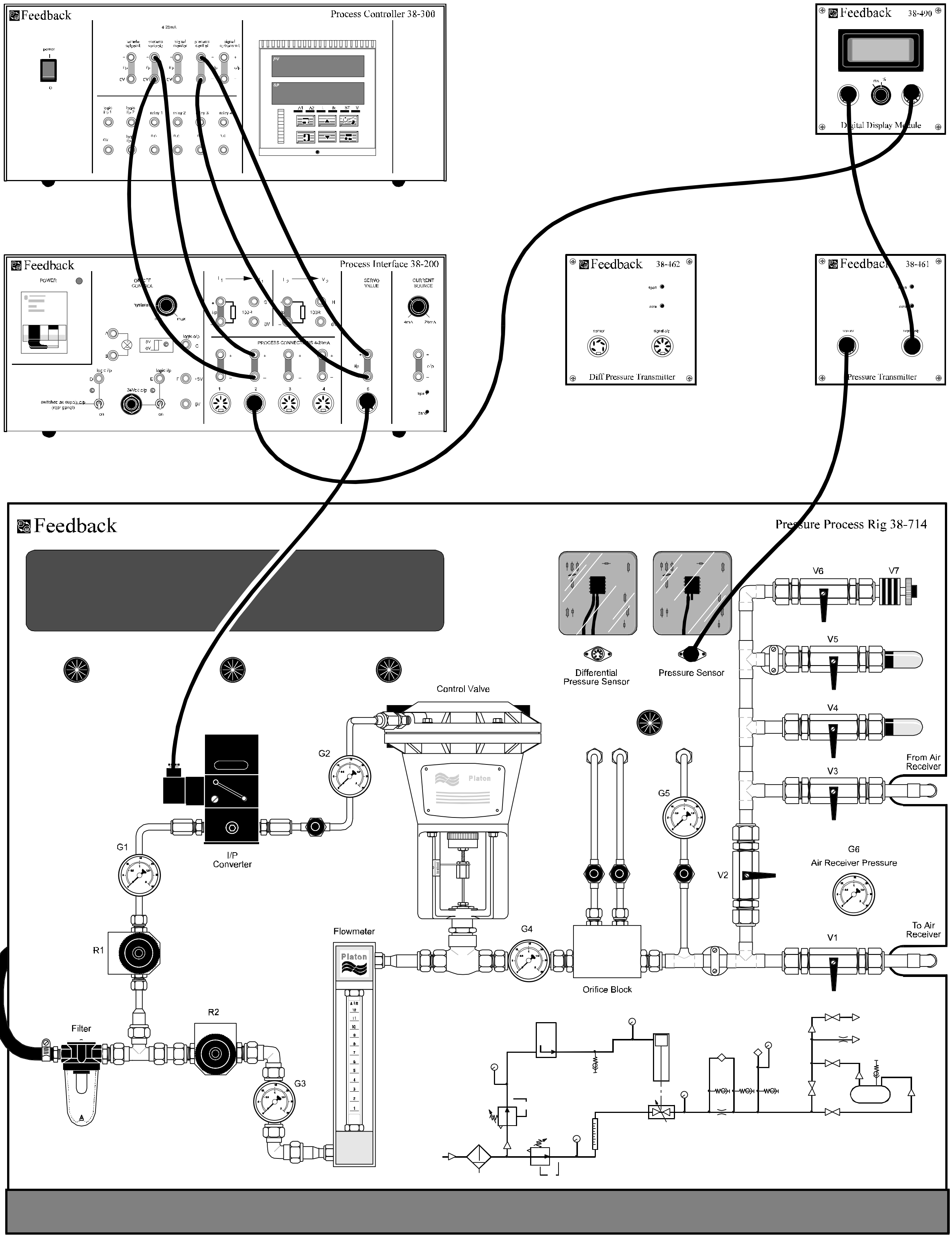

Fig 10 - Experiment 6 Connection Diagram

EXPERIMENT 6

Object of Experiment:

To demonstrate the characteristics of a (P) Proportional only Process Controller and the response to a change in set point or a disturbance in the process.

Note: It is assumed that the operator understands the meaning of Proportional Band.

Equipment Required:

38-200 Process Interface

38-300 Process Controller

38-714 Pressure Control Module

38-461 Pressure Transmitter

38-490 Digital Display Module

Note: The equipment requires a supply of clean compressed air.

Optional Equipment:

None.

Initial Settings:

Complete the connections shown in Figure 10.

V1, V3, V5 & V6	Closed
R1, R2, V2 & V4	Open

Adjust R1 to give 25 psi on gauge G1.

Adjust R2 to give 10 psi on gauge G5 with Pneumatic Control Valve open.

For this set of demonstrations the Process Controller should be configured for proportional control with the following initial settings:

Controller Parameter	Setting	Units	
Set Point	40	%	
Proportional Band	300	%	Check value
Integral Time	OFF	Secs	
Reset	50	%	
Derivative Time	OFF	Secs	
Span	100	%	at 20mA input
Zero	0	%	at 4mA input

The set-point can be assigned by pressing the Up or Down buttons until the lower display shows '50.0'.

The proportional band is assigned by pressing the Page Advance button until the 'Contrl page' display is seen. Press the Parameter Advance button until the proportional band page is reached; 'prop' is shown in the upper display. Change the proportional band value to 300 by pressing the Up or Down buttons. Confirm the change by pressing the Enter button.

The integral time is assigned by pressing the Parameter Advance button whilst in the control page until 'intgrl' is shown in the upper display. Adjust the integral time using the Up or Down buttons until 'off' is shown in the lower display. Confirm the change by pressing the Enter button.

The derivative time is assigned by pressing the Parameter Advance button whilst in the control page until 'deriv' is shown in the upper display. Adjust the derivative time using the Up or Down buttons until 'off' is shown in the lower display. Confirm the change by pressing the Enter button.

The span and zero parameters are preset and require no adjustment.

The Pressure Sensor and Transmitter are calibrated in the following way:

0 psi at G5 produces 4mA from Pressure Transmitter, representing 0% of range

10 psi at G5 produces 20mA from Pressure Transmitter, representing 100% of range

Experimental Details:

The object of the demonstration is to control the pressure in the process pipe using a P' only controller to operate the Pneumatic Control Valve.

As the Pneumatic Control Valve is open when 4mA is applied to the I/P Converter and a pressure below set point requires the valve to be opened, the controller must be configured for DIRECT action. The control action can be checked, and altered if necessary, by pressing the Page Advance button until the display shows 'setup contrl'. Press the Parameter Advance button until the upper display shows 'action'. The lower display will toggle between 'rev' and 'dir' (the required setting) when pressing the Up and Down buttons. Press the Enter button to confirm any change.

Connect the equipment as shown in the set-up diagram.

A recorder may be connected to the Pressure Transmitter output/Controller input and Controller output/Current to Pressure Converter input 4-20mA loops to provide a record of the response.

Removing offsets

The controller fitted in the 38-300 has an option for the removal of offsets in proportional only systems. This option is known as manual reset and allows the operator to reduce the offsets to zero by offsetting the proportional band between 0 and 100% in 0.1% increments.

The Manual reset option will only function when no integral action has been selected.

We need to consider how the manual reset function operates.

Ensure the Integeral and Derivative options are turned off.

Set the Proportional Band to 300% and set the setpoint to 50%.

On the process rig set valves V1, V3 and V6 to closed and valves V2, V4 and V5 to open.

From the operating panel of the controller select the manual reset option by pressing the Paramater Advance twice. The lower display shows the character r followed by the current value of manual reset. The top display shows the measured value of the process variable, in this case the pressure at gauge G5.

Adjust the manual reset option until the measured value is 50%, hence there is no offset. This should be till about 38% of normal reset.

Change the set point to 40% and observe the effect on offset. Notice the offset has returned. Hence we have shown the manual reset option only reduces the offset for a given setpoint. Moving the setpoint requires the operator to make an adjustment to the amount of normal reset.

Return the setpoint to 50% and observe the offset is removed using the proceedure previouly outlined.

Close valve V4 and observe the effect on the offset. Adjust the manual reset until the offset is reduced to zero. This should be around 21%. Hence we have shown that when there is a change in demand in the process the controller requires manual adjustment to reduce the offset in a Proportional only system.

Reduce the Proportional Band to 200% and observe the effect on the offset. Notice the offset is unaffected by the changed PB.

Reduce the PB to 100% and open valve V4 to introduce a step response on the system. Observe the oscillating response from the process. It takes around 20 seconds to settle. Increase the PB to 400% and close valve V4. Once the system has settled, open valve V4. Notice how less oscillatory the process is.

Effect of disturbances

Open valve V3 a little more to give a disturbance to the process.

Observe the response of the system. The Pneumatic Control Valve will open to give additional inflow to maintain the pressure at the set point.

Observe the offset from the set point.

Return valve V4 to its original position. Observe the response as the Pneumatic Control Valve closes to maintain the pressure. Observe that the pressure returns to the set point.

Effect of changing the set point

Adjust the set point to 70% on the Process Controller.

The Pneumatic Control Valve will open to increase the flow into the process pipe to compensate for the increased pressure requirement. Observe that the pressure does not achieve the revised set point.

Adjust the set point to 30% on the Process Controller. Once again, observe the changes in the pressure and the valve operation.

Adjust the set point to 50% on the Process Controller.

Observe that the pressure returns to the set point.

Adjust the set point to 70% on the Process Controller.

Manually adjust output from the controller to maintain the process variable at 70%.

Return the controller to Automatic operation and observe that offset from the set point is removed.

Adjust the set point to 50% on the Process Controller.

Observe that the process variable is offset from the set point.

Further Experiments:

Effect of changing the Proportional Band:

Set the Proportional Band to 20% on the controller. Repeat the above experiment and observe the reduction in offsets.

Set the Proportional Band to 5% on the controller. Repeat the above experiment and observe the dramatic reduction in offsets.

Set the Proportional Band to 1% on the controller. Observe that the process has become unstable, ie the Proportional Band setting is too small.

Conclusions:

As the process variable deviates from the set point, the output from the controller will change in an attempt to restore the process variable to the set point.

A small setting of Proportional Band means a large change in controller output (large movement of the valve) for a small deviation from the set point.

If the setting of the Proportional Band is too small, the control loop will be unstable and continuous large scale oscillation of the control valve will occur.

If the setting of the Proportional Band is too large, the process variable will be offset from the set point by a large amount.

The controller centralises the Proportional Band about the set point. If a new set point is instructed by the operator, the controller will produce an output of 50% (12mA) when the process variable matches the new set point.

The operator can offset the output to give accurate control of the process by setting the system up manually before transferring to Automatic control. Any changes in the process (e.g. change in outflow from the process tank) will result in an offset from the set point. Any offset applied to the controller output will be transferred if a new set point is instructed, ie the output will be centralised about the new set point but offset by the amount of offset at the previous set point.

The optimum setting of Proportional Band is the smallest setting which will allow the process to operate with minimum offset while not allowing the system to become unstable.

The process should be operated manually to achieve the required operating conditions then transferred to Automatic operation to minimise offsets from the set point.

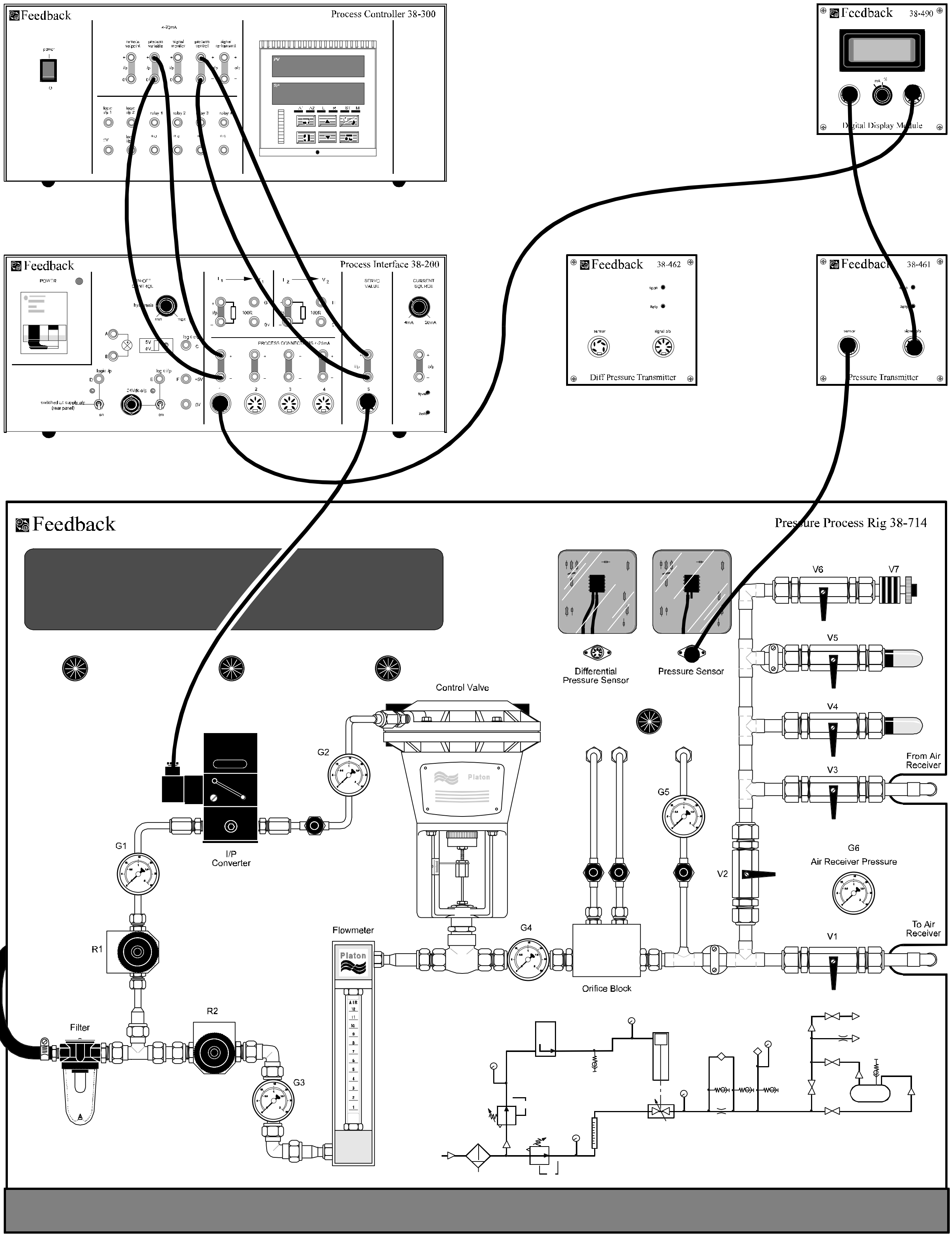

Fig 11 - Experiment 7 Connection Diagram

EXPERIMENT 7

Object of Experiment:

To demonstrate the characteristics of a (P + I) Proportional + Integral Action Process Controller and the response to a change in set point or a disturbance to the process.

Note: It is assumed that the operator understands the meaning of Proportional Band and Integral Action.

Equipment Required:

38-200 Process Interface

38-300 Process Controller

38-714 Pressure Control Module

38-461 Pressure Transmitter

38-490 Digital Display Module

Note: The equipment requires a supply of clean compressed air.

Initial Settings:

Complete the connections shown in Figure 11.

V1, V3 & V6	Closed
R1, R2, V2, V4 & V5	Open

Adjust R1 to give 25psi on G1.

Adjust R2 to give 10psi on G5 with the Pneumatic Control Valve open.

For this set of demonstrations the Process Controller should be configured for three-term control with the following initial settings:

Controller Parameter	Setting	Units	
Set Point	50	%	
Proportional Band	300	%	
Integral Time	5	Secs	
Derivative Time	OFF	Secs	
Span	100	%	at 20mA input
Zero	0	%	at 4mA input

Follow the instructions given in earlier experiments regarding operation of the Process Controller. Further information can be found in the Process Controller user manual.

The Pressure Sensor and Transmitter are calibrated in the following way:

0 psi at G5 produces 4mA from Pressure Transmitter, representing 0% of range

10 psi at G5 produces 20mA from Pressure Transmitter, representing 100% of range

Experimental Details:

The object of the demonstration is to control the pressure in the process pipe using a 'P+I' controller to operate the Pneumatic Control Valve.

As the Pneumatic Control Valve is open when 4mA is applied to the current/pressure converter and a pressure below the set point requires the valve to be opened, the Process Controller is configured for DIRECT action. See the instructions given in earlier experiments regarding setting the controller for direct or reverse action.

Connect the equipment as shown in the set-up diagram.

A recorder or the 38-906 Software running on a suitable computer may be connected to the Pressure Transmitter output/controller input and controller output/current to pressure converter input 4-20mA loops to provide a record of the response.

Note: The controller is set for 300% Proportional Band and 5 secs Integral Action Time.

Effect of disturbances

Allow the system to settle with no deviation.

Close valve V4 further to give a disturbance to the process.

Observe the response of the system. The Pneumatic Control Valve will close to reduce the pressure at the set point. Observe that the initial offset from the set point is gradually removed as the Integral Action moves to the required position. Now open V4 and observe the system responding by increasing the air flow until the pressure is returned to the setpoint.

Effect of changing the set point

Adjust the set point to 70% on the Process Controller.

Observe the initial response due to Proportional Action followed by the gradual correction due to Integral Action.

Adjust the set point to 30% on the Process Controller. Once again, observe the changes in the pressure and the valve operation.

Adjust the set point to 50% on the Process Controller and allow the process to settle at the set point.

Further Experiments:

Effect of changing the Integral Action Time

Set the Integral Action Time to 1 second on the controller.

Repeat the above experiment and observe the reduced effect of the Integral Action (the effect is the same but the time taken to reduce the offset is decreased).

Effect of changing the Proportional Band

Set the Proportional Band to 200% and the Integral Action to 5 seconds on the controller.

Apply a disturbance to the process or change the set point as described above and observe the response of the process.

Besides the reduced offset due to Proportional Action observe that the amount of correction applied by Integral Action is increased.

Open valves V1 & V3 and close V2 to connect the air receiver. Observe the effect of this while repeating the above.

Conclusions:

Integral Action will remove offsets from the set point which occur with Proportional control.

Correction is applied to the output from the controller while any deviation from the set point exists.

A short setting of Integral Action Time means greater Integral Action effect on the output from the controller. (The output is corrected more frequently).

The amount of correction applied to the output by the Integral Action is related to the Proportional Band setting. (A large Proportional Band means a smaller correction due to the Integral Action).

Increasing the time constant of the system makes the process more oscillatory and increases the setting time.

Note: Short settings of the Integral Action Time can be used in the pressure control demonstration to give fast correction of large offsets because the system responds quickly to changes. In a process where disturbances take a long time to affect the process variable, the amount of Integral Action must be limited (ie use longer Integral Action Time) to avoid problems of saturation. If the IAT setting is too small, extreme actuation of the control valve will occur before the process has responded to initial valve adjustments. 38-100 and 38-600 involve processes with longer response times and may be used to demonstrate this feature.

NOTES

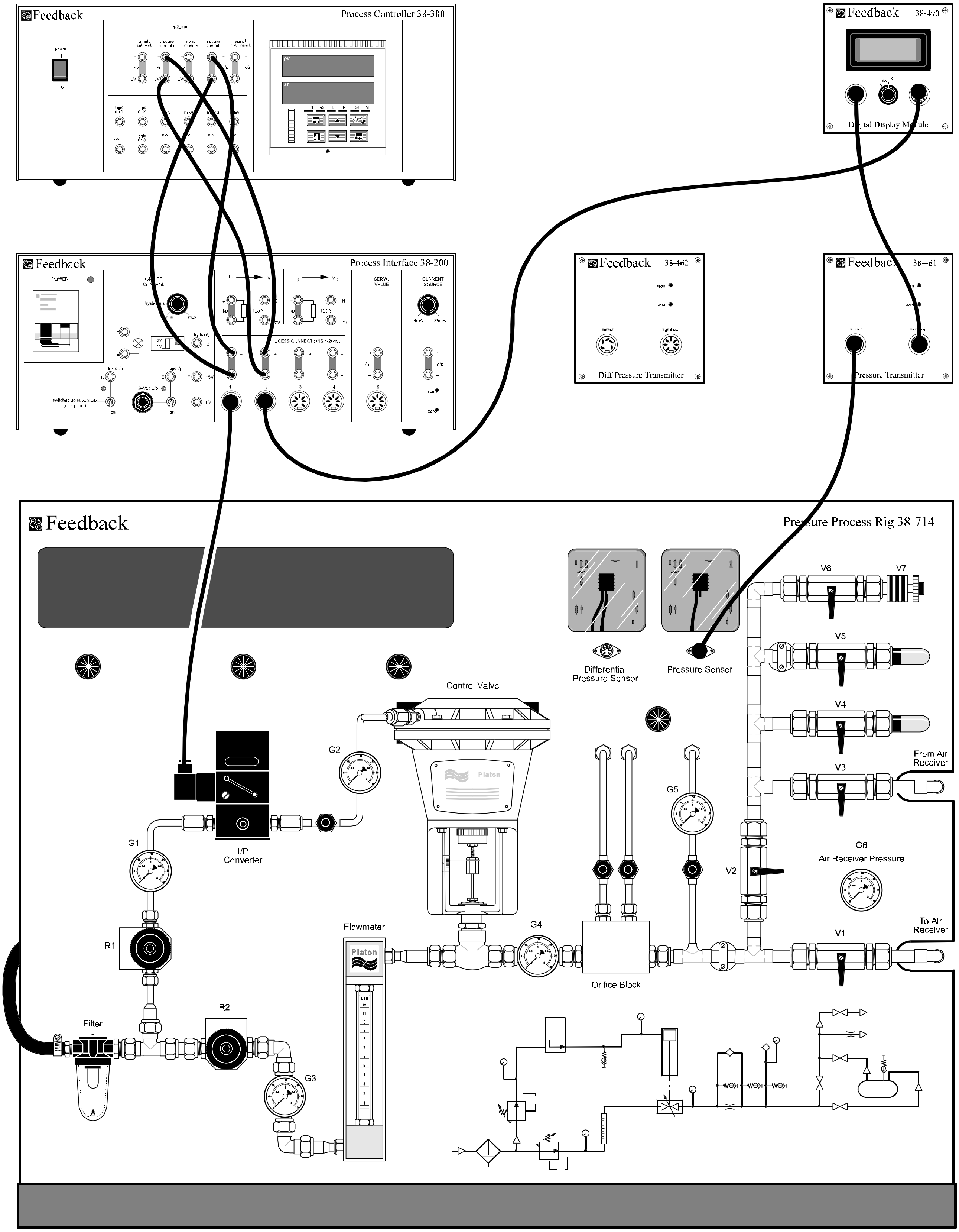

Fig 12 - Experiment 8 Connection Diagram

EXPERIMENT 8

Object of Experiment:

To demonstrate the characteristics of a (P + D) Proportional + Derivative Action Process Controller and the response to a change in set point or a disturbance to the process.

Note: It is assumed that the operator understands the meaning of Proportional Band and Derivative Action.

Equipment Required:

38-200 Process Interface

38-300 Process Controller

38-714 Pressure Control Module

38-461 Pressure Transmitter

38-490 Digital Display Module

Note: The equipment requires a supply of clean compressed air.

Initial Settings:

Complete the connections shown in Figure 12.

V1, V3 & V6	Closed
R1, R2, V2, V4 & V5	Open

Adjust R1 to give 25psi on G1.

Adjust R2 to give 10psi on G5 with the Pneumatic Control Valve open.

For this set of demonstrations the Process Controller should be configured for three-term control with the following initial settings:

Controller Parameter	Setting	Units	
Set Point	50	%	
Proportional Band	300	%	
Integral Time	OFF	Secs	
Derivative Time	2	Secs	
Span	100	%	at 20mA input
Zero	0	%	at 4mA input

Follow the instructions given in earlier experiments regarding operation of the Process Controller. Further information can be found in the Process Controller user manual.

The Pressure Sensor and Transmitter are calibrated in the following way:

0 psi at G5 produces 4mA from Pressure Transmitter, representing 0% of range

10 psi at G5 produces 20mA from Pressure Transmitter, representing 100% of range

<u>Experimental Details</u>:

The object of the demonstration is to control the pressure in the process pipe using a 'P+D' controller to operate the Pneumatic Control Valve.

As the Pneumatic Control Valve is open when 4mA is applied to the current/pressure converter and a pressure below the set point requires the valve to be opened, the Process Controller is configured for DIRECT action. See the instructions given in earlier experiments regarding setting the controller for direct or reverse action.

Connect the equipment as shown in the set-up diagram.

A recorder may be connected to the Pressure Transmitter output/controller input and controller output/current to pressure converter input 4-20mA loops to provide a record of the response.

Note: The controller is set for a 50% Proportional Band and a Derivative Action Time of 6 seconds.

Manual operation to remove initial offsets

Carry out the procedure for removal of offsets detailed on page 6-6-3.

Effect of disturbances

Close valve V4 further to give a disturbance to the process. Observe the response of the system as the Pneumatic Control Valve closes to reduce the pressure at the set point. Observe the large initial closing of the control valve occurs as the process variable moves away from the set point followed by an opening of the valve as the process variable approaches the set point. Note that the offset from the set point is not removed by the Derivative Action.

Return valve V4 to its initial position. Observe the response as the Pneumatic Control Valve opens to maintain the pressure. Observe that the large movements of the control valve as the process variable moves away from and towards the set point.

Effect of changing the set point

Adjust the set point to 70% on the Process Controller.

Observe the initial response due to Derivative Action followed by the conventional response due to the Proportional action. Note once again that the deviation from the set point is not corrected.

Adjust the set point to 30% on the Process Controller. Once again, observe the changes in the pressure and the valve operation.

Further Experiments:

Effect of changing the Derivative Time:

Adjust the Derivative Action Time in steps of 1 until the process becomes unstable. This will happen at a setting of 8 or 9.

Repeat the above experiment at each step and observe the increased effect of the Derivative Action (the effect is the same but the time taken for the valve to return to the position dictated by the Proportional setting is increased).

Effect of changing the Proportional Band

Set the Proportional Band to 20% on the controller. Set the Derivative Action Time to 6 seconds.

Apply a disturbance to the process by opening valves V6 and V7 or change the set point.

Besides the reduced offset due to Proportional Action observe that the amount of correction applied by Derivative Action is increased.

Conclusions:

Derivative Action cannot reduce offsets from the set point which result with Proportional control.

Correction is applied to the output from the controller whenever the process variable is changing. (The faster the process variable changes, the larger the amount of correction due to Derivative Action).

A short setting of Derivative Action Time means less Derivative Action effect on the output of the controller. (Any correction applied to the output lasts for a shorter period of time).

The amount of correction applied to the controller output by the Derivative Action is related to the proportional Band setting. (A large Proportional Band means a smaller correction due to the Derivative Action).

Note: Short settings of the Derivative Time may be applied to this pressure process for the purpose of demonstration provided the setting of the Proportional Band is not too small. If the Derivative Time setting is too long, the corrections to the control valve will be excessive and the process will be unstable. Derivative Action is usually applied to processes which have a slow reaction rate, moderate lags and small changes in load to the process. The large initial correction to the control valve allows the process to stabilise more quickly. The 38-100 Basic Process Rig and 38-600 Temperature Process Rig involve processes with longer response times and may be used to demonstrate this feature.

NOTES

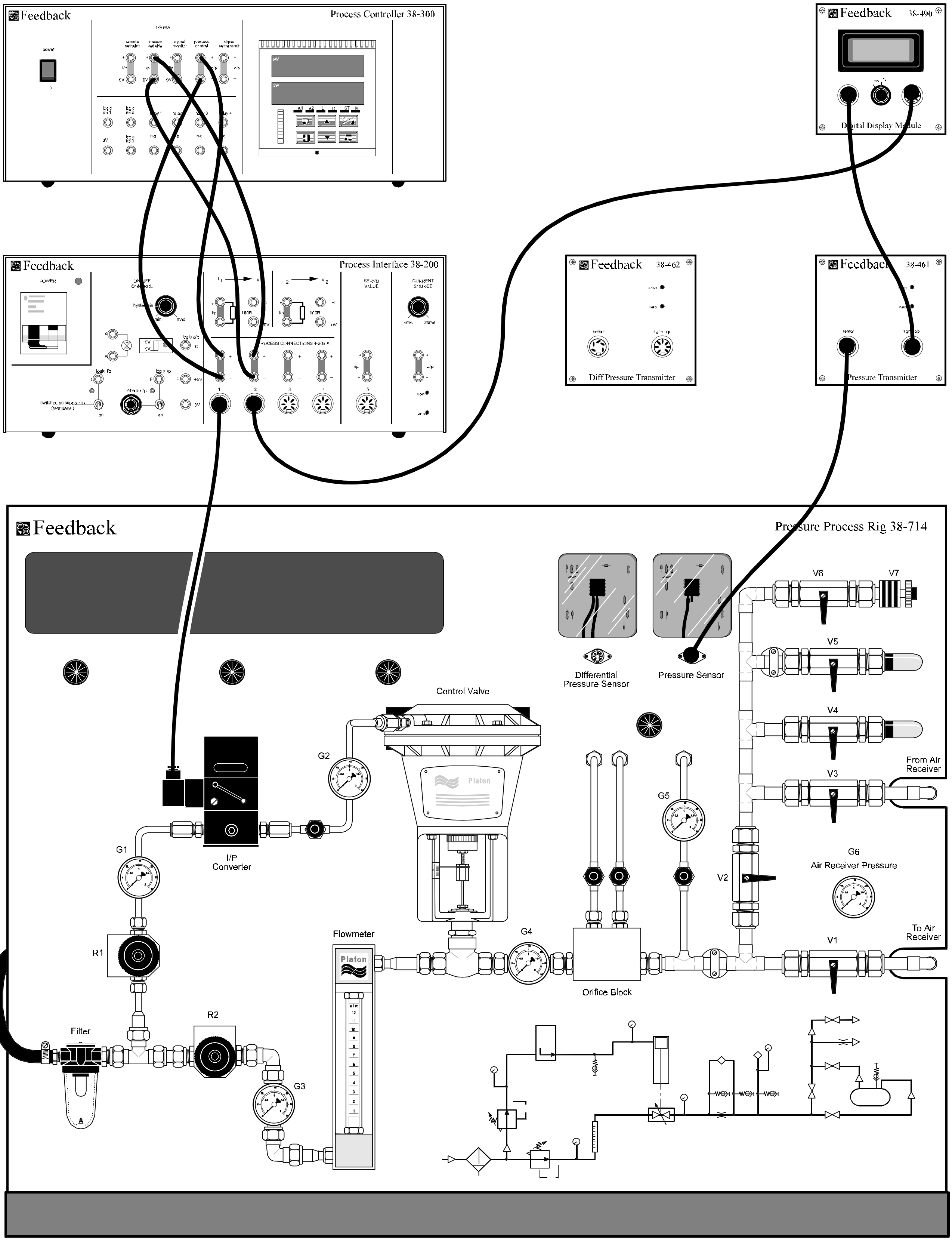

Fig 13 - Experiment 9 Connection Diagram

EXPERIMENT 9

Object of Experiment:

To demonstrate typical procedures for optimising the settings of a three-term controller to suit a particular process.

When selecting the settings for a three-term controller, consideration must be given to those characteristics of the process which affect its controllability. These are load changes (how large and how fast), process lags (capacity lags and resistance lags), process reaction lags, response lags of sensors etc. and dead time.

The object of this experiment is to use one of the widely used field methods for optimising the P, I and D settings on the controller to suit the characteristics of the process. In this instance the Ultimate Period/Ziegler-Nichols (closed loop) and Reaction Curve (open loop) methods will be used.

Equipment Required:

38-200 Process Interface

38-300 Process Controller

38-714 Pressure Control Module

38-461 Pressure Transmitter

38-490 Digital Display Module

Chart Recorder (not supplied)

Note: The equipment requires a supply of clean compressed air.

Initial Settings:

Complete the connections shown in Figure 13.

V1, V3 & V6	Closed
R1, R2, V2, V4 & V5	Open

Adjust R1 to give 25 psi on G1.

Adjust R2 to give 10 psi on G5 with V2 open and V4 closed.

For this set of demonstrations the Process Controller should be configured for Proportional control with the following initial settings:

Controller Parameter	Setting	Units	
Set Point	50	%	
Proportional Band	300	%	
Integral Time	OFF	Secs	
Derivative Time	OFF	Secs	
Span	100	%	at 20mA input
Zero	0	%	at 4mA input

Follow the instructions given in earlier experiments regarding operation of the Process Controller. Further information can be found in the Process Controller user manual.

The Pressure Sensor and Transmitter are calibrated in the following way:

0 psi at G5 produces 4mA from Pressure Transmitter, representing 0% of range

10 psi at G5 produces 20mA from Pressure Transmitter, representing 100% of range

Experimental Details:

Connect the equipment as shown in the set-up diagram. A recorder must be connected to the Pressure Transmitter output/controller input and controller output/current to pressure converter input 4-20mA loops to provide a record of the process response.

ULTIMATE PERIOD METHOD (Ziegler-Nichols)

Data for the analysis is obtained using the controller configured for Proportional control only.

Ensure that the Integral and Derivative settings on the controller are turned off.

Allow the process variable to settle then apply a step change to the process by closing valve V4.

As the process variable remains steady, decrease the Proportional Band and re-apply a step change (by closing V4).

Continue adjusting the Proportional Band and applying a step change until the process variable continually oscillates. Note the setting of the Proportional Band at which continual cycling occurs. From the trace obtained on the recorder measure the Period of the oscillation Pc in minutes.

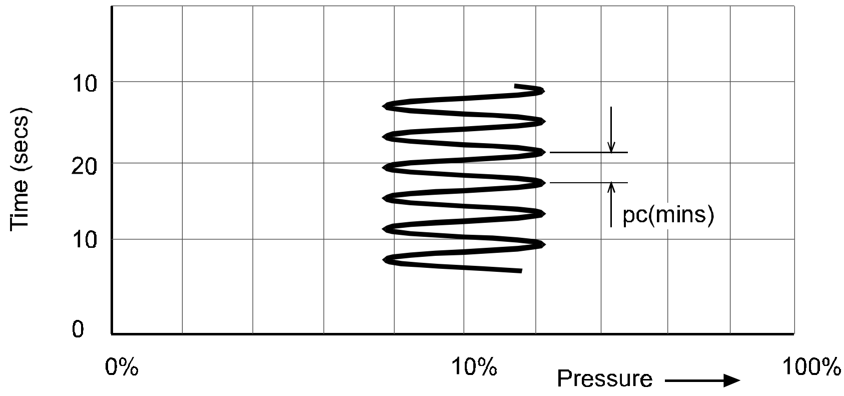

Fig 9.1

Typical response obtained using 38-200 and 38-300 Process Interface and Controller.

The optimum settings for the controller may be calculated as follows:

P only	PB = 2	PBc		
P + I	PB = 2.2	PBc	IAT = 0.83 Pc	
P + I + D	PB = 1.7	PBc	IAT = 0.50 Pc	DAT = 0.13 Pc

REACTION CURVE METHOD

Set the controller for Manual operation.

Adjust the output from the controller to give a steady pressure in the system with the process variable display showing 50%.

Leave the controller in Manual operation and apply a step disturbance to the process by changing the position of the Pneumatic Control Valve slightly. Note the step change applied (M%).

The step change will result in a new pressure in the system. The open loop response may be analysed from the trace on the recorder to determine the optimum settings for P, I & D.

A typical response curve is shown below.

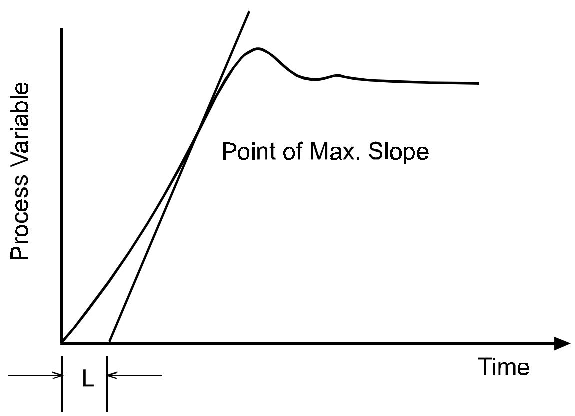

Fig 9.2

Draw a straight line through the point of maximum slope so that the line intersects the time axis.

Measure the dead time L in minutes. (Time at which step change is applied to time where straight line intersects time axis).

Calculate the maximum slope R.

Determine R1 using the equation $R1 = \frac{R}{\Delta M}$

The optimum settings for the controller may be calculated as follows:

P only	PB = R1 x L		
PI	PB = 1.1 (R1 x L)	IAT= 3.0 L	
PID	PB = 0.5 (R1 x L) to 0.8 (R1 x L)	IAT= 2.0 L to2.5 L	DAT=0.3 L to0.5 L

Compare the values obtained with those obtained using the Zieglar-Nichols method.

<u>Further Experiments</u>:

Evaluation of the controller settings by applying a disturbance to the process

Enter the settings of P, I and D to be evaluated on the Process Controller. Set the set point to 50%.

Set the controller to Manual operation and adjust the valve position to maintain the required set point (50% process variable, 4 psi on G5). Set the controller to Automatic operation then apply a disturbance by opening valve V4. Observe the behaviour of the process.

Repeat the procedure for the settings of the controller suggested by the other technique.

<u>Conclusions</u>:

Techniques exist which allow the settings of a three-term controller to be determined to suit a particular process.

The settings predicted by these techniques will differ and should be treated as a starting condition for the setting up of the controller. Satisfactory control may be obtained from these settings but the commissioning engineer may need to make fine adjustments to obtain the required operating characteristics.

NOTES

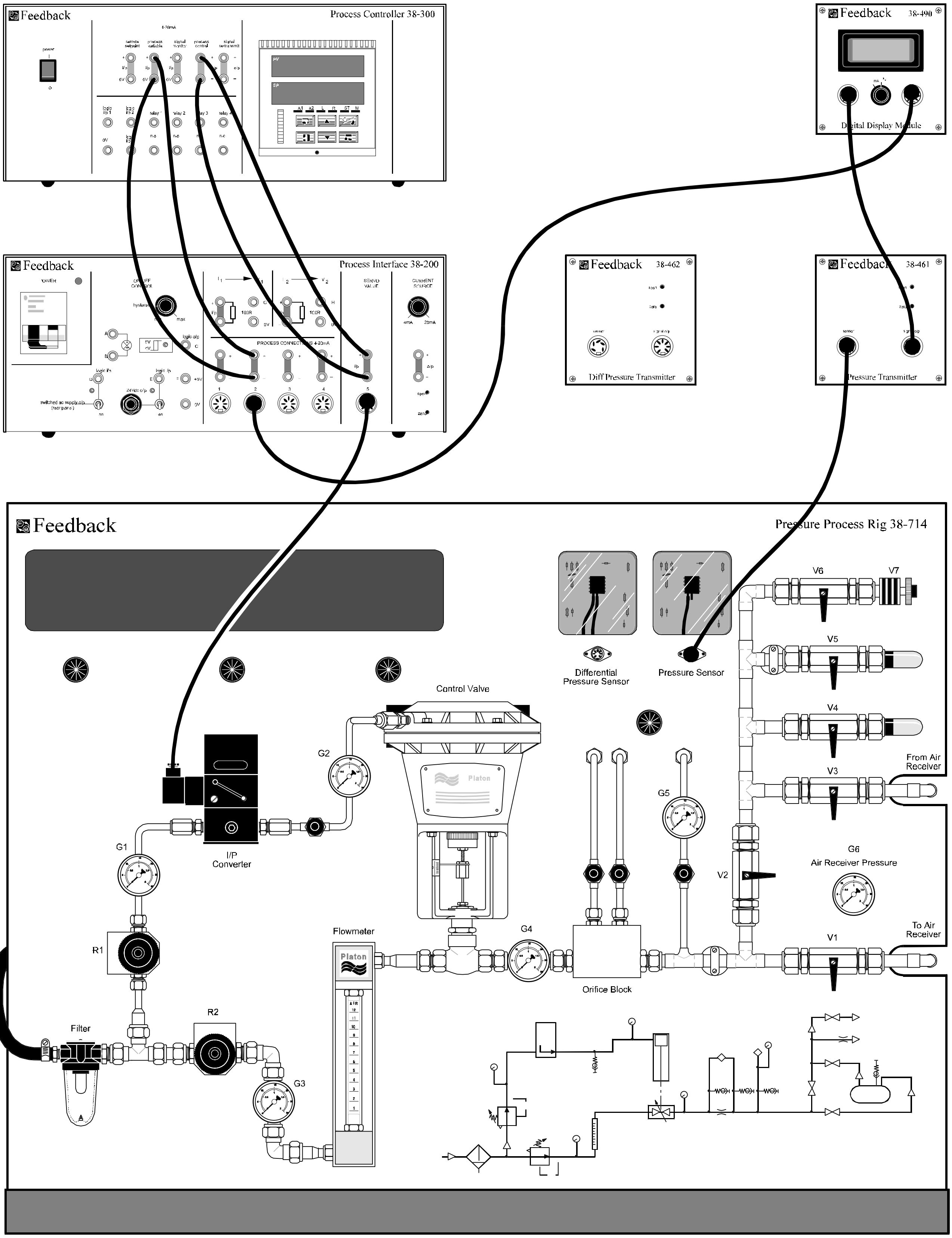

Fig 14 - Experiment 10 Connection Diagram

EXPERIMENT 10

Object of Experiment:

To demonstrate the effect of the Air Receiver on the response of the process and to determine the optimum settings for the Process Controller.

Equipment Required:

38-200 Process Interface

38-300 Process Controller

38-714 Pressure Control Module

38-461 Pressure Transmitter

38-490 Digital Display Module

Note: The equipment requires a supply of clean compressed air.

Initial Settings:

Complete the connections shown in Figure 14.

V2 & V6 Closed

R1, R2, V1, V2, V4 & V5 Open

Adjust R1 to give 25 psi on G1.

Adjust R2 to give 10 psi on G5 with the Pneumatic Control Valve open.

For this set of demonstrations the Process Controller should be configured for three-term control with the following initial settings:

Controller Parameter	Setting	Units	
Set Point	50	%	
Proportional Band	50	%	
Integral Time	12	Secs	
Derivative Time	OFF	Secs	
Span	100	%	at 20mA input
Zero	0	%	at 4mA input

Follow the instructions given in earlier experiments regarding operation of the Process Controller. Further information can be found in the Process Controller user manual.

The Pressure Sensor and Transmitter are calibrated in the following way:

0 psi at G5 produces 4mA from Pressure Transmitter, representing 0% of range

10 psi at G5 produces 20mA from Pressure Transmitter, representing 100% of range

Experimental Details:

Connect the equipment as shown in the set-up diagram with the Air Receiver in series with the process pipe.

A recorder may be connected to the Pressure Transmitter output/controller input and controller output/current to pressure converter input 4-20mA loops to provide a record of the response.

As the Pneumatic Control Valve is open when 4mA is applied to the I/P Converter and a pressure below set point requires the valve to be opened, the Process Controller is configured for DIRECT action.

Observe the response of the system when valve V4 is opened and closed to give a disturbance.

Isolate the Air Receiver from the process pipe by opening V2 and closing V1 and V3.

Apply a disturbance to the new configuration and observe the change in response.

Further Experiments:

Determining optimum settings for the Process Controller

Using the techniques described in Experiment 9, determine the optimum settings for the three-term controller to suit the two systems. Apply the optimum settings for each system and evaluate the response of both systems using valve V4 to apply a step change to the outflow from the system. Observe that the process becomes unstable if the settings relating to the Air Receiver in series are applied to the process without the Air Receiver.

Conclusions:

The addition of the Air Receiver makes the response of the system correspondingly slower. (Pressure cannot change as quickly in the process pipe when a disturbance occurs or a new set point is instructed).

Any change in the response of a process will necessitate a change in the settings of the three terms on the controller to achieve optimum control.

Where the response of a process will change in operation, the controller must be configured to give stable control under all operating conditions. This may necessitate a reduction in performance at some conditions.

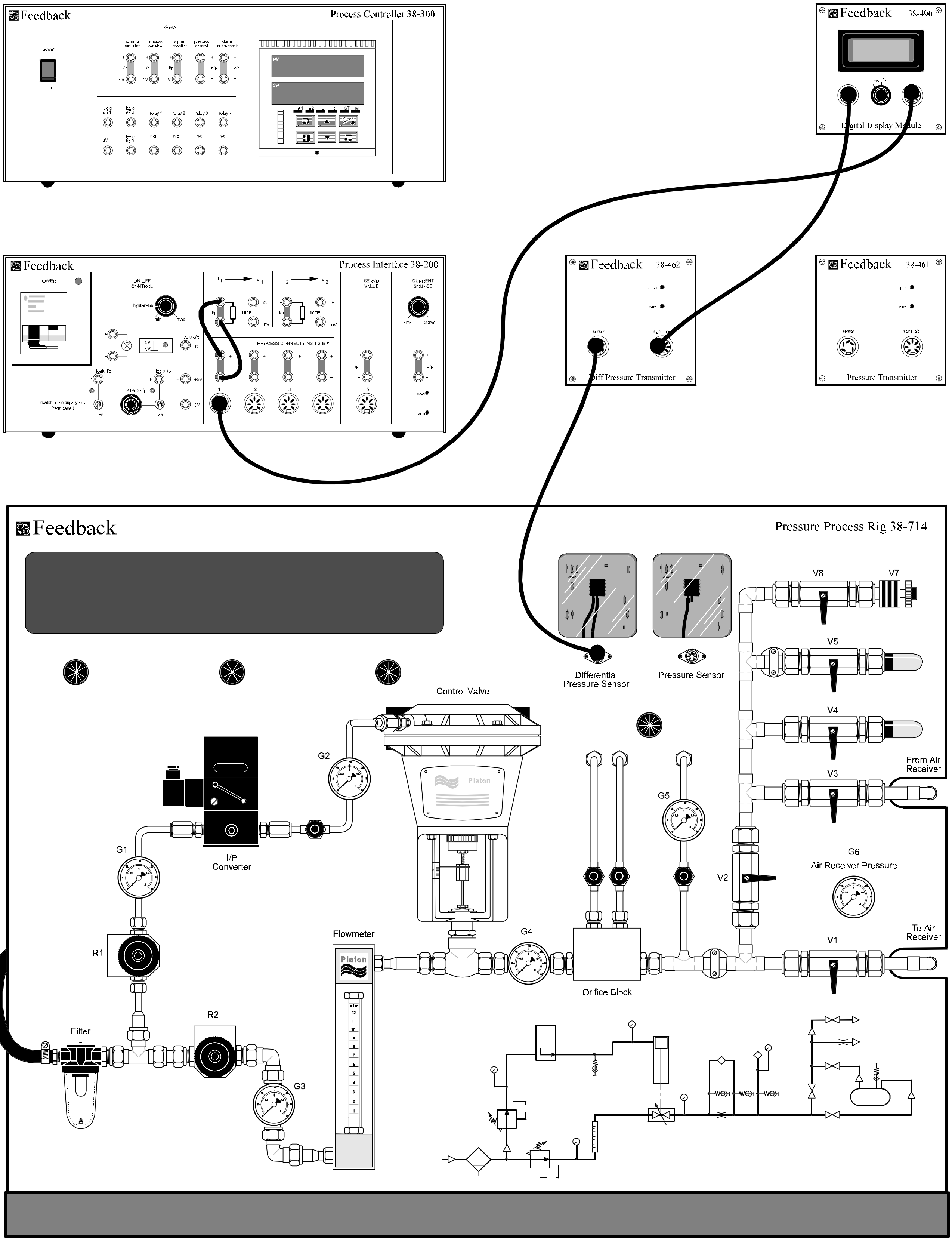

Fig 15 - Experiment 11 Connection Diagram

EXPERIMENT 11

Object of Experiment:

To calibrate the Differential Pressure Sensor and Differential Pressure Transmitter.

Equipment Required:

38-200 Process Interface

38-300 Process Controller

38-714 Pressure Process Rig

38-472 Differential Pressure Transmitter

38-490 Digital Display Module

Note: The equipment requires a supply of clean compressed air.

Initial Settings:

Complete the connections shown in Figure 15.

V1, V3, V4 & V5	Closed
R1, R2, V2, V6	Open and V7 fully open

Adjust R1 to give 25 psi on G1.

Adjust R2 to give 15 psi on G4 with the Pneumatic Control Valve open. Adjust V4 to give 5 psi on G5. Re-adjust R2 and V4 until G4 reads 15 psi and G5 reads 5.

For this set of demonstrations the controller will be used manually to operate the control valve via the I/P Converter and to monitor the differential pressure in the process pipe.

Once there is a pressure difference of 10 psi between G4 and G5, reduce the pressure with R2 until G4 reads 10 psi. G5 will now be reading zero.

Controller Calibration:

Span	100% at 20mA input
Zero	0% at 4mA input

Experimental Details:

The aim of this experiment is to calibrate the Differential Pressure Sensor/Transmitter to suit the process.

The Differential Pressure Sensor is connected to the tappings upstream and downstream of an Orifice Block located in the process pipe. Pressure drop across the Orifice Block is related to the flow of air in the pipe (pressure drop is proportional to the square of the flow). The aperture in the Orifice Block is 1.5mm in diameter.

The flowmeter installed on the 38-714 allows the relationship between the actual flow rate and the output from the sensor to be considered. The sensor and transmitter can be calibrated to the minimum and maximum conditions of flow through the pipe so as to be of use in control applications (the corresponding real values of the flow being known from the flowmeter reading).

Minimum flow produces 4mA output from the transmitter.

Maximum flow produces 20mA output from the transmitter.

All connections are shown in the equipment set-up diagram.

Connect the compressed air supply to the inlet.

Note: The Pneumatic Control Valve is designed to open with lack of air. With 4mA input to the I/P Converter, the valve will remain open.

Set the controller to Manual operation and open the control valve by setting output to 0%.

With the Pneumatic Control Valve open adjust R2 to give a flow rate of 25 L/min, adjust the span on the differential pressure transducer to give 100% reading on the controller.

Increase the controller output to close the control valve until the flow is zero, gauge G5 will read 0 psi. Use the trim tool supplied with 38-300 to adjust the zero control on the Differential Pressure conditioning module to give a reading of 4.0mA on the Digital Display Module.

Set the flow in the system to the maximum required by opening the Pneumatic Control Valve (pressure process variable should return to 100%). When the flow is steady, adjust the span control on the Differential Pressure conditioning module to give a reading of 20.0mA on the Digital Display Module.

Repeat the minimum and maximum settings until no further adjustments of the zero and span controls is required.

The Differential Pressure Sensor/Transmitter has now been calibrated to give readings from 4-20mA (0-100% if used with the Process Controller) corresponding to the range of flow rates available in the process pipe.

Conclusions:

A Differential Pressure Sensor may be used to give a remote reading of the differential pressure in a system. (This feature will be used in later experiments to enable the flow to be controlled automatically).

It is necessary to calibrate an electrical sensor before use to provide an output which is meaningful.

The Differential Pressure Sensor may be calibrated to suit the operating range and datum required for a particular application. The readings obtained can be related to actual flow rates from the flowmeter.

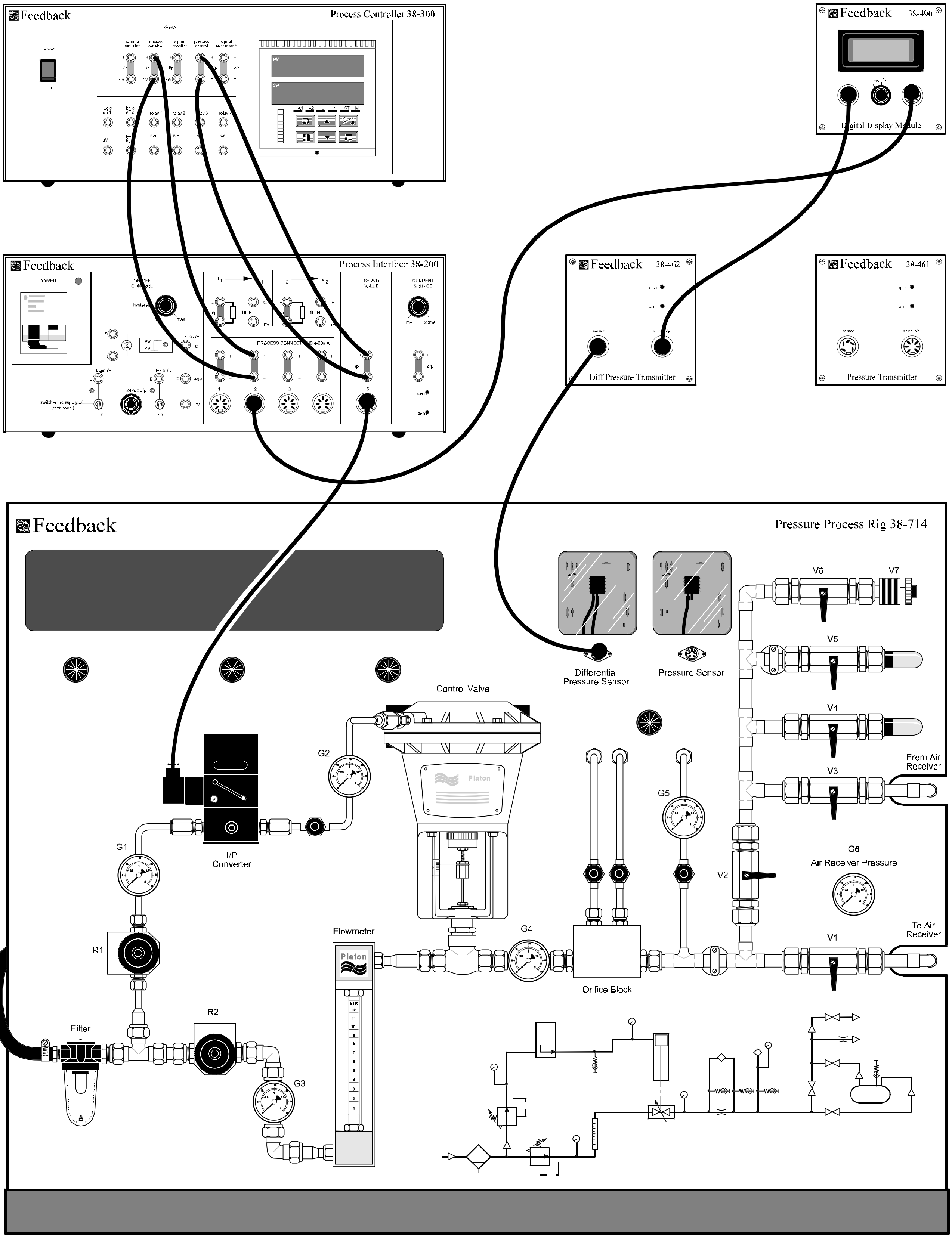

Fig 16 - Experiment 12 Connection Diagram

EXPERIMENT 12

Object of Experiment:

To control flow in the process pipe using a Differential Pressure Sensor/Orifice Block with square root extractor and three-term Process Controller with a 4-20mA proportional output to an I/P Converter and Pneumatic Control Valve.

Equipment Required:

38-200 Process Interface

38-300 Process Controller

38-714 Pressure Process Rig

38-462 Differential Pressure Transmitter

38-490 Digital Display Module

Note: The equipment requires a supply of clean compressed air.

Initial Settings:

Complete the connections shown in Figure 16.

V1, V3, V4, &V5 Closed

V2, V6 & V7 (fully open) R1 & R2 Open

Adjust R1 to give 25 psi on G1.

Adjust R2 to give 25 L/min on the flow meter with the Pneumatic Control Valve open.

For this set of demonstrations the Process Controller should be configured for three-term control with the following initial settings:

Controller Parameter	Setting	Units	
Set Point	50	%	
Proportional Band	300	%	
Integral Time	5	Secs	
Derivative Time	OFF	Secs	
Span	100	%	at 20mA input
Zero	0	%	at 4mA input

Follow the instructions given in earlier experiments regarding operation of the Process Controller. Further information can be found in the Process Controller user manual.

The Pressure Sensor and Transmitter are calibrated in the following way:

0 psi at G5 produces 4mA from Pressure Transmitter, representing 0% of range

10 psi at G5 produces 20mA from Pressure Transmitter, representing 100% of range

The Process Controller must also be configured to extract the square root from the process variable. This will produce a controller input which is linear to flow.

From the normal process variable/set-point display press the Page Advance button until the Setup Process display is seen. 'Setup PrCESS' will be displayed. Press the Parameter Advance button until 'Intypi' is shown in the upper display. This indicates the Lineariser Type page. Press the Up or Down buttons until 'SQ.rt' is shown in the lower display. Press the Enter button to confirm the selection.

The input range must now be specified. Press the Parameter Advance button once to show the Input Range Full Scale page (r-hi-i in upper display). A full scale of 20.0mA is required, so the lower display must be set to 200 by use of the Up or Down buttons. The decimal point is added by pressing the Parameter Advance button once to the Decimal Point page (dec-pt in upper display). Move the decimal point to the correct position by use of the Up or Down buttons. Press the Enter button to confirm the change.

Press the Parameter Advance button once to show the Input Range Zero page (r-lo-i in upper display). Set this to 4.0 by use of the Up or Down buttons. Press the Enter button to confirm the change.

Return to the Operating Page by pressing the Page Advance button followed by the Enter button.

<u>Experimental Details</u>:

The object of the demonstration is to maintain the flow at mid range in the process pipe (50% set point) by adjusting the opening of the Pneumatic Control Valve to allow the required amount of air to flow through the pipe.

As the Pneumatic Control Valve is open when 4mA is applied to the I/P Converter and a low flow (below set point) requires the valve to be opened, the Process Controller is configured for DIRECT action.

Connect the equipment as shown in the set-up diagram.

A recorder may be connected to the sensor output/controller input and controller output/current to pressure converter input 4-20mA loops to provide a record of the response.

If the set-up is correct, air should discharge from the main orifice. The flow should remain at 50% (process variable).

Observe that the flow is controlled at the set point.

Operation of Square Root Extractor

Connect the equipment as shown in fig 16.

To demonstrate the effect of the square root extractor, the output from the differential pressure transmitter will be plotted against flow with the square root option set on the process controller.

Open valves V2, V4, V5, V6 & V7 (fully open)

Close valves V1 & V3.

With the control valve fully open adjust the flow rate to 24 L/min. This should give a pressure drop of about 10 psi across the orifice plate (G4 – G5 = 10 psi).

Set the span on the differential pressure transmitter to 100%.

Reduce the flow to zero and set the zero on the differential pressure transmitter to 0%.

With the controller in manual mode set the o/p to 0%. Increase the output in steps of 10% up to 100%. Record the process variable display on the controller and the actual flow rate on the flow meter.

Controller O/P	Flow L/min	Process variable %
0	24.0	100
10	23.0	98.4
20	22.0	95.6
30	21.0	91.7
40	19.5	85.2
50	17.0	77.0
60	14.5	64.0
70	11.0	49.2
80	7.5	34.0
90	3.0	16.1
100	0	0

Repeat the reading with the square root extraction option turned off. Plot the two sets of data flow against process variable.

Controller O/P	Flow L/min	Process variable %
0	24.0	100
10	23.0	92.4
20	22.0	86.0
30	21.0	78.2
40	19.5	68.0
50	17.0	54.0
60	14.5	38.0
70	11.0	21.9
80	7.5	9.2
90	3.0	1.7
100	0	0

Flow Control

The object of the demonstration is to maintain the flow at the mid point in the process pipe at a set point of 50% by controlling the opening of the pneumatic control valve.

Further Experiments:

Changing the set point remotely

In the basic set-up the flow was controlled about a mean value of 50%.

Adjust the set point to 60% on the Process Controller. Observe how the flow changes to the required setting and the position of the Pneumatic Control Valve varies to suit the conditions.

Adjust the set point to 40% on the Process Controller. Once again, observe the changes in the flow and the valve operation.

Repeat of pressure control experiments

If required, the flow process may be studied in detail by following the procedures detailed in Experiments 6 to 9 for pressure control. Optimum controller settings and effects of the Air Receiver may be investigated.

Conclusions:

Flow in the process pipe can be measured using a Differential Pressure Sensor connected to an Orifice Block.

As the pressure drop across the Orifice Block changes with the square of the velocity, the output from the Differential Pressure Sensor is highly non-linear. The output from the Transmitter can be linearised using a square root extractor to provide a signal which is proportional to flow.

Flow in the process pipe can be controlled using a flow sensor/conditioner and Process Controller configured for proportional output (4-20mA) and square-root extraction to an I/P Converter to position a Pneumatic Control Valve as required at the inlet to the pipe.

Proportional control of the pneumatic control valve allows the flow to be held at the set point without the undue oscillations which are inherent in an on/off control system.

The flow in the pipe may be changed by setting an alternative set point on the controller. No adjustment to the process or sensor is required provided the inlet and outlet conditions are compatible with the new setting.

NOTES