MODELLING AND ADVANCED REGULATORY CONTROL OF A TWO INTERACTING TANK IN A SERIES

By

Yusasnor bin Md Yusof

Dissertation submitted in partial fulfillment of
The requirements for the
Bachelor of Engineering (Hons) Chemical

January 2006

Universiti Teknologi PETRONAS

Bandar Seri Iskandar

31750 Tronoh

Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

MODELLING AND ADVANCED REGULATORY CONTROL OF A TWO INTERACTING TANK IN A SERIES

By
Yusasnor bin Md Yusof

A project dissertation submitted to the
Chemical Engineering Programme
Universiti Teknologi PETRONAS
In partial fulfillment of the requirement for the
BACHELOR OF ENGINEERING (Hons)
CHEMICAL ENGINEERING

Approved by,

(Mr. Nasser bin Ramli)
Main Supervisor

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

Jan 2006

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted for this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been taken or done by unspecified sources or persons.

YUSASNOR BIN MD YUSOF

ABSTRACT

This dissertation contains the study on modelling and advanced regulatory control f two interacting tanks in a series. It covers the background of the study, some literature reviews and related theories; methodology used for completion of the project and finally, concludes the results obtained from this research. The main objective of this study is to study on the flow characteristics and its effect to the level characteristics to further understand the process and to compare the experimental data with the modeling result. In order to achieve the best result, there is certain parameter for the author to fully concentrating on such as on feedback controller, PID controller design and also model-based design method, Internal Model Control (IMC). Comparisons between the experimental data with modeling result are not done yet. It is due to some problem that results lagging in the time frame to cope with this project.

ACKNOWLEDGEMENTS

First of all I would like express my thankfulness to Allah the Almighty who gave me the strengths to face challenges in completing this dissertation to fulfill the Final Year Research Project.

This study would not be possible without the assistance and guidance from key individuals whose contributions have helped in the completion of this study.

First of all and most importantly, I would like to express my sincere and deepest gratitude to my project supervisor, Mr Nasser bin Ramli for her valuable input and guidance at all times throughout the course of this study.

I would also like to express my gratitude to the School of Chemical Engineering Postgraduate student, Mr. Iqbal for giving his technical assistance in using flow and level control equipment, WLF 922 and WL 922. His assistance is very much appreciated.

Not to forget, a high appreciation to the Final Year Project (FYP) Committee Members of Chemical Engineering, lecturers of UTP, and everyone who involves directly and indirectly throughout the project.

TABLE OF CONTENTS

5. CHAPTER 5: CONCLUSION AND RECOMMENDATION

6. CHAPTER 6: REFERENCES AND APPENDICES

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1
INTRODUCTION

1.1 Background of study

Until fairly recent time, most of the applications of industrial process control used simple feedback loops which regulated flows, temperature, pressures, levels and the like. Occasionally ratio and cascade control loops could be found; on even rare occasions one might find a feedforward control loops. As long as most of the control system were implemented with analogue hardware, either pneumatic or electronic, the cost of hardware, the additional interconnection required, the burden maintaining additional components, plus the vulnerability to failure too many devices in the control loop limited most applications to simple regulatory control. With the advent of digital control systems, first in the form of central computer control then distributed control systems and single-loop controllers, more sophisticated control loops become feasible. Advanced regulatory control loops, including ratio, cascade and feedforward which were previously mentioned, plus additional forms such as constraint (selector) control and decoupling could readily be implemented simply by configuring software function blocks.

There are many source of benefit for the use of advanced regulatory control. One of the most important is simply closer control of the process. It will be made very clear that with basic regulatory for example feedback control, before control action can occur, there must be a deviation set point. This is called feedback penalty. The objective of advanced regulatory control is to be able to take the control action without paying the feedback penalty. The reduction in feedback penalty may be stated in a variety ways, such as reduction of the maximum deviation from the set point, reduction of the standard deviation, or simply as reduction in the amount of off-spec product produced. This can provide several forms of economic benefit, such as improvement of product quality, energy saving, increased throughput, longer equipment life and so on.

Process control is but one part of overall control hierarchy that extends downward to safety controls and other directly connected process devices and upward to encompass process optimization and even higher business levels of control such as scheduling, inventory management and so on. Indeed, a greater contribution to the enhancement of corporate profitability may come from these higher level activities than from improved process control. However, since each layer of hierarchy depends upon the proper functioning of lower layers, one of the primary benefits of advanced regulatory control is that of enabling the higher level of controls such as optimization. An optimization procedure normally calculates target operating points for key process variables which are introduced to the regulatory control layers as set points. It does not good, however to calculate an optimal set point if the underlying control strategies fail to maintain the key process variable at that set point. Hence, an adequate control structure at the lower levels is a prerequisite to a successful optimization procedure.

One of the example of advanced regulatory control is to research and study about the interaction of flow and level by following some method. This project is all about modeling and advanced regulatory control of a two interacting tank in a series. The equipment was water as the process medium. The unit consists of a tank whose discharge can be either gravity or by pumped flow, thus demonstrating self-regulatory and non-self regulatory control. The total system consists of the level tank together with liquid sump, pumps and associated pipelines. The unit demonstrates the level control and flow control by manipulating the valve opening. These can be studied independently before attempting the level –flow cascade control system. After all, simulation of this process will be done using MATLAB to look out for a different in the experimental data and the simulation of the process.

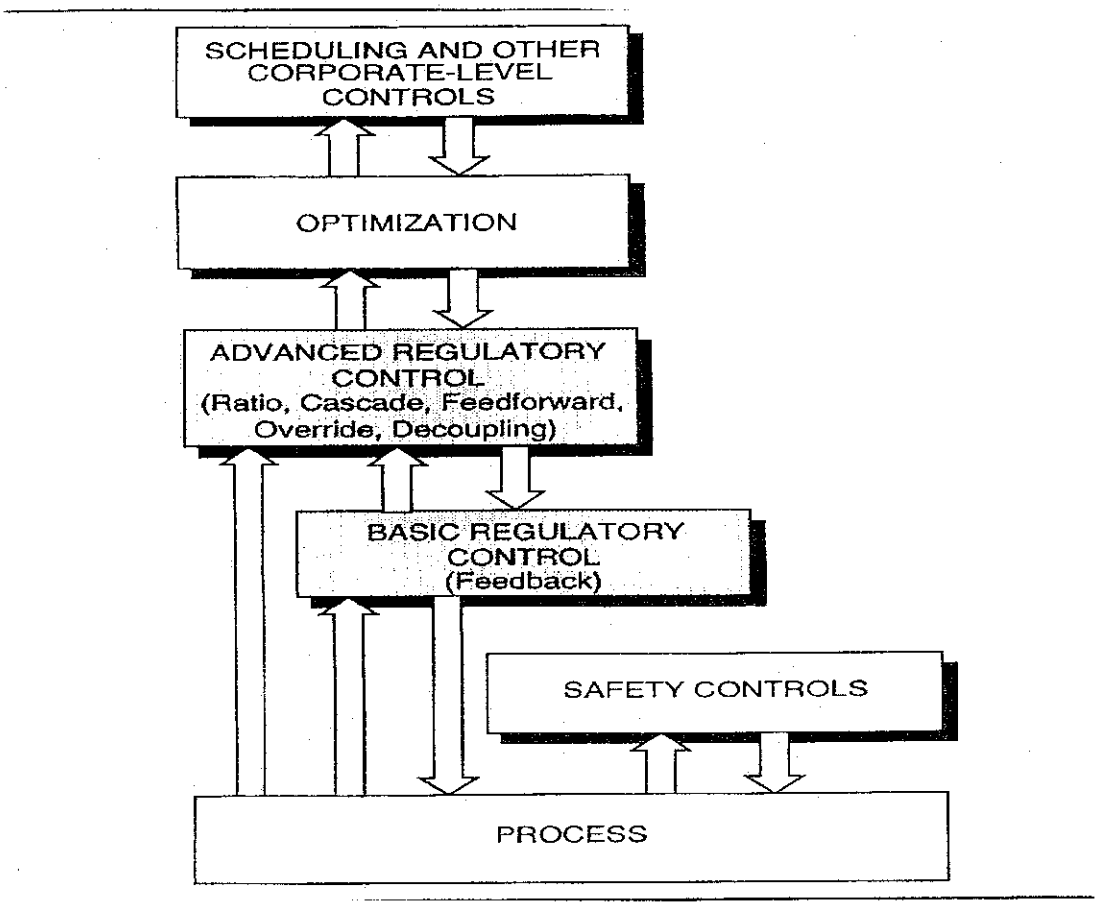


Figure 1.1: Overall Control Hierachy

1.2 Problem statement

Level and flow are important process parameter in industry. All inventory control process schemes are based on level-flow control techniques. The type of level process and its time constant play important roles in level-control. The main agenda of doing this project is to understand more on control process of level and flow. It is also a requirement for this project to make a comparison between the experimental data result and the simulation using a MATLAB. In order to achieve the best result, there is certain parameter for the author to fully concentrating on such as on feedback controller, PID controller design and also model-based design method, Internal Model Control (IMC).

1.3 Objectives and Scope of Study

1.3.1 Objectives

This research project has been carried out to achieve several objectives as stated below:

1. To study on the flow characteristics and its effect to the level characteristics to further understand the process.
2. To conduct experimental test to determine the effect of level and flow characteristic based on SCADA selector switch
3. To understand the mechanisms of the level and flow controls
4. Select the best result between the experimental data and using MATLAB

1.3.2 Scope of Study

These research projects mainly involve the experimental work and also modeling. Two different experiment, that is open loops and close loop have been done. There are few stages should be faced before the objectives can be accomplished.

First stage:
Experiment of open loop and close loop using equipment WLF 922 and WL 922. This experiment will be focused on finding of the best result of controller gain, kc and time integral time; τ_I for open loop experiment and then used that value to run the close loop experiment. It can be achieve by finding the best value of change of process variable by increase the manipulated variable value. All the experiments are carried out at Control Laboratory of chemical Engineering Department, Universiti Teknologi PETRONAS.

Second stage:

Comparison with modeling results

Comparison of the results will be made, with the results from experiment are going to be used as the main source for comparing.

1.4 Basic Concept of Modeling Fundamental

Models are an integral parts of any kind of human activity. However, we are mostly unaware of this. Most models are quantitative in nature and are no formulated explicitly. Such models are not reproducible and cannot easily be verified or proven to be false. Models guide our activity and throughout our entire life we are constantly modifying those models that affect our everyday behavior. The most scientific and technically useful types of models are expressed in mathematical models in the field on the use of dynamic mathematical models in the field of engineering.

1.5 Chemical Modeling

the use of models in chemical engineering is well established, but the use of dynamics models, as opposed to the more tradition use of steady state models for chemical plant analysis, is much more recent. This is reflected in the development of new powerful commercial software packages for dynamic simulation, which has arisen owing to the increasing pressure for design validation, process integrity and operation studies for which dynamic simulator is an essential tool. Indeed it is possible to envisage dynamic simulation becoming a mandatory condition in the safety assessment of plant, with consideration of such factors as start up, shutdown, abnormal operation, and relief situation assuming an increasing importance. Dynamic simulation can thus be seen to be an essential part of any hazard or operability study, both in assessing the consequences of plant failure and in the mitigation of possible effect. Dynamic simulation is thus of equal importance in large scale continuous process operations, as in other inherently dynamic operations such as batch, semi-batch and cyclic manufacturing processes. Dynamic simulation also aids in a very positive sense in enabling a better understanding of process performance and is a powerful tool for plant optimization, both at the operational and at the design stage. Furthermore steady-state operational is then seen in its rightful place as the end result of a dynamic process for which rates of change have become eventually zero.

CHAPTER 2

LITERATURE REVIEW AND THEORY

2.1 Interacting Process

Most of the system considered so far has been simple process with single processes with a single input and single output that could be isolated and treated individually. Unfortunately, for many common processes this cannot be done. Typically, process with variables that interact with each other or that contain internal feedback of material or energy will exhibit so-called interacting behavior.

When we considered this project includes two interacting tank in series, the process must be affected by the level of the tank because h_1 depends on h_2 (and vice versa) as a result of the interconnecting stream with a flow rate f_1;

$$f_1 = c_v \, x_1 (\Delta P_1)^{1/2} \text{ where } \Delta P_1 = \rho_1 g h_1$$

$$f_2 = c_v \, x_2 (\Delta P_2)^{1/2} \text{ where } \Delta P_2 = \rho_2 g h_2$$

$$f_1 - f_p = A_1 \frac{dh_1}{dt} \quad \text{and} \quad f_1 - f_2 = A_2 \frac{dh_2}{dt}$$

2.2 Dynamic Characteristic

Process dynamic characteristic can be classified into three broad categories ;

- Self-regulating processes
- Nonself-regulating processes
- Runaway processes

Self-regulating processes are those that, if all inputs are fixed, will seek their own equilibrium for example if the flow into the vessel is fixed, the process will reach an equilibrium when the tank level rises or falls into the vessel at which the hydrostatic pressure at the base of the tank causes the outflow to exactly equal the inflow.

A nonself-regulating process can be depicted by the hydraulic analogy. Here, there is a fixed flow rate out of the tank; it does not depend upon the level in the tank. Unless the inflow is precisely the same as the outflow, the level will continue to rise or fall until either the tank is empty or overflows.

A mathematical expression for a process of this type is given by the following integral equation;

$$Ah = \int (f_{in} - f_{out})\, dt$$

Where:

h = height (depth) of fluid in tank

A = cross-sectional area

f_{in} , f_{out} = volumetric flow rates

For this reason, there are often called integrating process. In actual practice, liquid level control can often be represented as an integrating process. A few processes are unstable in the open loop means without feedback control and this process is called runaway process.

2.3 Characteristics of Types of Control Loops

2.3.1 Flow Control loops

Flow control loops are widely used in the process industries. About half of the control loops in oil refinery are used for flow. Flow and pressure control are characterized by fast responses (on the order of seconds), with essentially no time delay. The process dynamics result from compressibility (in a gas stream) or inertial effects (in a liquid) plus control valve dynamics for a large diameter pipeline. Disturbance in a flow systems tend to be frequent but generally small. Most of the disturbances are high frequency noise (periodic or randomly) due to upstream turbulence, valve change and pump vibration.

For flow control loops, PI control is generally used with intermediate values of controller gain. Flow control loops usually have relatively small settling times (compared to other loops), there is little incentive to use derivative action to make the loop respond even faster.

2.3.2 Liquid level

Liquid storage vessel with a pump on its exit line act as an integrating process. Standard P or PI controllers are widely used for level control. However, these level control problems have an unusual characteristic; increasing the gain of a PI controller can increase stability, while reducing the gain can increase the degree of oscillation and this reduce stability. Of course if Kc become too large, oscillation or even instability can result. Integral control action is often used but can be omitted if small offset in the liquid level can be tolerated. Derivative action is not normally used for level control because the level measurement is often noisy as a result of the splashing and turbulence of the liquid entering the tank.

For some application, tight level control is desirable. For example, a constant liquid level is desirable for some chemical reactor or bioreactor in order to keep the residence time constant. In this situation, the level controller setting can be specified using standard tuning methods. If level control also involves heat transfer, such as for a vaporizer or a evaporator, the controller design becomes much more complicated. In such situations special control methods can be advantageous.

2.4 Development of Standard PID Control

2.4.1 Feedback Control

The principal of feedback controller is one of the most intuitive concept known. An action taken, more than likely to correct a less-than-satisfactory situation, then the result of the action are evaluated. If the situation is not corrected, then further action may be warranted.

The corrective action and the necessity for evaluating the effect for possibly further corrective action are intuitively obvious. Feedback control can be classified by the form of the controller output.

Feedback controllers use one, two or three methods to determine the value of the controller output. These methods called the modes of control include the following;

- Proportional (P)
- Integral (I)
- Derivative (D)

2.4.2 Modes of Control

2.4.2.1 Proportional Mode

With a controller containing only the proportional mode, the controller output is proportional to the measurement value only. No history of measurement value only and no consideration of its rate of change are utilized. Adjusting or tuning the controller for the desired performance is simple, since there is essentially only one adjustment to be made. The proportional controller suffers from a serious deficiency. However an offset exists between the set point and measurement value under most load conditions.

The amount by which the process variable must change to cause 100% change in controller output is called proportional band. There is a direct relationship between controller gain, Kc and proportional band, given by the following;

$$PB = \frac{100}{Kc} \qquad Kc = \frac{100}{PB}$$

Among commercially available controllers, both proportional band and gain adjustment knobs are found as a means of tuning of proportional mode of the controller. Some microprocessor-based system permit the user to configure the system to display either proportional band or gain.

The relationship between process input and output can be presented in the concept of the process graph, as the steady-state relationship between the process input (signal to valve) and output (measurement) for a particular load condition. An example was given by figure 2.1.

If there are load change on the process that result in shifting of the process graph, a new value of the controller variable will be required. It is the duty of control system to find precisely the point of process graph that brings the measurement to the desired value.

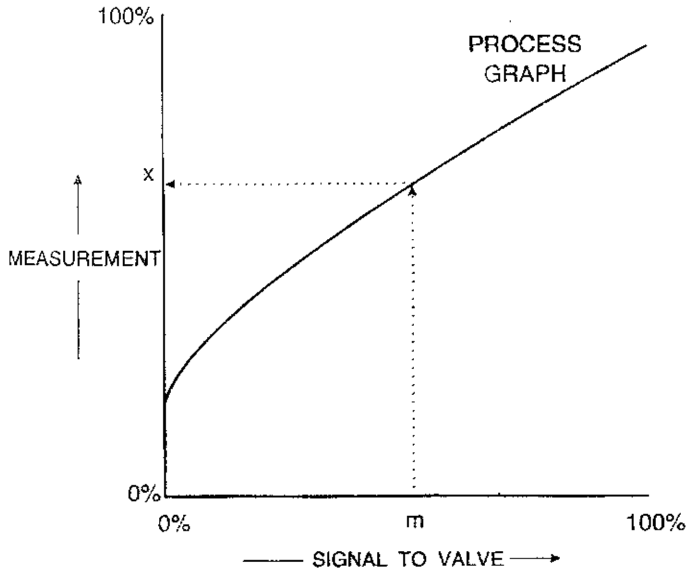


Figure 2.1: The Process Graph Determines the Value Position Required to Bring the Measurement to a Desired Value

Although for even combination of disturbance variable we will know a precise process graph, there are certain attributes that we should know. We must know whether the process graph slopes upward or downward that is equivalent to saying that we must know whether our process is direct-acting or reverse-acting. Sloping upward represents a direct-acting process (an increase in controller output causes an increase in measurement). Sloping downward is reverse-acting. Recall that to avoid positive feedback, the controller must be of opposite action – reverse acting for a direct acting process and vice versa.

Either explicitly or implicitly, the amount of slope of the process graph, at least in the vicinity of the most probable operating point. The slope can be stated as the change in measurement divided by the change in controller output. This is called process gain. Specifically, process gain, Kp can be define as;

2.4.1.3 Derivative Mode

Now that we have provided for the elimination of the steady-state offset, let's consider an enhancement for our control loop performance. By adding a component to the controller output that is proportional to the rate of change of the measurement, we can anticipate the effect of load changes, thereby reducing the total amount of deviation. The contribution of the derivative mode to the controller output is based upon the rate of change (derivative) of the product of controller gain time's error. The tuning parameter, T_D, allows us to adjust the relative effect of this mode of control.

$$m = Kc\left(e + \frac{1}{T_1}\int e\,dt + T_D\frac{de}{dt}\right)$$

The combination of P,PI and PID cover most of the actual feedback controller application. This is a summary of feedback control modes ;

Mode	Common name	Tuning parameter	Application
'roportional	Proportional	Gain, Kc or proportional band	Used when ; Simple form of control is desired, load does not change significantly or offset is acceptable. Also used when the control loop dynamic permit setting a relatively high gain without causing excessive oscillation. Then, even if there is only

			minimal offset.
ntegral	Reset Auto reset	Min/repeat or Repeats/min	Used almost always in conjunction with proportional mode to eliminate steady-state offset. Occasionally used alone; known as integral controller. For most application, I-only controller would have inferior performance when compared with PI modes.
Derivative	Rate action Pre-act	Derivative time	Used usually in combination with P and I modes to improve loop performance by anticipating effect of load change. Used mainly on slow response

Table 2.1: Summary of feedback control modes

2.5 Open-loop Control

An open-loop control system is one in which the control input to the system is not affected in any way by the output of the system. It is also necessary however that the system itself is not varied in any way in response to the system output.

Such a definition indicates that open-loop systems are in general relatively simple and therefore often inexpensive. Clearly the response of an open-loop is dependent on the characteristics of the system itself in terms of the relationship between the system input and output signals. It is apparent therefore that if the system characteristics change at some time then both the response accuracy and repeatability can be severely impaired. In almost all cases however the open-loop system will present no problems insofar as stability is concerned, for example if an input is applied the output will not shoot off to infinity – it is not much use as an open-loop system if this is the case.

2.6 Close-loop Control

In a close-loop system the control input is affected by the system output. By using output information to affect in some way the control input of the system, feedback is being applied to that system.

It is often the case that the signal fed back from the system output is compared with a reference input signal, the result of this comparison (the difference) then being used to obtain the control or actuating system input.

The procedure for making a close-loop test is to test the integral action to a minimum, remove all derivation action and set the gain to a low value. Then put the controller in automatic, with the measurement near the normal operating point and make a small change in set point. If the process does not oscillate or if the oscillation quickly decays, increase the gain and repeat the test. The objective is ultimately to have the gain high enough that a sustained oscillation will result.

Once sustained oscillation is attained, measure the period of oscillation and note the gain that ultimately produced sustained oscillation. The ultimate proportional band, PB, may be determined instead. If so, use the usual relationship

$$K = \frac{100}{PB}$$

2.7 Controller Tuning Relations

Analytical expression for PID controller setting has been derived from the other perspective as well. This expression are referred to as controller tuning relations. The most widely used tuning relations are ;

2.7.1 IMC tuning relations

The IMC method can be used to derive PID controller setting for a variety of transfer function model. Different tuning relations can be derived on the type of lowpass filter *f* and time-delay approximation that are selected. In this experiment, IMC-based PID controller setting is used to calculate the controller gain, Kc and Integral time, value. We used case M to get the best result. The equation used is;

Table 2.2 IMC-Based PID Controller Settings for Gc (s) (Chief and Fruehauf, 1990) used for this experiment

Case	Model	KcK	τ_c	τ_D
M	$\frac{Ke^{-\theta s}}{s}$	$\frac{2\tau_C + \theta}{(\tau_C + \theta)^2}$	$2\tau_C + \theta$	none

2.7.2 Miscellaneous tuning relations

Two early controller tuning relations published are Ziegler-Nichols and Coohen-Coon. These well-known tuning relations were developing to provide closed-loop responses that have a ¼ decay ratio.

CHAPTER 3

METHODOLOGY/ PROJECT WORK

3.1 Procedure Identification

The initial stage of the research project is to review the equipment manual given by the supervisor. Since this is a final year project, a full understanding on what steps had been done is essential. This stage of revision also important to get enough information to conduct further research and experiment on advanced control and regulatory. The author also uses the Internet to find information about the information regarding to this project. After all the information gather, the next step is to get familiarize with the experiment apparatus and also to get familiar with the term in the process control field of studies. Finally, the author has to come out with the experimental procedure to run the project work and collect all the data needed. The important value needed for further analysis is;

I. Change of process variable, ΔPV
II. Time constant, τ_C
III. Time delay, τ_D
IV. Controller gain, k_c

After done all the experiment and done some discussion base on the result, the author must be prepared to do a simulation using MATLAB simulink. After all finish, the record of the result will be compared each other and get prepare for final presentation and final report.

A simple diagram of the equipment used for the experiment is what as shown in Figure 3.1:

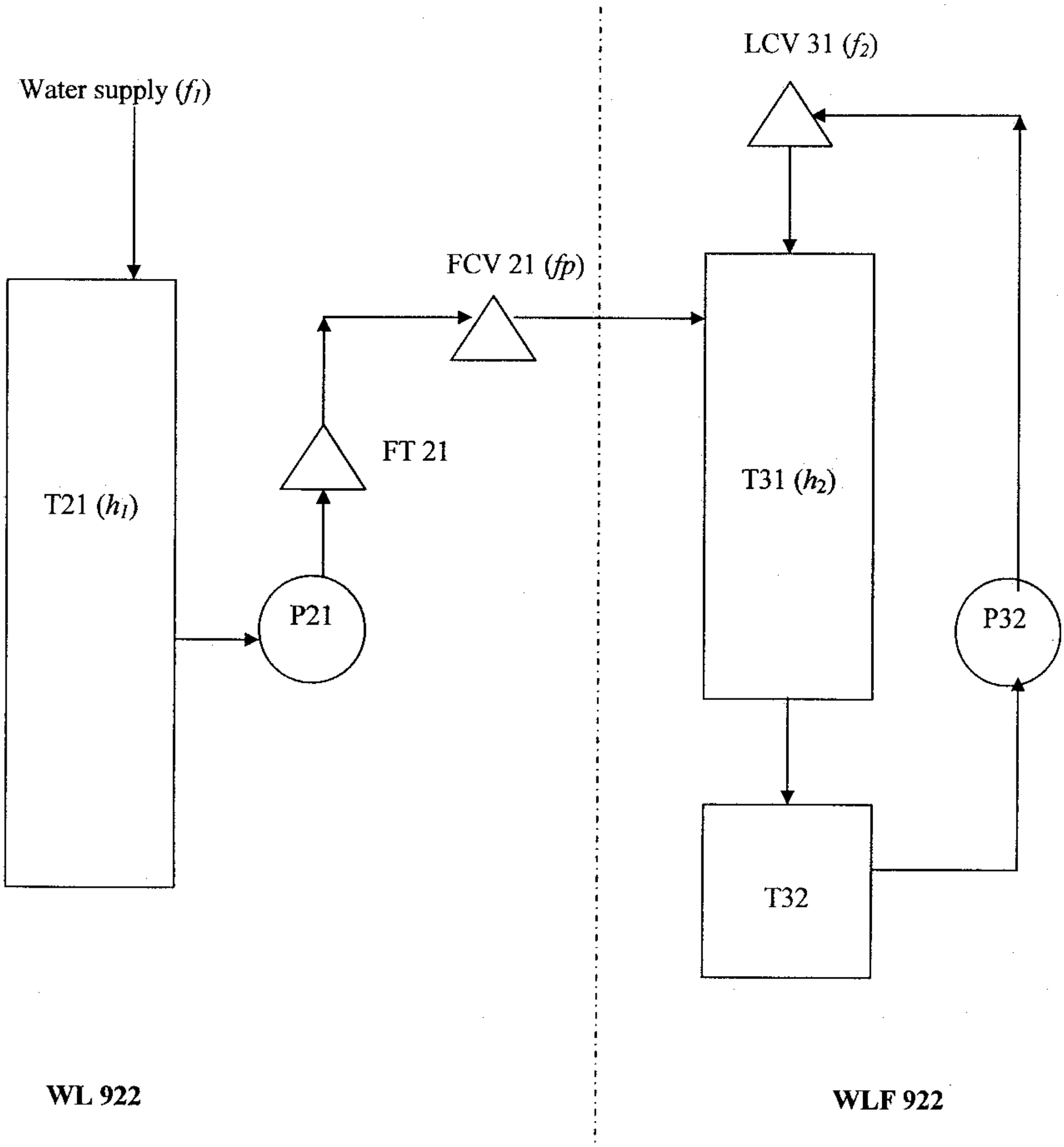


Figure 3.1: Equipment Used for the Experiment

3.2 Equipment Description

3.2.1 WLF 922

The total system consists of the level tank together with liquid sump, pumps and associated pipelines. The unit demonstrates the flow-level control by manipulating the valve opening. These can be studied independently before attempting the level –flow cascade control system. The medium used is water. This equipment licensed by Yokogawa Inc. It consist of two tanks, T31 and T32, three pumps, P31, P32 and P33 but for this experiment we only used P32 caused it's already provide sufficient pressure needed to flow the water to T31. This equipment use FCV 31 as our flow controller.

The equipment also comes with panel instrument, SCADA. For PID controller, LIC 31/FIC31 is one unit of Yokogawa YS 170 Single loop Programmable controller configured with two PID controller that is LIC31 (PID1, loop 1) and FIC 31(PID2, loop2). It can be switch to 2 positions. Position 1 for single level loop and switch to position 2 for cascade LIC31-FIC31 or single loop FIC31.

Compressed air is required to operate the valve system LCY31/PP/ LCV 31 and to pressurize tank 31. Before run this experiment, ensure the pressure is in accordance to the pressure indicated at the air pressure regulator (IAS). It also has a Positioner (PP) but usually for this experiment, we just bypass the Positioner.

3.2.2 WL 922

This equipment is quite the same with the WLF 922. The total system consists of the level tank together with liquid sump, pumps and associated pipelines. The unit demonstrates the flow control by manipulating the valve opening. The medium used is water. This equipment licensed by Yokogawa Inc. It consist of one tanks, T21, three pumps, P20, P21 and P22 but for this experiment we only used P21 caused it's already provide sufficient pressure needed to flow the water to T31.

This equipment also consist of two flow controller but refer to the experiment procedure, we only use FCV 21 as our flow controller. This equipment is connected to WLF 922 using hose that being clipped above the T31. Compressed air is required to operate the valve system LCY21/PP/ LCV 21. Before run this experiment, ensure the pressure is in accordance to the pressure indicated at the air pressure regulator (IAS). It also has a Positioner (PP) but usually for this experiment, we just bypass the Positioner.

3.3 Methodology

3.3.1 Open-loop Experiment

3.3.1.1 Start up procedure for model WF 922

1. Fill up T21 with water by allowing "water supply ext" to be opened which located at the equipment itself.
2. Connected a pipe from T21 to T31.
3. Switch on P21 so that the water from T21 could be pumped to T32.
4. Set P22A/B and P20 on OFF mode. This action is taken to prevent the water from circulating back into T21.
5. Fully shut "to WLF 922" valve and "from WT 922" valve.
6. Fully shut the discharge valve and if the water level is exceeding the limit, the water will flows through the overflow route and then to the drain.
7. Check whether the pressure is accordance to the pressure indicated at the air pressure regulator (IAS) and air regulator (AR31). It is a good practice to purge the air regulator (IAS) to remove any condensed water.

3.3.1.2 Experiment Procedures

1. Switch on the main power supply at the front of the cubicle. (Note: if an annuciator is activated, press the acknowledge button to silence the buzzer and rationalize the cause of the alarm condition)

2. Pay attention to the following switches and push button but do not switch ON any pump yet;

- PANEL,SCADA/DCS selector switch (switch to "PANEL,SCADA" position for panel operation)
- Pump P20 (remain this pump in OFF mode)
- Pump 21 (pumping inflow from T21 to T32. To be switched ON during operation)
- Pump P22A/B (remain this pump in OFF mode)

3. Switch to position 1 by using 1-2 position selector switch, display FIC 21 and press M (manual) and leave in manual mode.
4. In manual mode manually stroke the control valve MCV 21 with MV = 30% and wait until PV become steady.
5. When PV has reached its steady state, press the RCD button ON to start recording.
6. Introduce a step change on MV by manually stroke the control valve MCV 21 with MV = 40%.
7. When the step response curve is obtained, switch OFF the recorder chart drive.
8. Repeat procedure (step 4-7) for different value of step change as listed in the table after achieves a good result on the LIC 21.

3.3.1.3 Start up procedure for model WLF 922

1. Fill up T32 with water by allowing "water supply ext" to be opened which located at the equipment itself.
2. Switch on P32 so that the water from T32 could be pumped to T31.
3. Set P31 and P33 on OFF mode. This action is taken to prevent the water from circulating back into T32.
4. Fully shut "to WLF 922" valve.
5. Fully shut the discharge valve and if the water level is exceeding the limit, the water will flows through the overflow route and then to the drain.

6. Check whether the pressure is accordance to the pressure indicated at the air pressure regulator (IAS) and air regulator (AR31). It is a good practice to purge the air regulator (IAS) to remove any condensed water.

3.3.1.4 Experiment Procedures

1. Switch on the main power supply at the front of the cubicle. (Note: if an annunciator is activated, press the acknowledge button to silence the buzzer and rationalize the cause of the alarm condition)
2. Pay attention to the following switches and push button but do not switch ON any pump yet;

- PANEL,SCADA/DCS selector switch (switch to "PANEL,SCADA" position for panel operation)
- Pump P31 (remain this pump in OFF mode)
- Pump 32 (pumping inflow from T32 to T31. To be switched ON during operation)
- Pump P33 (remain this pump in OFF mode)

3. Switch to position 1 by using 1-2 position selector switch, display LIC 21 and press M (manual) and leave in manual mode. At the same time, open up the globe valve in the bottom of T31.
4. In manual mode manually stroke the control valve MCV 21 with MV = 30% and wait until PV become steady after flow from WL922 become steady.
5. When PV has reached its steady state, press the RCD button ON to start recording.
6. Introduce a step change on MV by manually stroke the control valve MCV 21 with MV = 40%.
7. When the step response curve is obtained, switch OFF the recorder chart drive.
8. Repeat procedure (step 4-7) for different value with increment of 20%, 30% and 40% of step change as listed in the table.

3.3.2 Closed-loop experiment

The start up procedure for both equipment, WL 922 and WLF 922 is same as the open-loop experiment. Just repeat the point in 3.3.1.1 and 3.3.1.3

3.3.2.1 Experimental Procedure

1. Repeat step 1 until step 3 from 3.3.1.2
2. Key in the value of controller gain, Kc and integral time, τ_I obtained in the open-loop experiment.
3. In manual mode manually set the set point (SV) value at 1.50 and wait until PV reach that value of SV.
4. When PV has reached SV value, increase the SV 10% (about 1.65) and change it from manual to automatic mode.
5. Press the RCD button ON to start recording.
6. When the step response curve is obtained, switch OFF the recorder chart drive.
7. Repeat procedure (step 2-4) for different value of SV that increase 20% and 30%.
8. Assume at this point, the WLF 922 start up procedure already done.
9. Repeat step 1 to step 3 from 3.3.1.4
10. Key in the value of controller gain, Kc and integral time, τ_I obtained in the open-loop experiment.
11. In manual mode manually set the set point (SV) value at 400 and wait until PV reach that value of SV.
12. Ensure that in the WL 922 the flow rate value of SV and PV already reach at the same value.
13. When PV has reached SV value at WLF 922, increase the SV 10% (about 440) and change it from manual to automatic mode.
14. Press the RCD button ON to start recording.
15. When the step response curve is obtained, switch OFF the recorder chart drive.
16. Repeat procedure (step 9-12) for different value of SV that increase 20% and 30%.

3.4 General Modelling Procedure

One of the important features of modeling is the frequent need to reassess both the basic theory and the mathematical equation, representing the physical mode (mathematical mode) in order to achieve agreement, between the model prediction and actual process behaviors (experimental data).

As shown in figure 3.2 below, the following stages in the modeling procedure can be identified;

1. The first involves the proper definition of the problem and hence the goals and objectives of the study.
2. All the available knowledge concerning the understanding of the problem must be assessed in combination with any practical experience, and perhaps alternative physical models may need to be developed and examined.
3. The problem description must then be formulated in mathematical terms and the mathematical model solved by computer silmulation.
4. The validity of the computer prediction must be checked. After agreeing sufficiently well with available knowledge, experiments must then be designed to further check its validity and to estimate parameter values. Step 1 to step 4 will often need to be revised at frequent intervals.
5. The model may now be used at the defined depth of development for design, control and for other purposes.

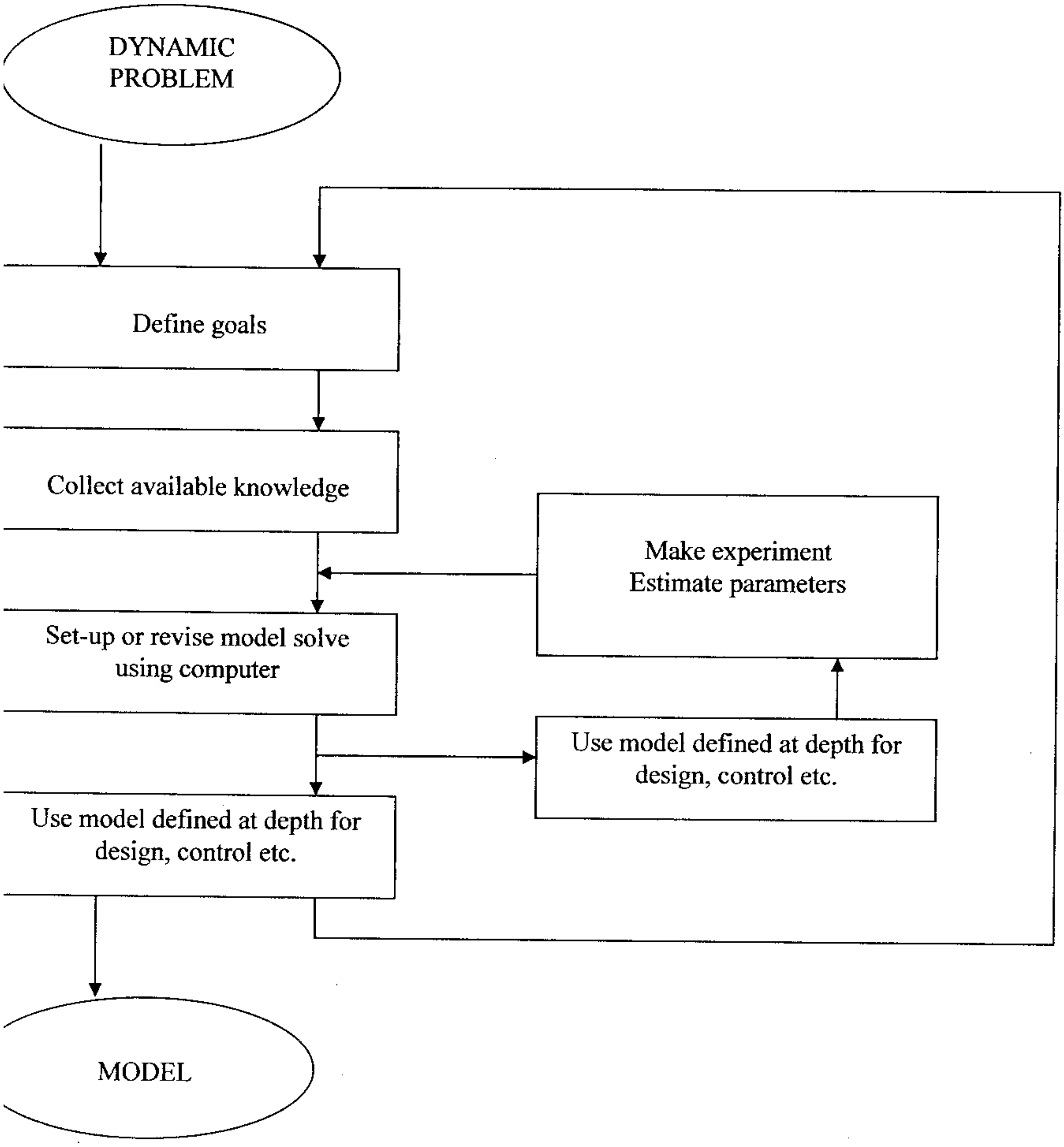


Figure 3.2: Steps in model building

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Tuning Open-loop Test Data

The graph for this experiment obtained shown in Figure 4.1. There are three curves for flow control loops and each curve represents the change in the manipulated variable for 10%, 20% and 30 % increment.

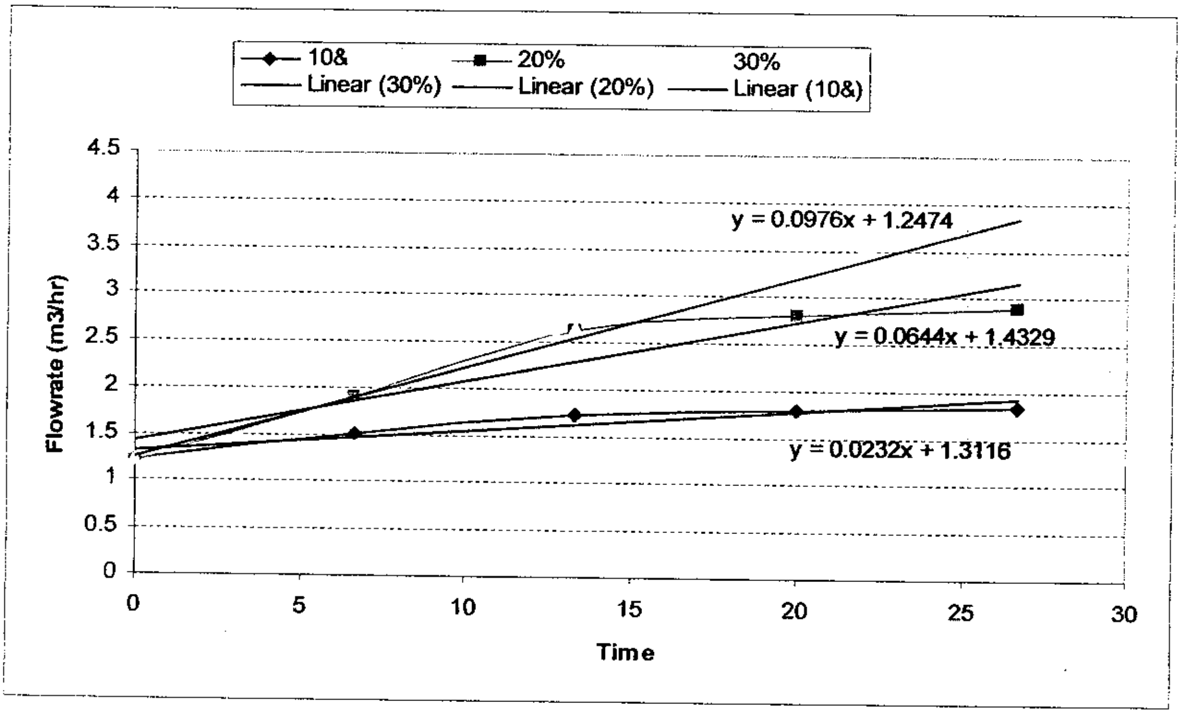


Figure 4.1: Flow control loops Process Response to an Open-Loop Test

Figure 4.2 represent the level control loop curve and same as the flow control loop, each curve represent the change of manipulated variable by increase it 10%, 20% and 30%.

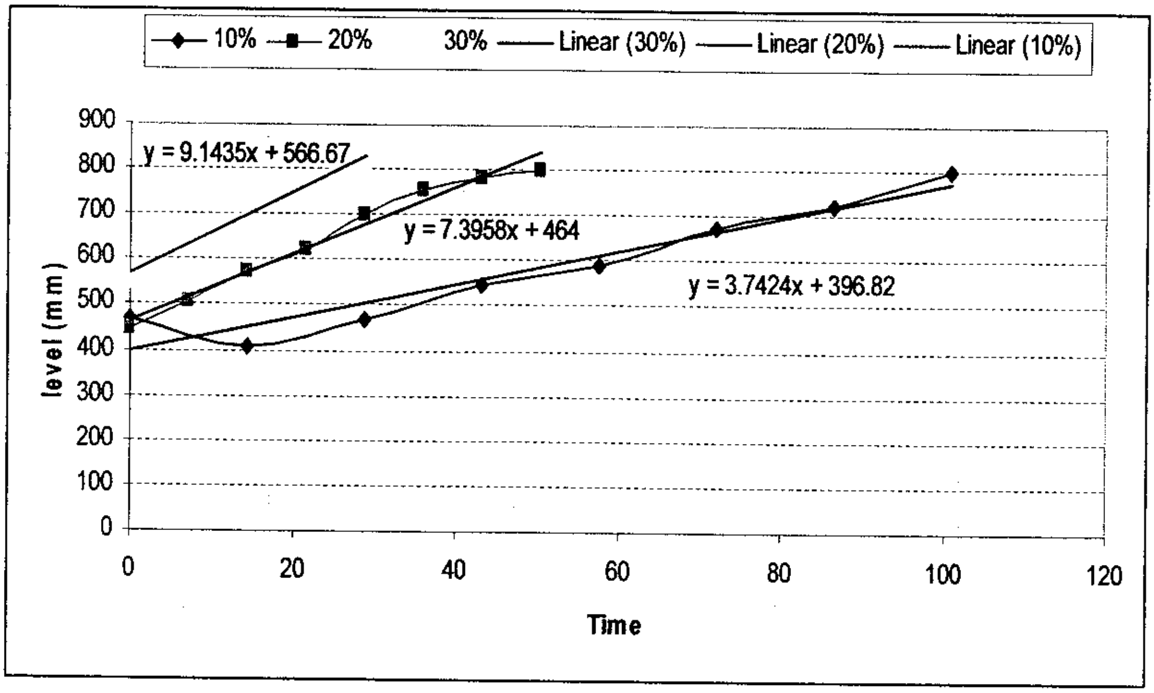


Figure 4.2: Level control loops Process Response to an Open-Loop Test

In the open-loop test, the controller is placed in manual and controller output adjusted until the measurement is near the normal operating point. Then the controller output is changed in a step fashion. From the process response to this step change, parameter values for a simple process model are determined; theoretical step response of this simple process should approximate the response of the actual process.

Since for most response to a step change in process input (controller output) is in a S shaped curve that initially rises very gradually then rises more rapidly, followed by a gradual rise to equilibrium, this type process response can usually be approximated by a first-order lag plus dead time (FOLPDT) model as shown in figure 4.3.

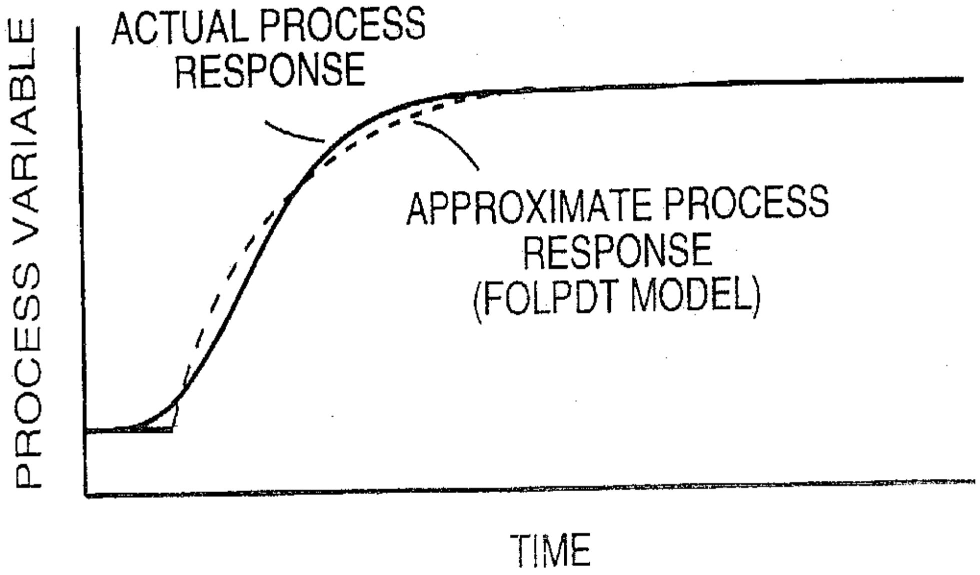


Figure 4.3 Actual and Approximate Process Response to an Open-Loop Test

Three parameter values are required;

- Process gain, Kp
- Dead Time (delay), τ_D
- Process time constant, τ_C

Once the parameter values are determined, use the equation from table .... To determine controller tuning values for the modes of control P, PI or PID that will be used. The values of parameter are included in table 4.1;

	FIC 31			LIC 31		
ΔMV	10	20	30	10	20	30
ΔPV	0.63	1.7	2.2	470	350	250
τ_D	26.67	33.33	26.67	100.8	50.4	28.8
τ_C	13.22	13.07	13.97	61.52	28.02	15.46
k	0.232	0.322	0.325	37.424	36.979	30.478
k_c	0.143867	0.085784	0.101738	0.000227	0.000468	0.001
τ_I	53.11	59.47	54.61	223.84	106.44	59.72

Table 4.1: Value of Parameter for Controller Tuning (open-loop)

The success open-loop test method depends upon several factors, including how well a first-order lag plus dead time model actually matches the true process response and how accurately the model parameter are determined. Based on the graph form figure 4.1 and 4.2, both result did not give a good result and it is not matches the true process response. That's mean the value are not an accurate value. Very few process, however will exibit a true FOLPDT response. For most process, an unknown number of lags in the system can be arranged in a infinite variety of ways. The smaller lag produce an apparent dead time even if no true dead time is present.

4.2 Tuning From Close-Loop Test Data

Through the experiment, curve is being obtained for each of the equipment;

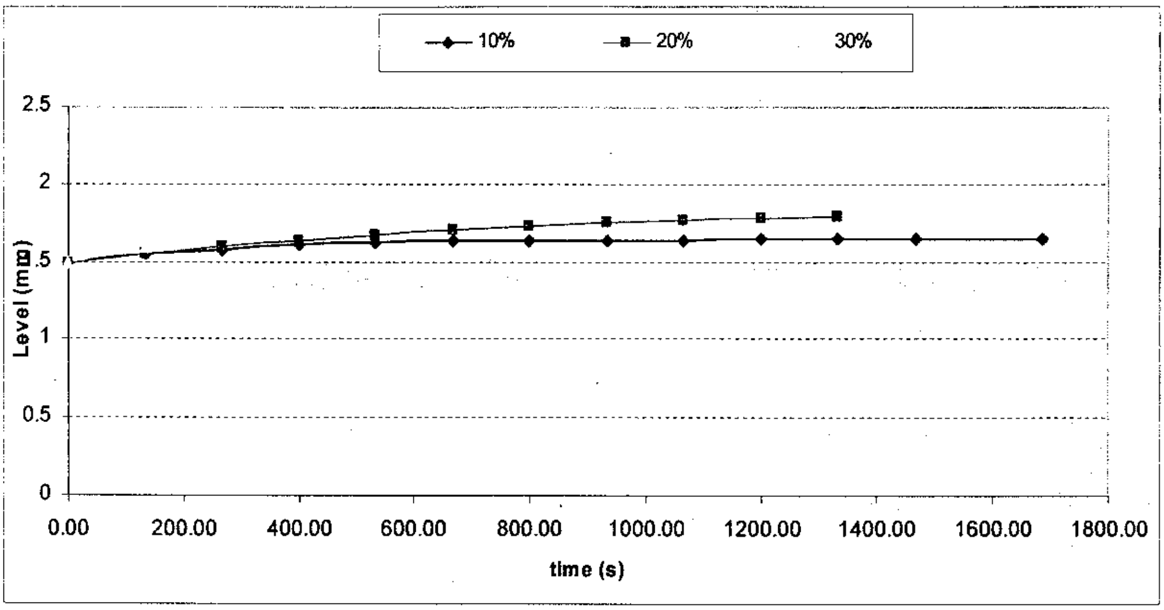


Figure 4.4: Flow control loops Process Response to an Closed-Loop Test

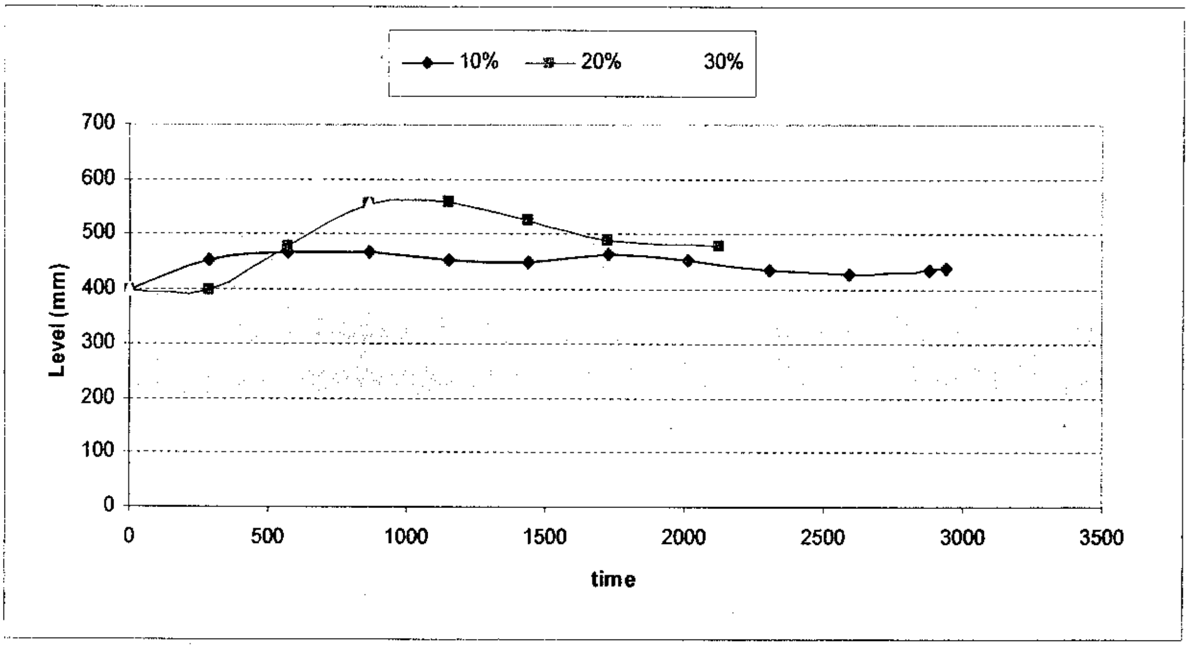


Figure 4.5: Level control loops Process Response to an Open-Loop Test

	FIC 31			LIC 31		
initial MV	45.5	45.8	46.2	15.5	15.8	15.8
Final MV	47.7	50.3	52.5	13.4	9.8	7.4
ΔMV	2.2	4.5	6.3	2.1	6.0	8.4
ΔPV	0.15	0.30	0.45	40	80	120
τ_D	1686.67	1333.33	1053.33	2937.6	2124.0	1152.0
τ_C	481.43	747.00	563.5	-	203.57	572.86
k	0.0032	0.0044	0.0065	-	0.747	0.711
k_c	0.175	0.149	0.128	-	0.00063	0.00109
τ_I	2649.53	2827.33	2180.33	-	2531.14	2297.72

Table 4.2: Value of Parameter for Controller Tuning (close-loop)

In this close-loop test, the mechanics of performing a close-loop test are relatively easy to describe. It may not be nearly so easy to actually implemented the test, however for several reason;

1. It is difficult to control the amplitude of oscillation. A large amplitude is not requires in fact it need be only sufficiently large to distinguish control oscillation from measurement noise band. Even so, a small change in set point may yield a larger than expected amplitude of oscillation.
2. For many applications a sustained oscillation may not be tolerable.
3. Many supervisory and operations personnel may object to a sustained oscillation, even though the test is made in order to obtain better controller tuning.
4. Several test, requiring a long testing period and consequently a lengthy period of off-spec production may be required to obtain sustained oscillation.

Despite the disadvantages, the close-loop test has the following advantages over the open-loop test;

1. The close-loop method makes no priority assumption as to the form of the process model. It is not force the process to look like a first-order lag plus dead time.

2. The data obtained from the close-loop test is much higher with the close loop method that with the open-loop method. This is because frequency or period can be measured very precisely, whereas dead time and time constant can only be approximated.

In many field of information, there are many thing discuss about self-regulating processes, very little discuss about techniques for tuning loops for non-self regulating processes such as liquid level control loops. There are perhaps several reasons;

1. In theory, a noise free, pure integrating process could be controlled by a high gain, proportional-only mode controller with very little offset from set point. In practice, however this ideal may not be achievable.
2. For many applications, the control of liquid level is not critical. If the application is for level control in a buffer storage tank between processing units, the outflow is probably a feed rate to the downstream process unit. It is usually preferable to tolerate fluctuation in the level and maintain a relatively constant rate to the downstream unit rather than tight level control with a fluctuating feed rate.

Al though there is no theoretical upper limit for the gain of proportional-only controller for an integrating process, in practice this will be limited by resonance that may occur within the loop. If the level sensor is an external cage type, there may be manometer effect between the liquid in the tank and the liquid within the level sensor cage. This will appear as an oscillation within the control loop, even though the total mass holdup may be unchanging. If there is a large surface area on the liquid, a resonant sloshing may occur, with a period that is proportional to the cross-sectional dimension. For a point-source measurement, this will also show up as an oscillation within the loop. Thus, there will be a practical limit to the controller gain as high as 10 or 20 (proportional band of 5% - 10%). With a high gain, any measurement noise present will cause excessive valve action. Therefore, the gain may be reduced in favor of utilizing some integral action within the controller.

If there is too much reliance on integral action, the controller approaches an integral-only controller. With this, both the controller and the process act as integrators. A feedback loop around two integrators in series will always produce an oscillating condition. Therefore, it is good practice to set the gain as high as practical in order to limit the fluctuation and rely to a lesser extent on reset to eliminate offset.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This research has been done to learn more about modelling and advanced regulatory control of two interacting in a series. This project is done by using the equipment in the Chemical Engineering Control Laboratory, WL 922 and WLF 922. The research has not yet been successfully conducted and the objectives have not yet been achieved. Until this time, the conclusions from this research project are:

- For flow control loops, PI control is generally used with intermediate values of the controller gain.
- For liquid level control loops, because the offset is not important in averaging level control, it is reasonable to use a proportional-only controller.

Comparisons with modelling are not achieved yet because by some factors that is beyond the author control. Thus, the objective to compare between the experimental data and modelling data is not achieved yet. This project will be proceeding after this to achieve the objective stated.

5.2 Recommendation

Up until this stage of this project, there are a few recommendations can be made to give a better result and improvement to obtain a better view of curve in the graph.

5.2.1 Flow Rate

In this experiment, value of controller gain, Kc and integral time is too high. Fruehauf recommend that the following controller setting is about $0.5<Kc<0.7$ and $0.2<\tau_I<0.3$. the presence of recurring high-frequency noise discourage the use of derivative action because it amplified the noise. Furthermore, because flow control loops usually have relatively small settling times, there is little incentive to use derivative action to make the loop respond even faster.

5.2.2 Controller Tuning Relations

In this experiment, only IMC method is used to find out the controller gain and integral time value. It is suggested to use others method as well such as Ziegler-Nichols or Coohen-Coon so that we can compare and find a better result.

5.2.3 Using a Bigger size of tank

It is good to have a bigger tankage so that the interacting process between the two equipment can run smoothly and without any rushing.

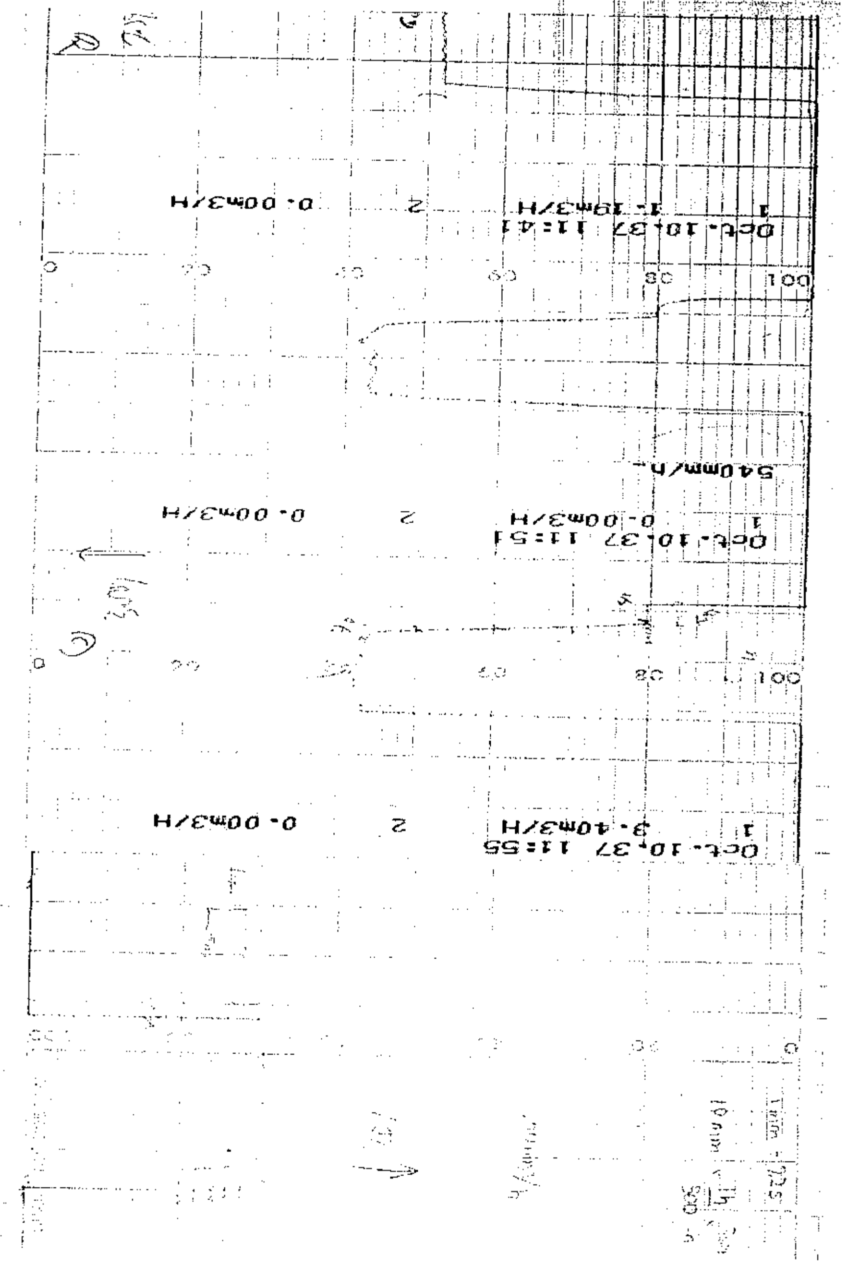
CHAPTER 6

REFERENCES AND APPENDICES

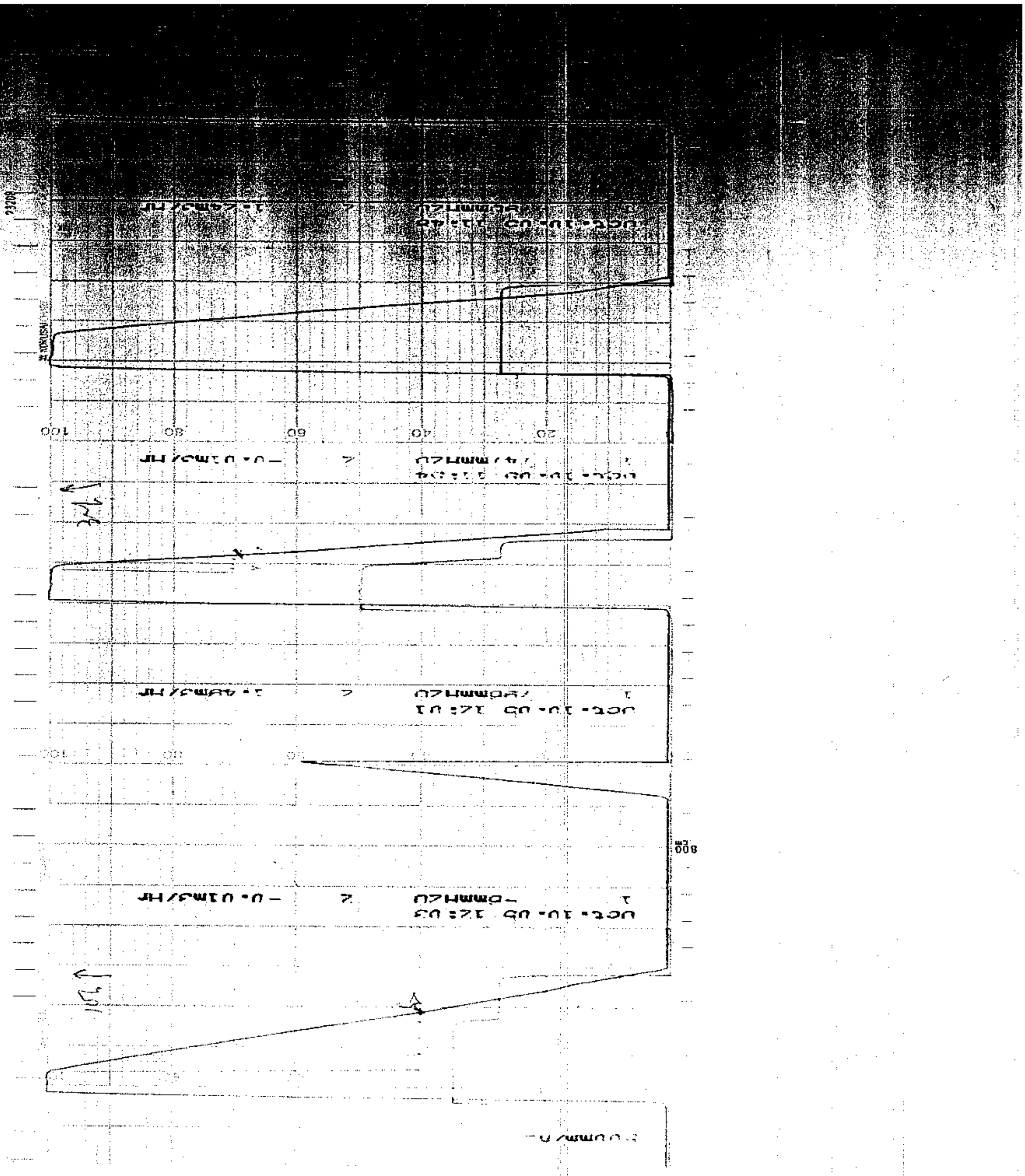
6.1 References

1. Dale E. Seborg, Thomas F. Edgar and Duncan A. Mellichamp, Process Dynamics and Control, United State of America, 2nd Edition, 2004
2. Harold L. Wade, Regulatory and Advanced Regulatory Control: System Development, United State of America, 1994
3. Kevin Warwick, An Introduction to Control Systems, London, 2nd Edition 1996
4. Jacqueline Wilkie, Michael Johnson and Reza Katebi, Control Engineering: An Introductory Coarse , New York, 2002

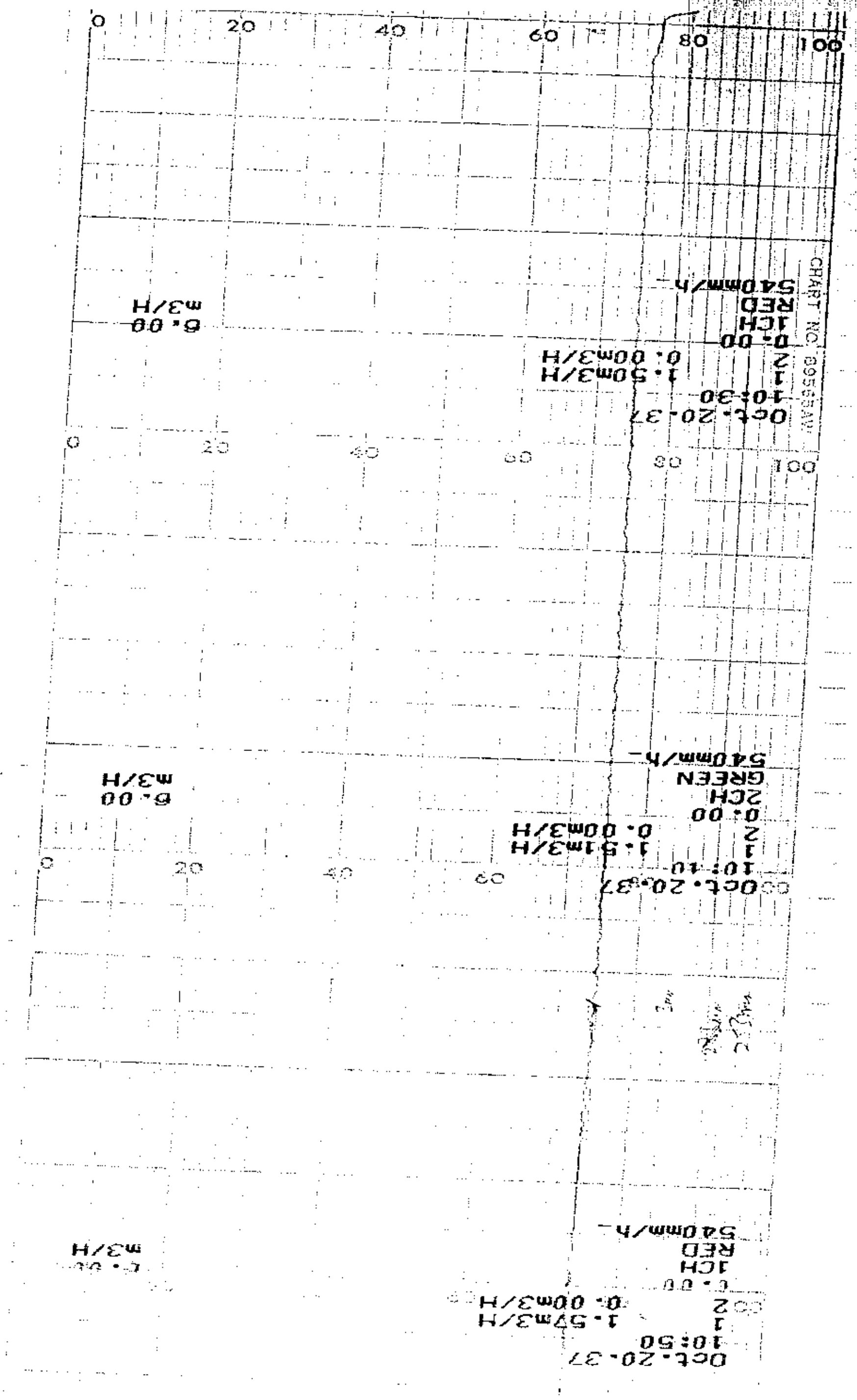
6.2 Appendices



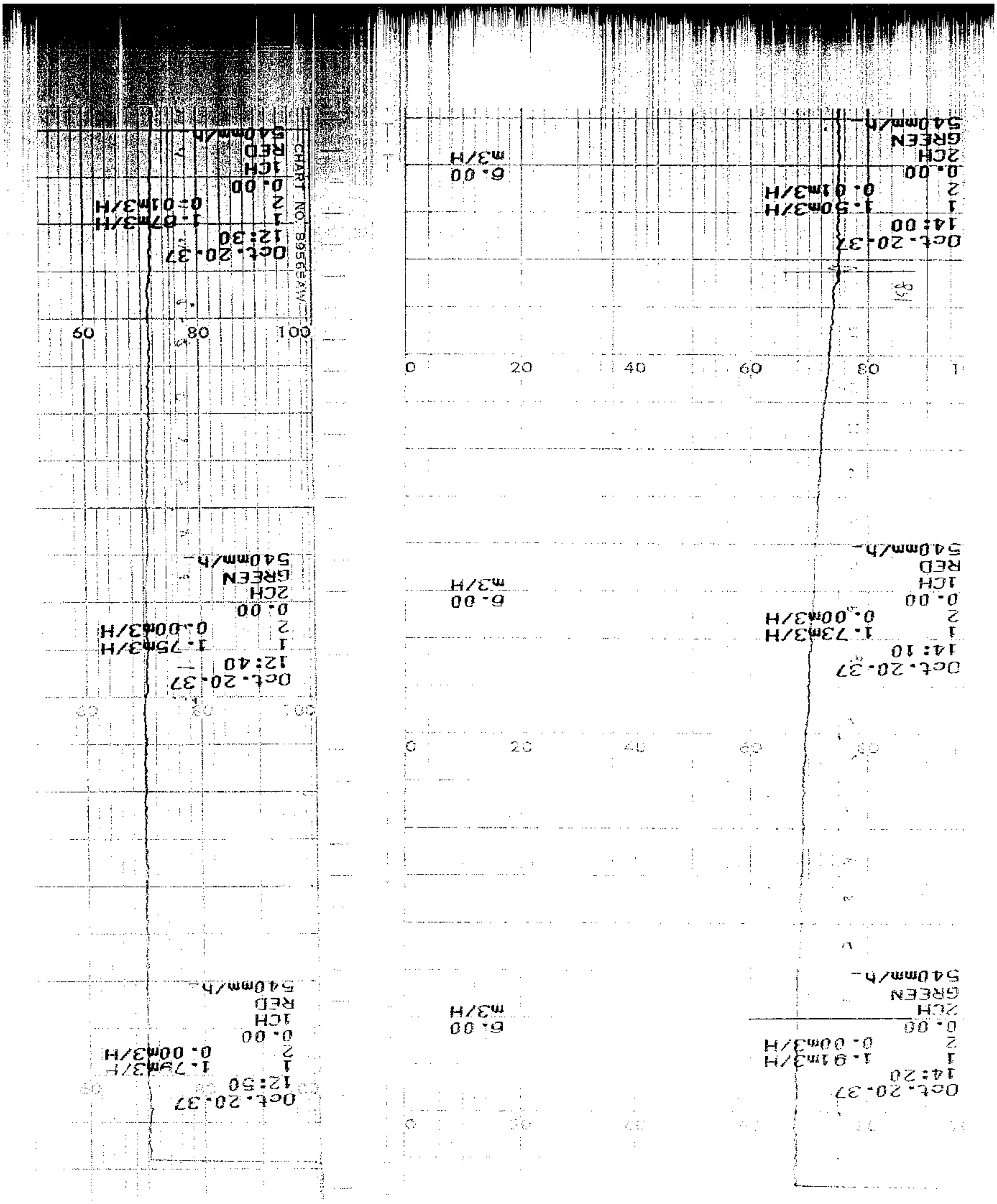
Open-loop SCADA graph for FIC31



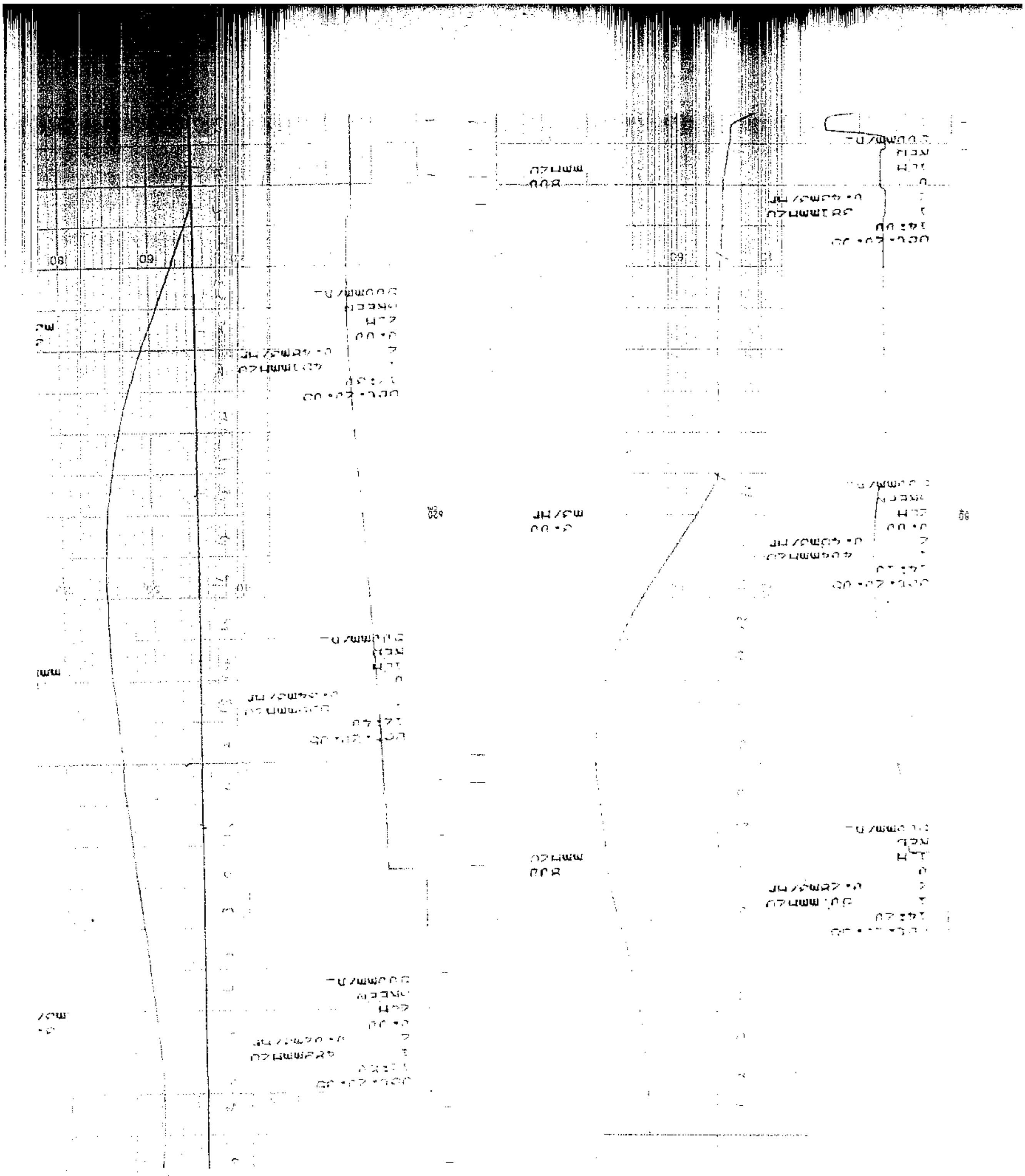
Open-loop SCADA graph for LIC31



Close-loop SCADA graph for FIC31 (change of set point for 10%)



Close-loop SCADA graph for FIC31 (change of set point for 20% and 30%)



Close-loop SCADA graph for LIC31 (change of set point for 20% and 30%)