GUIDELINES FOR THE STRUCTURING OF A USER REQUIREMENT SPECIFICATION IN THE PROCESS CONTROL INDUSTRY

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RIGLYNE VIR DIE STRUKTURERING VAN 'N GEBRUIKERSBEHOEFTE SPESIFIKASIE IN DIE PROSESS BEHEER INDUSTRIE

OMVANG VAN DIE STUDIE

'n Gebruikersbehoefte spesifikasie (GBS) in die proses beheer industrie beskryf die kliënt of gebruiker se vereistes waaraan 'n proses beheer sisteem moet voldoen en behoort dan ook deur hom of haar geskryf te word. Vir hierdie rede is dit belangrik dat die kliënt geidentifiseer word by die vroegste moontlike geleentheid en ook bewus gemaak word vir die behoefte vir en sy verantwoordelikheid om so 'n spesifikasie voor te lê.

Die GBS vorm die basis vir die kies van oplossings en kan ook beskou word as 'n tender uitnodigingsdokument waarop ontwerp ingenieurs hul oplossings formuleer. Vir hierdie rede moet die spesifikasie geen persepsie van 'n oplossing in terme van sagteware of hardeware bevat nie behalwe waar daar sekere voorkeure bestaan. Later in die funksionele spesifikasie fase van die projek lewenssiklus sal die ontwerp ingenieurs in detail beskryf hoe daar aan die behoeftes in die GBS voldoen sal word.

Uit die kliënt se oogpunt moet sy bepaalde behoeftes in die GBS gedefinieer word, terwyl vanuit die ontwerp ingenieur se oogpunt die GBS 'n sterk platform daar stel vir die projek ontwikkelingsprogram. Dit veroorsaak dat minimum misverstande en hul gevolglike vertragings op latere stadiums in die projek ondervind word.

Die GBS moet dien as die enigste manier om behoeftes te kommunikeer tussen die kliënt en die ontwerper of verskaffer.

Die vaardighede van kliënte kan varieër. Die kliënt kan in 'n bepaalde geval die aanleg of chemiese ingenieur wees, die instrumentasie, elektriese of aanleg bestuurder, die verskaffer of vervaardiger van 'n sisteem, die kontrakteur of installeerder van die sisteem of die vervaardigende besigheidseenheid. Addisioneel mag die kliënt ook nie die nodige ondervinding het om behoeftes te spesifiseer nie.

In groot projekte is die ontwerp of projek span, wat gelei word deur die projek bestuurder, verantwoordelik vir die volledige omvang van die proses en projek spesifikasies. In hierdie omstandighede is die onderrig van die kliënt deur die ontwerp ingenieur baie belangrik en moet dit ook vooraf as 'n oorhoofse item in terme van tyd en koste goedgekeur wees. Die voordele hiervan vir die kliënt en die ontwerper behoort te dien as regverdiging van enige addisionele koste.

In die velede was daar 'n neiging deur kliënte om beheer sisteme te beskou as "swart kaste". Hierdie benadering kan uitgeskakel word deur goeie samewerking tussen die ontwerpers en die kliënte. Deur die kliënt "aan boord te kry" en deur aan hom te verduidelik wat alles moontlik is, gee altyd aanleiding to 'n goeie GBS.

'n Hollistiese benadering behoort geneem to word in die oorweging en spesifisering van wat die verwagte impak wat die implementering van 'n projek op die besigheid sal hê. Dit kan gedoen word deur die besigheid te vergelyk voor en nadat die projek geimplimenteer is.

In die GBS word al die veranderlikes wat 'n invloed het op bogenoemde sisteme vooraf geidentifiseer en gelys. Gedurende die ontwerp fase van die projek word hierdie veranderlikes dan geadresseer en in die ontwerp ingebou om maksimaal voordeel te verkry vir die kapitale koste wat aangegaan word vir die implementering van die projek.

PROBLEEMSTELLING

In die Suid Afrikaanse omgewing, en spesifiek in die proses beheer industrie, is hoër produktiwiteit, meer effektiwiteit en verhoogde werkverrigting essensieël vir industrie oorlewing. Projekte behoort voltooi te word tot beide die kliënt en die ontwerper se tevredenheid. Nie die kliënt of die ontwerper of verskaffer kan dit enigsins bekostig om te argumenteer oor wat in die projek kontrak moes gespesifiseer gewees het nie. Sodoende word kontrakbreuk aangeleenthede tot die minimum beperk.

Oorspandering in terme van koste en tyd gedurende die uitvoering van projekte is 'n algemene probleem wat veroorsaak word deur voortdurende projek omvang veranderinge deur die kliënt en verkeerde interpretasies deur die ontwerper of verskaffer van wat die kliënt werklik wil hê. Baie groot kontrakte is al verloor deur die kleinste van tegniese aspekte wat die kliënt vergeet het om in te sluit in sy of haar behoeftespesifikasie.

In hierdie navorsingsverslag sal sekere sleutel aspekte voorgestel word wat geadresseer behoort te word gedurende die opstel van 'n GBS. Die GBS kan dan geskryf word tot die tevredenheid van al die partye wat by die projek betrokke is.

DOELSTELLINGS VAN DIE ONDERSOEK

Die oorkoepelende doelstelling van die studie is die beskrywing van die inhoud, raamwerk, voorbereiding en hersiening van 'n gebruikersbehoefte spesifikasie vir die gebruik in die proses beheer industrie. Die doel is nie om 'n instruksie of prosedure te voorsien nie, maar om dit eerder as 'n riglyn te laat dien om die belangrikste behoeftes en beste praktyke gedurende die projek lewenssiklus te identifiseer.

NAVORSINGSMETODOLOGIE

'n Kwalitatiewe metodologie is gevolg in die navorsingsondersoek. Formele onderhoude is gehou ten einde data in te win en om addisionele informasie oor huidige gebruikerbehoefte spesifikasies wat in gebruik is, te versamel. Hieruit kan die kritiese elemente bepaal word wat nodig is om 'n goeie GBS in die proses beheer industrie op te stel om 'n kompeterende voordeel aan die maatskappy te verskaf. Hierdie elemente sal dan gekombineer word met die ondervinding van die skrywer oor die spesifieke onderwerp en dan saamgestel word in 'n riglyn. Verder sal 'n vinnige verwysingslys voorgestel word om die volledigheid van die GBS te toets.

GEVOLGTREKKINGS

Met die uitvoering van die navorsingsstudie kan die volgende gevolgtrekkings gemaak word:

- Uit die ontleding van die resultate het daar baie gemeenskaplike fiete, probleme en voorstellings oor die onderwerp uitgekom, wat 'n indikasie is dat almal doen die basiese en belangrike aspekte korrek, maar dat dit die kleiner en partykeer onbelangrike dinge is wat die struikelblokke in die uitvoering van projekte veroorsaak.

- Geen formele strukture of riglyne vir die opstel van behoefte spesifikasies bestaan huidiglik binne die maatskappye wat ondersoek is nie. Maatskappye en individue besef die belangrikheid van 'n GBS, maar niemand het nog enige poging aangewend om die enorme hoeveelheid kennis en ondervindinge van individue in die maatskappy te ontgin en te dokumenteer in verband met hierdie onderwerp nie.

- Teorie oor hierdie onderwerp is baie skaars. Geen gepubliseerde artikels oor die onderwerp kon gevind word nie. Maatskappy interne dokumente soos kwaliteit versekering, standaarde, prosedures, riglyne, kontrak en tender dokumente bevat sekere aspekte van spesifikasies, maar is egter baie onvolledig.

- Omdat daar geen vaste riglyne bestaan met die spesifisering van behoeftes nie, onstaan wrywing en valse persepsies tussen kliente, verskaffers en onwerpers aangesien, die werklike behoeftes nie altyd bevredig word nie.

- Die sleutel tot 'n goeie spesifikasie is beplanning. Voordat die spesifikasie geskryf word, moet die hele projek goed deurdink word. Die spesifikasie transformeer dan hierdie beplanning in woorde.

- Die struktuur van die GBS hoef nie noodwendig in die volgorde wat voorgestel word in Hoofstuk 5 gebruik te word nie. Meer detail aspekte wat aangespreek behoort te word, word bevat in die onderafdelings.

AANBEVELINGS

Uit die navorsing wat gedoen is kan die volgende aanbevelings gedoen word:

- Hierdie studie behoort gebruik te word as riglyne en nie as prosedures of standaarde nie.
- Die toepassing van hierdie riglyne moet buigbaar wees en behoort met inagneming van die tipe en grootte van die projek, aangepas te word tot voordeel van die onderneming.
- Die aanbevole riglyne is hoofsaaklik van toepassing op die proses beheer industrie maar kan met sukses ook toegepas word in die rekenaar industrie.
- Soortgelyke studies kan gedoen word vir die meganiese, elektriese en siviele dissiplines wat normaalweg gebruik word in projekte.

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CHAPTER 1

NATURE AND SCOPE OF STUDY

1.1 INTRODUCTION

Within a project environment, a User Requirement Specification (URS) in general is a written document, listing all **the needs and expectations** of the client. It is concerned with describing **what the client** wants from the project or a system to do and as such should be written by him or her. For this reason it is important that the client is actually identified at the earliest possible opportunity during the initial stages of a project and that he is aware of the need for and his responsibilities to produce the URS.

The client, where possible, should be assisted by a design engineer to explain the purpose of the URS, each section of the document and provide technical guidance.

The URS forms the basis for the selection of a solution and can be thought of as an "invitation to tender" document, upon which design engineers will base a solution. According to Skrokov (1980:193), the URS has two major commercial functions: it serves as an aid in selection of the vendor and as a way of determining exactly what the selected vendor must provide. For these reasons it should **not** contain any perception of a **solution** in either software or hardware terms unless specific client preferences exist. Later in the Functional Specification phase or conceptual design phase of the project life cycle (refer to figure 3.1), design engineers will detail **how** the requirements in the URS are to be met.

From the client's viewpoint, the URS should define **what** is required, and from the design engineer's or developer's view, the URS should form a strong foundation of the development programme and create an environment on which the project design is based. This should minimise unnecessary misunderstandings with their consequent delays at a later stage.

The URS should serve as the only means of communicating requirements between the client and developer or supplier.

1.2 BACKGROUND TO THE STUDY

The skill of clients varies. The client in a particular case may be a plant or chemical engineer or an instrument, electrical or plant manager or the supplier of a system. He may also be the contractor or implementor of the system, or even of another discipline. Additionally, the client may not be experienced in specifying requirements.

The appropriate project manager or project director leads the design or project team on large projects. This person is responsible for agreeing the detailed scope of the process and the project specifications, which is critical for the success of the project. Obviously, for the beneficial client input in these circumstances, education of the client by the design engineer is essential **and preferably should be pre-sanctioned in terms of both cost and time**. The benefits that accrue for clients and developers should more than mitigate any extra expenses.

In the past, there has been a tendency for clients to regard systems "black boxes". This approach, so often found to be wanting in the past, can be eliminated with good co-operation between design engineers and the clients. Getting the client "on-board" and explaining what is possible almost always leads to a good URS.

In past decades the rate of change for business was relatively slow. Business practices and procedures can be designed and implemented with consideration and sufficient time for refinement (Huntly, 1995:G1-1). Therefore, a holistic approach should be taken by considering and specifying what the impact is expected on the business by comparing the business before the implementation of the project and after the refurbishment or implementation. This impact is usually on the following systems:

- People - required with specific capabilities and skills. The compliment of manpower can decrease or increase. An example is the automation of processes where the manpower compliment is decreased.

- Inputs - in terms of type, quantity and quality. An example is when a plant is extended to manufacture new products and requires different raw materials.

- Process - it may change slightly or significantly leading to additional plant infrastructures, training of people and operation issues.

- Plant - including mechanical, civil, electrical, control and instrumentation and documentation.

- Procedures and paper systems - in terms of operational, training, equipment maintenance, legal, safety and control.

- Business results or performance - in terms of high production rates, plant availability, plant efficiencies and quality of produced or sold product.

In the URS, all variables that will influence the above-mentioned systems are initially identified in detail and listed accordingly. During the conceptual design and detail design phases of the project, these variables will be addressed and will be included in the design to optimally justify for the expenditure of implementing the project.

1.3 PROBLEM FORMULATION

In the South African context, and in particular in the process control field, higher productivity, more effective and increased efficiency is essential for industry survival. Projects should be completed to both the client and the developers or supplier's satisfaction. Neither the client, nor the supplier can afford any more to argue what should have been included in the project contract during contract breaching cases.

Over expenditure in terms of costs and time during execution of projects is a general problem, caused by continuous scope changes by the client and misinterpretations by the supplier of what the client really requires.

The following additional minor problems are continuously experienced with almost every project:

- Documentation is inadequate in quantity and quality.

- Managers and users do not know where things stand.

- Systems do not adequately take advantage of new design methodologies or new technologies.

- Users are not satisfied with the final product resulting in partial or total rejection.

Many major contracts have been lost on the smallest of technical issues that the client neglected to include in his or her need's specification.

In this dissertation, certain key issues will be proposed that should be addressed during the compilation of a user requirement specification. The URS can then be written to the satisfaction of all the project parties concerned. It is not to provide a procedure or instruction, but rather a guidance to identify the mandatory requirements and best practices during a project life cycle.

1.4 OBJECTIVES

A qualitative investigation will be done for the study aiming firstly at investigating the contents and structure of compiling a URS for use during a project and secondly, investigating what indirect benefits can be realised by using a proper compiled document. Publicised articles and documents are not readily available, and the objective is also to search company related and specific data on this subject. A questionnaire will be distributed specifically to potential users and this will be followed up with personal interviews to extract the wanted information from the relevant personnel.

The primary and secondary objectives to be achieved in this study can be listed as follows:

1.4.1 PRIMARY OBJECTIVES

The primary objective of this dissertation is to describe the recommended content, layout, preparation and reviewing of a user requirement specification for use in the process control industry. Such a document will be utilised by the following groups of people:

- Clients - who write user requirement specifications.
- Process production organisations - when specifying new process control systems.
- Design engineers - who formulate solutions in the process control environment.
- Software developers, programmers and configurators - during the programming of software applications.
- Project engineers - in the executing of discipline engineering during the project phases.
- Project managers - in their management of process control projects.
- Reviewers of user requirement specifications - to ensure requirement and contract conformance.
- Contractors and implementors of systems - to ensure the erection of the plant or system are physically and technically correct as specified by the client.

1.4.2 SECONDARY OBJECTIVES

The indirect or secondary objectives to be reached with this dissertation are the following:

- To research the literature that is available in the form of technical manuals and articles, as well as the unpublished and internal documentation from the mayor role players in the South African process control industry.
- To provide a basis or platform from which a control system project can be executed cost effectively.
- To ensure continued client satisfaction as the project can be measured to his or her requirements.
- To provide an effective means to manage change and project variation changes.
- To form the platform on which a process control project can be built, as all the other phases of the project will use this platform in an iterative process to ensure specification conformance.

1.5 FRAMEWORK OF THE STUDY

1.5.1 INDUSTRY

The field of the study is specifically focusing and was conducted on the process control industry and company resources available in South Africa. However, most of the companies consulted, originated from abroad and are still dependable on their mother companies for technical backup and expertise.

1.5.2 MAGNITUDE OF STUDY

The targeted industries using automated process control systems as part of their production processes can be extended to any industry plant in South Africa. The major players are petroleum, chemical, mining and manufacturing. These organisations are currently using their own project and technical personnel, the supplier of a particular system or external contractors to execute projects.

Expertise (people's knowledge), published articles, unpublished internal company documents and technical manuals were used for this research.

The target population of the investigation included:

- Five major South African process system suppliers.
- End users of the process control systems
- Construction companies.
- Implementors, integrators, engineers, developers, programmers and configurators of these systems.

The following subjects will also be described in detail:

- The importance of the user requirement specification phase, in a typical project life cycle.
- The elements of a good user requirement specification.
- The contents of a typical user requirement specification.

- The considerations to ensure the completeness of the user requirement specification.

The characteristics, advantages, disadvantages and key benefits of the above mentioned subjects will be investigated to determine how a guideline can be compiled in a synergistic and structured format.

1.6 RESEARCH METHODOLOGY

Very little information is available on this specific subject and whatever information is available, is difficult to get hold off. It is therefore decided to follow a qualitative methodology in the research investigation. The market research method will be used in combination with the method to use similarities of related problems that clients experienced in the past. These two methods will then be supplemented with the author's own experience in this field.

A questionnaire will be sent out, which will form the agenda for the formal interviews to be held to gather data and to collect additional information on current user specifications systems in use. Refer to Annexe A for the introduction letter and questionnaire. The gathered information will determine the requirements that are necessary for a good user requirement specification in the process control industry to provide the much needed competitive edge. These requirements will then be compiled with the author's own experience on this particular subject. A quick reference or checklist will be provided to ensure the completeness of the requirement specification.

1.7 LIMITATIONS

In general, literature in the form of articles and books on this specific subject is not commonly available. This dissertation will therefore be concentrated on available subsections embedded in system and engineering manuals, company specific quality manuals and documentation, the knowledge base of people in companies and the author's own experience in this specific field.

This study has been conducted and is intended to be only applicable to the process control industry. The recommended guidelines that are proposed should only be used as a guideline and not as standards, instructions or procedures.

1.8 CONCEPT EXPLANATIONS

The following concepts will be used in the study and is explained in more detail as follows:

1.8.1 QUALITY

Success in business depends ultimately upon satisfied clients who return and products that do not. However, the question is how to satisfy clients. According to Baulch-Jones (1993:49), this is achieved by meeting their requirements constantly. This does not happen by chance, but requires effort on behalf of management and employees to organise themselves to achieve client satisfaction. A quality management system must therefore serve the client and not itself. A URS can not be considered in isolation from a quality system, but forms an integral part of quality.

Fowler and Fowler (1988:843) describe *quality* amongst other words as "a degree of excellence" and "a relative nature or kind or character". These attributes can be described in general as:

- Fitness for purpose.

- Meeting the specification.

- Meeting the client's requirements.

- Getting it right first time.

1.8.2 GUIDELINES

Fowler and Fowler (1988:443) define a ***guideline*** as "a directing principle" and in general can be seen as:

- A set of direction giving indications based on best knowledge and practices.

- The state of the art principles followed from the empowerment of people.

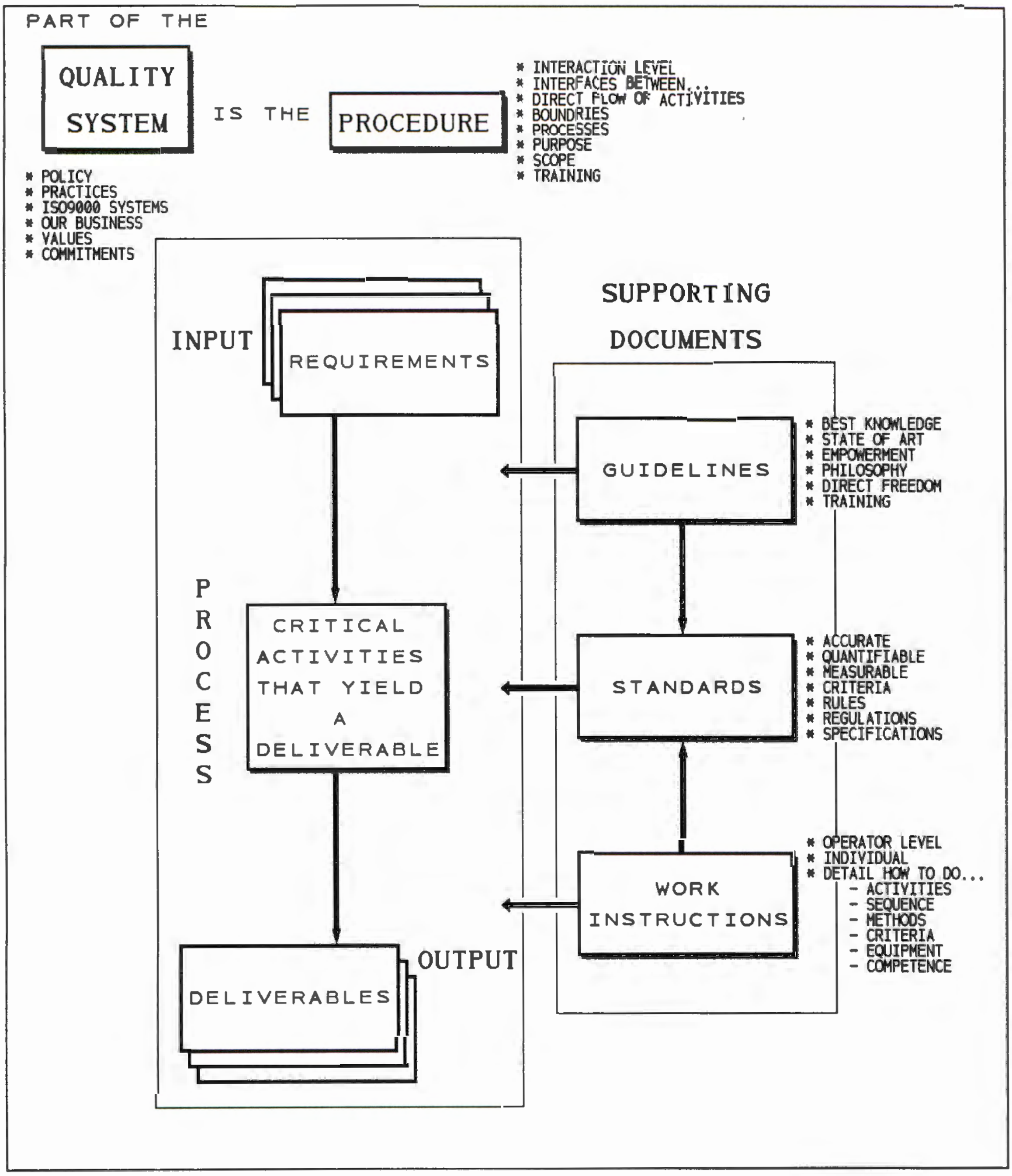
- The formulation of philosophies.

- An aid for training.

- An invitation for people to use their freedom.

This dissertation serves as a guideline in support of the establishment and recording of the requirements and should be considered as depicted in Figure 1.1 below.

Figure 1.1: Use of guidelines in support of the quality system



Source: Anon. (1995:Annexe 2).

1.8.3 SUPPLIER

Fowler and Fowler (1988:1072) describes a *supplier* as somebody who "finish, provide, make up for, meet, serve to obviate and to fill". In general the supplier can be described as the original equipment manufacturer (OEM) or the local agent doing business on behalf of the

OEM. The supplier will supply or provide the hardware and software platform(s) that can be considered as a "package" or system.

1.8.4 CLIENT OR CUSTOMER OR USER

Fowler and Fowler (1988:173) define a *client* as "a person using the services of professional man". The client or customer is the end user of the system, which receives the direct benefits. This is the person or entity to specify the requirements or give the inputs to what the proposed system should be complied. The client represents the business and can be a single person or a group of people consisting of multi-disciplined personnel, each to specify particular aspects of the requirements.

1.8.5 IMPLEMENTOR

The definition of *implementor* can be derived from the definition of implement (Fowler & Fowler, 1988:501) to "complete, fulfil, put into effect, fill up or supplement". The implementor is the person(s) or entity who uses the software and hardware platform(s) from the original equipment supplier and matches it to a specific application. These include further development, programming and configuration, functional and detail design, and construction and physical integration or connectivity.

1.9 LAYOUT OF THE STUDY

Chapter 2

This chapter gives a short functional overview of what is involved in a typical process control system, the importance, the uses, the problems associated with the installation, costing and financial issues. The beneficial operation and functional integration of such a system leads to overall factors that prompt this study.

Chapter 3

This chapter explores the theoretical aspects of the user requirement specification with regards to the project life cycle and the characteristics of such a specification.

Chapter 4

This chapter explains the method of gathering data and indicates the results obtained from the study.

Chapter 5

This chapter takes the gained knowledge and results from the study and formulates the recommended guidelines for the user requirement specification.

Chapter 6

This chapter is an extension of the previous chapter and proposes some guidelines for the production and review of the user requirement specification.

Chapter 7

This chapter concludes the study and makes recommendations to the process control industries.

CHAPTER 2
FUNCTIONAL OVERVIEW OF A TYPICAL PROCESS CONTROL SYSTEM

2.1 INTRODUCTION

A typical medium to large manufacturing plant consists of raw material inputs, a conversion process to convert these inputs and the converted outputs which are normally the saleable products. The process control system is typical an electronic system to control the conversion process and can be manually or automatically operated by an operator. Modern process control systems operates on a computer-based platform and operator display stations provide a visual interface of the process to the operator. Manufacturing costs during any process is relatively high, and the manufacturer always strives to reduce costs, optimise the process and increase the throughput. Older plants are still operated manually and the tendency is to automate these plants with modern control systems such as Distributed Control Systems (DCSs), Programmable Logic Controllers (PLCs) and Supervisory Control Alarming and Data Acquisition Systems (SCADAs).

The aim of this chapter is to give a short functional overview of what is involved in a typical process control system, the importance, the uses, problems associated with the installation, costing and financial factors. The factors that prompt this study will be discussed in order to fulfil the overall purpose of beneficial operation and functional integration of such systems. Not much detail will be discussed in this chapter, but the aim is rather to explain the concepts.

2.2 BACKGROUND

For over 100 years, South Africa has exploiting its rich mineral wealth. We have developed leading techniques and technologies to deal with the conditions encountered in deep mining, shallow mining and surface mining. Perhaps the greatest criticism levelled against our mining industry is that it becomes too successful. We have come to rely on it as our primary source of exports and as one of our biggest employers.

Now that South Africa is taking its rightful place on the economic stage, we have to be very aware that the leading industry nations never base their economies on primary industries like mining and agriculture. Instead, secondary and tertiary industries such as manufacturing, services and technology form the backbone of an international, world-class economy.

Surveys conducted in the last few years have shown that 83% of the instrumentation requirements of South African industries come from overseas suppliers, mostly from Germany, the United States, United Kingdom and Japan. These products are mainly distributed through the local offices of overseas manufacturers and the amount of local value added is practically zeroed. This high level of dependence of imported products is all the more surprising considering the amount of disinvestment and import restrictions that took place during the 1980s.

With a few notable exceptions we have been stuck **with what overseas manufacturers think we need for our industries.** Of even greater concern, we have only a very small technology and manufacturing platform upon which to build our own process control and instrumentation industry.

The number of different types of control and field instrumentation is vast and includes the following:

- Programmable logic controllers (PLCs) and distributed control systems (DCSs) of endless variety for control.
- Pressure and flow transducers.
- Temperature and pressure sensors.
- Level and position indicators.
- Alignment lasers.
- Fieldbuses and repeaters.
- Fibre-optic communication systems.

The list is long and the number of applications is endless.

What can we do to develop all our process control and instrumentation products and requirements to higher levels? Richards (1997:4) states that there is an oft-cited dictum stating "Think globally but act locally". This has never been more appropriate than it is now in South Africa. The transition of South African industry from its primary roots to a globally competitive manufacturing sector will rely on a commitment by existing companies to local technology. Furthermore, in order for our manufacturing sector to effectively export its technology and systems, it will need as much local content as possible. It is no longer a luxury for South Africa to expand into export markets. It is now a necessity (Toffler, 1991:58). We should not underestimate the capability of local manufacturing to compete in a global market. It takes technology, products, manufacturing facilities, and marketing. In the process control and instrumentation fields, the first three can only be developed with the support of our established manufacturing industries.

2.3 PROCESS OVERVIEW

The conversion process of a typical plant is represented on paper either as engineering line diagrams (ELDs) or Process and Instrumentation diagrams (P&IDs). Annexe B gives a representation of an engineering line diagram (ELD) of a typical steam and condensate system for a chemical plant. This diagram is also a direct representation of the display for the operator, indicating the information required for operating the plant.

From this diagram, the mechanical vessel F008 represents a condensate drum, and F009 and F010 represent heat exchangers. The instrumentation in the form of measuring sensors are indicated as tags with the prefix FIC for a flow controller, prefix LIC for a level controller and prefix LAH for a high level alarm. The controllers are connected to control valves situated in the pipeline. Various measuring sensors or primary elements are on the market available, which can be used in a wide range of applications. Similarly, a complete range of control devices or final control elements is available for use to control any type of process.

2.4 APPLICATIONS OF PROCESS CONTROL SYSTEMS

Process control systems, with their ability to process the masses of data and measurements necessary to gauge conditions and evaluate changes in a complex system, are ideal controllers of production operations and processes. Manufacturing, research, medical, communications, military, space, and governmental groups are realising the direct benefits of process control systems, which include the following:

- Reduced operating costs - more efficient utilisation of material, power, and equipment.
- Increased production - greater throughput or yield and reduced unit cost.
- Better product quality control - less quality give-away, less off-specification product.
- Labour and equipment savings.
- Safety - immediate proper corrective action can be taken as well as merely activating alarms or printouts of special instructions.
- Research - process improvements resulting from detailed analysis of data, and development of new processing techniques, now impracticable, which become possible if operation is under computer-control.
- Real time control.

2.5 CONTROL SYSTEM OVERVIEW

All the electrical control signals are routed to the main control room. The distributed control system (DCS) provides a window to the operator in the form of a computer screen(s). All information is displayed on these screens. Interaction with the control system is via a pointing device such as a keyboard, tracker ball or mouse. The control system can interface to other foreign equipment such as printers, other computers, and recorders. Operators are situated in the control room from where the plant is controlled.

A typical plant is operated in the following way:

- Electrical analogue signals are routed from the measuring sensors to the main control room where they enter the distributed control system (DCS) via the input hardware. These signals are displayed in the schematics on the visual display units (VDUs) in front of the panel operator. The specific process conditions in the pipeline can be changed with the control valve situated in the pipeline. The operator enters a percentage value for the controller output and this output value is converted to an electrical analogue signal, routed from the output hardware to the control valve in the pipe. The control-valve then opens or closes, depending on the percentage output given.

- Similar electrical digital (on or off) input signals are received from level switches, limit switches, and temperature, pressure and flow sensors.

- Electrical output digital (on or off) signals are used for the stopping and starting of electric motors, pumps, fans, blowers and compressors, and closing or opening of shutdown valves.

- The control system provides to the operator other information such as alarms, reports, logs, graph and trending displays.

2.6 PROCESS CONTROL SYSTEM FUNCTIONS

A typical process control system provides the following functions to the operations, maintenance and managing personnel of the specific plant:

2.6.1 FOR THE OPERATOR

The process control system is critical to the operator and establishes his daily working environment. It also provides to him a means of controlling large capital equipment, plant, raw materials and services to directly produce some return on the capital invested by the shareholders. In order to create this environment, the control system should provide the following functionality:

- A window to the plant through schematic displays on screens.
- Automated control.
- Alarming of out-of-range signals.
- Reports, logs and events.
- Modelling of the processes.
- Historical trending of data.
- Data logging.
- Programming and calculations.
- Built-in product support.
- On-line product tutorials.
- Shutdown and interlocking of the plant.
- Sequencing and batch applications.

2.6.2 FOR MAINTENANCE PERSONNEL

In order to perform a good and reliable maintenance service to the plant and to increase the plant availability and on-line time, the following functionality should be available from the system to assist the maintenance artisan or technician in his day-to-day duty:

- Documentation of software.
- On-line diagnostics.
- Diagnostics on the hardware down to card level.
- Scheduling of equipment for maintenance.
- Trip and alarm checks.

2.6.3 FOR MANAGEMENT

Functionality to senior management is becoming increasingly important in assisting in the decision making, marketing strategies and production scheduling of the business. This would typically includes the following:

- Dynamic data exchange (DDE) to spreadsheet and word processing packages.
- Accounting data.
- Efficiency reports.

2.7 CAUSAL FACTORS TO THE STUDY

The causal factors leading to the undertaking of the study are identified and are discussed in more detail in the following sections.

2.7.1 BUSINESS ENVIRONMENT

The dynamic business environment of today with its vast amount of general, critical and special requirements makes it difficult for any company to stay in the mad race of production and manufacturing. Today's business climate is changing, and changing at an ever increasing pace, and to be able to gain the competitive edge on the opponents, an enterprise must become real smart. Environmental restrictions, globalisation and technology innovations demand from a company to be reactive and pro-actively adaptable to changes in its environment. Productivity in the South African manufacturing sector has been a concern for a decade now. The question to ask is what can be done to make the control of our processes better, to convert our raw materials more efficient, and simply to stay in business? This can be achieved by implementing projects on schedule or even faster, within budget, and still realising the effect of synergy.

2.7.2 NEW TECHNOLOGY

The process control industry has witnessed vast changes in technology due to the rapid development of distributed control systems (DCSs), programmable logic controllers (PLCs) and personal computer based supervisory controlling alarming and data acquisition systems (SCADAs) over the last decade. Adding to this, research is being done to integrate all these systems as the so-called "open systems technology" in which hardware and software from every supplier become compatible to every other supplier. With the development of hardware, the software also did not lag behind. Numerous software application packages are on the market today - the one trying to be better than the other.

More fast-emerging technologies are the emerging of Programmable Emergency Shutdown systems (PESs), the introduction of FIELDBUS, and all the good application software for management systems and modelling of plants.

All these technologies pose a problem to the design engineer. Which system will fit the best for the particular requirement? His decision must benefit the plant with all its expansions, modifications and future upgrades as from day one and for the next ten years to come.

2.7.3 SOFTWARE DEVELOPMENT

Important reasons why project costs are high relate to a lack of software specification, the inability to adapt software developments to changing environments, and a lack of modularity and unnecessarily complex designs. These factors effect the development phases of the life cycle, but their effect is most pronounced in the maintenance phases and after project implementation when modifications are required (Wilkie, 1993:7-8).

With the introduction of the Microsoft range of products, all suppliers are getting on this bandwagon to develop products as soon as possible. Whether the system is running on DOS, Windows NT, UNIX or OS2, new applications are emerging daily, enlarging the problem of local expertise, after sales support, training, compatibility and software upgrades. International standards and structured programming techniques such as SP88, NAMUR and other struggle with the dynamics of these changing environments.

The current problem for the developer and designer is what to select as the main operating system and what applications will suit the specifications best.

2.7.4 THE CONTROL PROBLEM

In most industrial operations, even with highly efficient automatic control systems, the task of integrating the controllers and supervising the process, becomes the responsibility of the operator. He is confronted with a dynamic operation, maybe 100 or more automatic controllers, each acting independently, and a great number of factors that must be equated and interrelated. These factors include not only those relating to the chemistry or physics of the process, but extrinsic economic ones as well.

Equating so many factors involves complicated long-drawn-out calculations requiring several hours or days for solution if done by the desk calculator. When completed, the answers may be useless, for conditions in the process change too rapidly and frequently. From a technical point, because of the dynamics of the processes, the operator relies on his judgement and experience to offset the disturbances such as feed-composition changes, impurities, and changes in atmospheric conditions. The time lags in detecting the disturbances, the operator's inability to assess analytically the effects of changes in controller set-points, and conservatism in making changes which may cause violation of limits, preclude maintaining optimal conditions.

Industrial operation plants are not the same as technology of the processes is different. The type of control system is selected to fit the processing plant and not visa versa. The characteristics which may be used to identify and to evaluate the applicability of the control system to particular processes are:

- The annual value of the product is sufficiently large so that even a small percentage improvement is valuable enough to justify computer control.

- The process is a complex, multi-variable one with many production specifications and operating constraints to be observed.

- The process has a sufficiently long expected lifetime (no foreseeable obsolescence) so that the benefits from computer control will continue for an appreciable time.

- The process is subject to relatively frequent disturbances, which alter the efficiency of operation. Furthermore, it must be possible to adjust the control variables to correct for these disturbances.

- The process is technologically advanced, that is, it must be well understood and well instrumented so that the necessary quantitative relationships, which constitute the system, may be obtained and the performance may be measured accurately.

- The mathematical model of the plant describes the interrelationships that are relevant to the control of the process within the region of economic, physical, and management objectives and restrictions.

- Before optimising a process, it is necessary to know what the process variables are doing at present and to predict what is going to happen to the process if all variables continue in the direction they are going.

To summarise the control problem, the designer or developer has an enormous task to find an optimal solution from the jungle of options on controlling the plant, to produce the required return on investment.

2.7.5 OTHER MINOR FACTORS

Combining with the factors above, the design, specifications of equipment, the physical installation of the systems, construction, commissioning and operation opens a new world of new added problems, too numerous to mention in detail. The final product is normally installed during a shutdown with limited time available. After the shutdown, the plant is required to operate from the new system, with trained personnel, with minimum errors and with all the bells and whistles as required.

People, as operation personnel, maintenance, investigations and management, contribute largely to an unstable project design, overruns of schedules, over-expenditure of the project with their demands and individual requirements, which were not fully listed during the initial stages of the project.

Evaluation of hardware and software technologies to match the requirements, is a heavy burden on the project team. Additionally, evaluation of the supplier and contractor is critical, as all the requirements must be fulfilled.

2.8 SUMMARY

This chapter paraphrased a typical process control overview within the process production environment and explained some of the concepts used in the industry. Typical applications of process control systems are listed and the functionality of these systems for the operator, maintenance and management personnel is discussed. Causal factors to the study is explained and include the dynamic business environment in which the production and manufacturing processes operate, new technology introductions and rapid software developments in process control and the integrated and complex nature of process control. Other minor factors applicable to the physical installation and commissioning are also discussed.

To expand on the factors listed and the background given in this chapter, the following section will concentrate more specifically on the URS, and what characteristics and concepts such a document contains. It will also give a theoretical background on the uses of a URS is and its relationship with regards to the other phases in a project.

CHAPTER 3

ANALYSIS OF THE LITERATURE

3.1 INTRODUCTION

The objective of the theoretical background is to discuss the concepts of a user requirement specification, the relationship of the URS in the project life cycle, and the characteristics of such a specification. The important advantages to a client or the business of using a well-structured and complete URS will be listed.

Specific characteristics of the URS document such as stability, the attributes required for quality, the requirements to reduce ambiguity of a URS document and the completeness and consistency will be discussed. Further important characteristics that will be explained in detail, is the verifiability of the document, and the question whether such a document is traceable and modifiable.

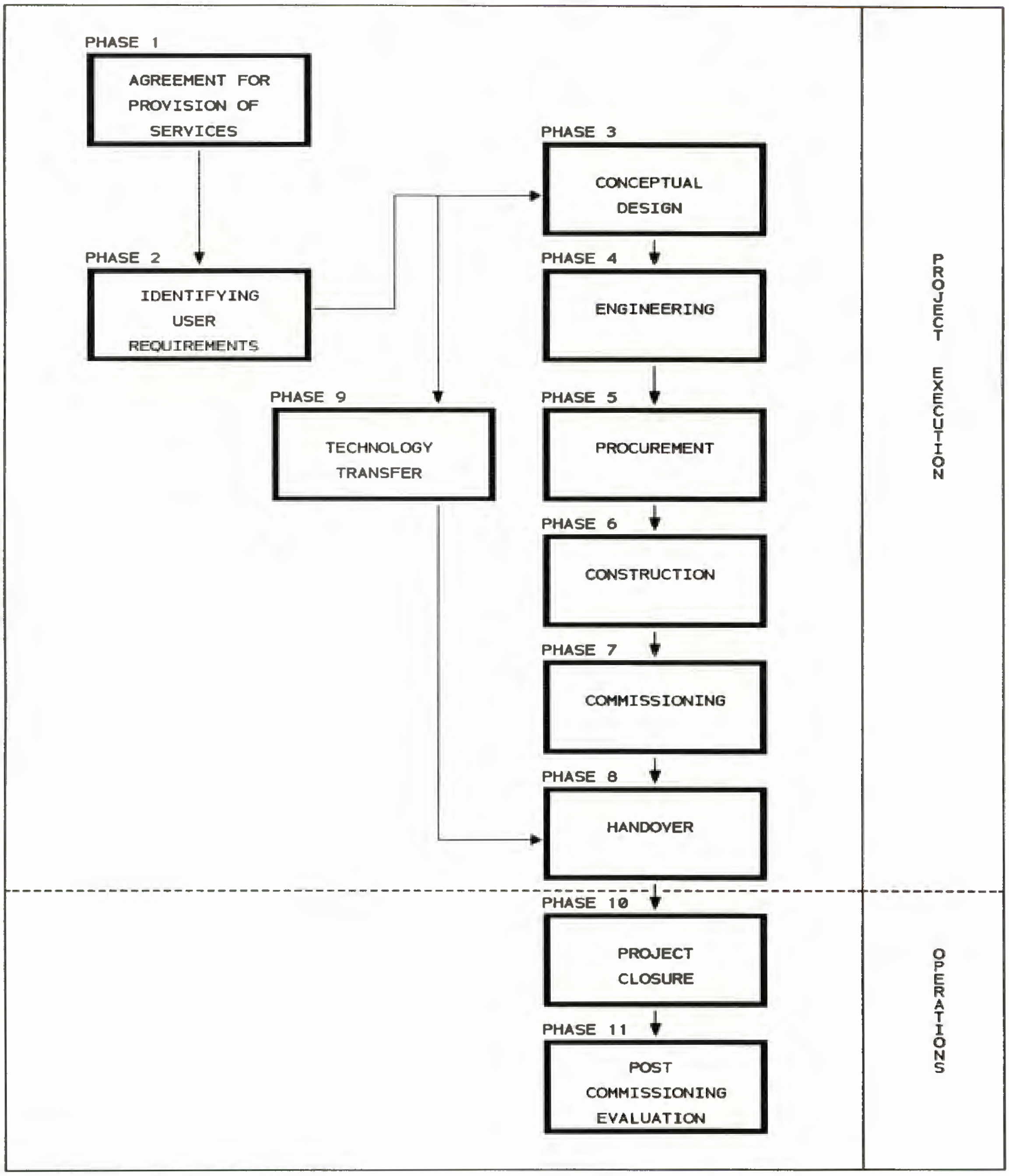
The identified concepts will form part of the compilation of the questionnaire in the investigation section.

3.2 URS AND THE PROJECT LIFE CYCLE

The URS serves as the foundation of any project life cycle. With the firm base of a coherent and complete URS, the entire development process is significantly enhanced. Skrokov (1980:193) states that in order to understand the importance of a URS in a process control project, a basic understanding of the tasks involved in a project and the relation of the URS towards the other phases of the project, is essential.

According to Anon. (1995:7), the relation of the URS phase with regard to the other phases in the complete project life cycle is depicted in Figure 3.1 below.

Figure 3.1: Project Life Cycle phases



Source: Anon. (1995:7).

Within the project phases, a number of definition stages exist. It should be noted that the different project phases overlap. The extent of overlap depends upon the integration of the project activities and is likely to be greatest when a single organisation is involved.

There is also a need for the controlled application of functional skills at different times. The organisation should avoid individual optimisation of each stage with consequent sub-optimisation of the whole. Time, the potential extent and complexities of multiple options and the effective use of effort is likely to make it impractical to recycle the total project activity (Anon., 1997:54).

It is also desirable to present and formally record the information at each stage so that it falls naturally into a consistent package for the particular stage. It will then form part of a final package describing the project, albeit with progressive elaboration.

It is important to stress the continuous iterative process that should be existed between all the phases of the project life cycle. The URS forms the basis of every project and each phase in the project life cycle should be continuously checked against the URS. According to Anon. (1997:55) typical questions that can be asked, include:

- Are all the specifications met?
- Does the design include all the client's requirements?
- Is the training adequate?
- Has a thorough review of the business strategies and plant operations been done?

- Is the emphasis on identification of control and optimisation objectives as well as process constraints and deficiencies?

Once all these checks have been thoroughly balanced against the URS, success of the project can be guaranteed.

Current structured techniques struggle with changing environments and final systems rarely satisfy the needs of the user at the time of implementation (Wilkie, 1993:8). The effects of these problems are:

- High production and maintenance costs.

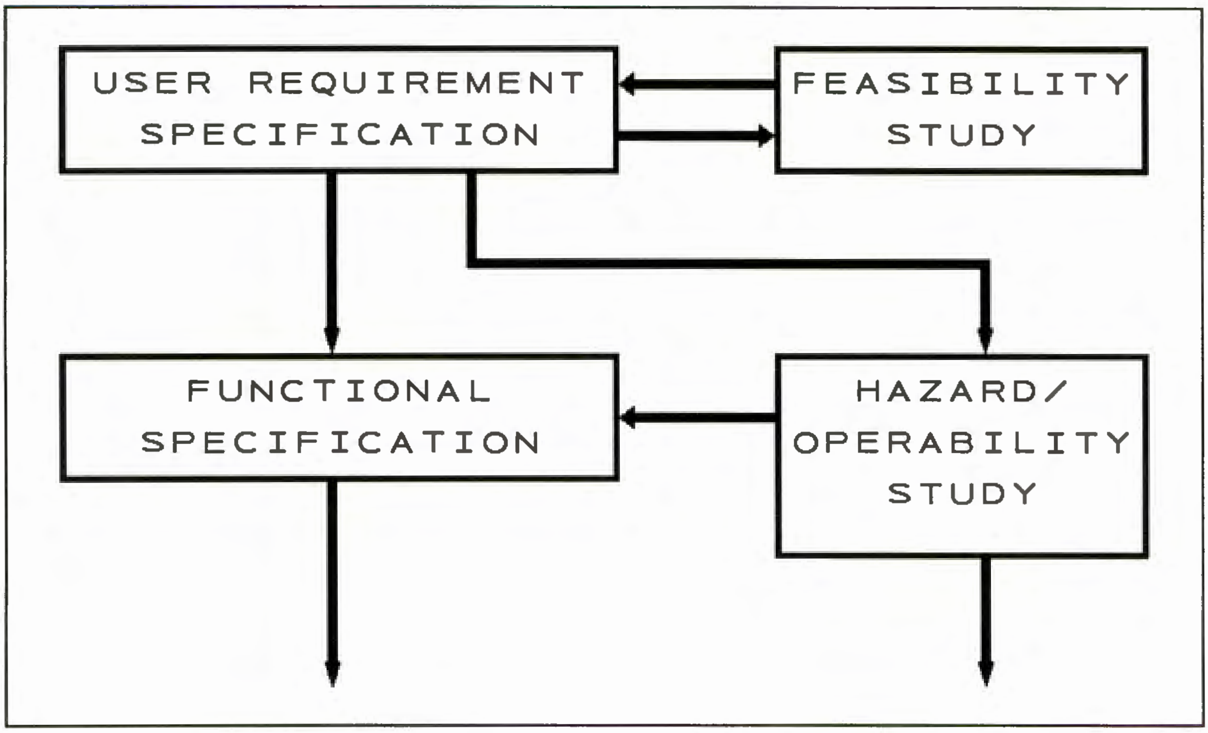
- Loss of competitive advantage through the inability to adapt quickly to a changing market.

- Low return on investment as system evolution diverges from business progression (Wilkie, 1993:8).

In practice, the preparation of (or more exactly the statement of) user requirements in the URS has other less obvious benefits. The URS works hand-in-glove with any feasibility study. Given a distillation of customer requirements in the URS, feasibility assessment becomes more accurate.

Immediately following the URS phase, a preliminary Computer Hazard and Operability Study (Hazop) takes place. If the client requirements are clearly stated, such a study reveals precise measures to be incorporated into the functional specification to maximise safety at an early stage. Figure 3.2 shows the relationship between the URS and these three peripherals, but nevertheless essential activities.

Figure 3.2: The URS in relation to feasibility and Hazard and Operability studies.



Source: Imrie and Nunns (1988:5).

The Functional Specification or Conceptual Design document describes how a supplier or software developer intends to provide a system or systems to meet the requirements defined in a URS.

3.3 ADVANTAGES OF A URS

According to Harwood and Pieters (1990:25) the advantages of a good and well-specified URS can lead to the following advantages:

- Customers would receive what they order - without non-conformances, on time, in the right quantities, shipped, and billed as agreed upon. Problem-free, long-term partnerships between client and supplier would be built.

- The suppliers would meet the client's requirements. Incoming inspections, inventory levels, and administrative problems would be reduced. The "use as is" as a way of handling off-specification material would be eliminated.

- Salespeople would spent their time with clients, understanding their needs and requirements, and getting orders, instead of acting as schedulers or expeditors taking the heat for poor quality, late delivery, or paperwork errors.

- New products and processes would be developed to agreed-upon requirements, as scheduled and at lower costs. Without the waste that results from changing requirements and subsequent re-work, more time would be available for positive creative development.

- People would enjoy their work, as they become proactive in doing their jobs. They would stop spending large amounts of time responding to crises and dealing with a constant level of recurring non-conformances and errors.

- By reducing misunderstandings between client and supplier, clients would receive what they think they are ordering. This should lead to an increased confidence in suppliers. The improvement of quality internally in a company leads to an improvement in the quality of goods awaiting shipment after further value-added processes. By reducing scrap, rework, stock-outs, lost time, and client dissatisfaction, the cost of quality actually reduces. This should ultimately improve financial performance.

- If suppliers wish to give added reassurance to clients, they may give them "certificates of conformity" (COCs) which state to the client that the goods supplied conform to the required specification as stated in the purchase order. Put most positively, it can increase profitability and market share.

3.4 STABILITY

URSs very seldom become stable or static. They are usually changed frequently throughout the project life cycle due to the continuous iterative interaction with other project phases. When people talk about a "frozen" URS, it usually means that the rate of change has decreased significantly. When licensing is involved, the rate of change may be very low, any and every change may have to undergo an appropriate re-licensing procedure. Le Roy (s.a.:11-31) states that the URS provides for determining adjustments to be made, and testing for effects of such changes on systems stability.

3.5 QUALITY

The question can be asked: "What is a good URS?" There are a number of attributes (Imrie & Nunns, 1988:5) which one should aim to achieve within a URS so that the maximum benefit can be gained from it. Unfortunately, with the present state of the art, it is not usually possible to achieve all of these absolutely or even to provide an objective scale of measurement for their achievement.

In producing the requirement specification, no pre-conceived stances should be adopted with the hope that an open mind would lead to the most suitable system be chosen. It is therefore essential to avoid special terminology of a specific supplier in the requirement specification. Brown (1987:7) states that this issue is a dangerous area to move into since the user must fully understand what the terminology means.

In order to proceed with design and development, the supplier should have a complete, unambiguous set of requirements. In addition, these requirements should include all aspects necessary to satisfy the users need. These may include, but not limited to performance, safety, reliability, security and privacy. These requirements should be stated precisely enough so as to allow validation during project acceptance Anon. (1991:4).

Imrie and Nunns (1988:5) state that a good URS is unambiguous, complete, consistent, verifiable, modifiable and traceable. Many such quality characteristics - especially the last two mentioned above - are very much easier to achieve and maintainable if the URS and its production are supported by suitable computer aids.

According to Motiska and Shilliff (1990:35), when the requirement specification is used for procurement, a poorly written specification will invariably yield an unsatisfactory product or service. Therefore, the content of the specification must be clear and free of ambiguous wording so that the supplier will understand what is required.

Every stated requirement should have the following attributes:

- A unique referential identity (name paragraph number).
- A readable body of text and symbols.
- Some indication of its strength (necessity).
- Other remarks that may aid the producer.
- Some notion of testability.

3.5.1 UNAMBIGUOUS

Imrie and Nunns (1988:6) state that a URS is unambiguous if every requirement that is described therein is unambiguous. It should have only one possible semantic interpretation. As a minimum, this requires that each specific item in the real world can be described using a unique term. In cases where a term is used in a particular context, have multiple meanings, the term shall be included in a glossary where its meaning is made more specific.

The use of a formal specification language within a URS can help to reduce ambiguity. This is due to the fact that each term in the language has only one semantic interpretation and a compiler can determine lexical, syntactic and some semantic errors automatically.

3.5.2 COMPLETENESS

Completeness of the URS implies the following number of qualities:

- No requirement or need of the client has been overlooked.

- For every possible set of inputs, some system response has been specified.

- Expressions such as "to be determined", or "this section intentionally left blank", have no place in a complete URS. However, during the construction of a URS, the information for some sections may not yet be available. In such cases, some explanation should be given including why the section is left incomplete and what shall be done to complete it.

- If a particular URS standard is being used, then the URS shall conform to that standard.

- The document should be textual complete, with all terms and references defined and all diagrams and tables appropriately labelled. (Imrie & Nunns, 1988:7).

3.5.3 CONSISTENT

A URS is consistent if and only if no set of individual requirements described therein conflict. Imrie and Nunns (1988:7) indicated that there are a number of types of conflicts:

- If two or more requirements describe the same system, different terms shall not be used to describe that object.

- Attributes of system objects shall not conflict (for example, one requirement, states that all lights shall be green and the other states that all lights shall be blue).

- There can be no temporal or logic conflict between two functions. For example, one requirement states that the program will add two inputs, and another states that the program will multiply them, or one requirement states that 'A' shall always follow 'B', and another requirement states that 'A' and 'B' always occur simultaneously.

3.5.4 VERIFIABLE

Anon. (1991:2) defines *verification* in the project life cycle as the process of evaluating the products of a given phase to ensure correctness and consistency with respect to the products and standards provided as input to that phase.

A URS is verifiable if and only if every requirement stated therein is verifiable (Imrie & Nunns, 1988:7). A requirement is verifiable only if there exists some finite process by which a person or machine can check that the product meets the requirement. The term "verifiable" is used here in a wide sense, encompassing both testing and other analytic techniques such as program proof. The following is an example of non-verifiable and verifiable statements to illustrate the concept:

- "The product should work well" or "The product should have a good human interface" are examples of non-verifiable requirements due to the inability to define "good" or "well" concretely.

- "The output of the program shall usually be given within 10 seconds" is non-verifiable because there is a lack of measurability in the term "usually".

- "The output of the program shall be within 20 seconds 60% of the time; and shall be given within 30 seconds 100% of the time" is potentially verifiable, depending on whether or not the demand profile has itself been adequately defined.

- "The program shall never enter an infinite loop" is an example of a non-testable requirement because the testing of this quality is theoretically impossible. However, it may be verifiable by program proof.

- "The output of the program shall always be given within 30 seconds" is verifiable, providing that the necessary proof can be derived. (Imrie & Nunns, 1988:7).

3.5.5 MODIFIABLE

A URS is modifiable if its structure and style are such that any necessary changes to the requirements can be made completely and consistently. This generally implies that a URS has a coherent and easy-to-use organisation, including a table of contents, an index, explicit cross-referencing and the like (Imrie & Nunns, 1988:7).

Redundancy - the repetition of requirements in several places in the URS - can sometimes be used to make the URS more readable. However, this can cause particular problems for modifiability and consistency. Attention should be given to explicit cross-referencing to prevent this latter inconsistent updating.

3.5.6 TRACEABLE

Imrie and Nunns (1988:8) state that a URS is traceable if the origin of each of its requirements is clear and if it facilitates the referencing of each requirement for future development and enhancement documentation. The requirements stated in the URS need to be traceable so that the source of any problem that arise such as incompatible system requirements can be identified. The effects of any future enhancements such as the need for new test procedures can then be determined.

The traceability concept can be divided into the following:

- Backward traceability - to previous stages of development, depend on each requirement having an implicit reference to its source in the previous documents.

- Forward traceability - to all documents spawned by the URS - depends upon each requirement being uniquely identifiable (by name or reference number).

3.6 SUMMARY

In this chapter, a theoretical overview was given on the relationship between the URS process and the rest of the project life cycle phases. The importance of the URS and the iterative process between the URS phase and the other phases has been highlighted and the advantages to the client or business for using a URS are indicated.

The URS forms the basis on which any process control project is built. It is therefore essential that a URS document contain certain characteristics and specifications. The document should not become stable or static, but should be flexible and dynamic. To compile a good URS, certain quality attributes are required and should be maintained throughout the production process of the URS. These attributes are ambiguity, completeness, consistency, verifiability, modifiability and traceability. Examples are given for each of these attributes to clarify the concept.

The theory discussion on what a URS exactly is, the relationship to the project life cycle and the characteristics of a URS stated in this chapter will form the basis for the investigation research. This will also be addressed when the structure of a URS is recommended in Chapter 5 and the sub sections are referenced to the different project phases.

CHAPTER 4
GATHERING OF DATA AND DISCUSSION OF RESULTS

4.1 INTRODUCTION

When quantitative information on the recent past is scarce, not publicly known, not widely publicised or difficult to obtain, then a qualitative research methodology is suggested. This method requires more judgement and intuition than quantitative research methods. In practice the following three methods are available to conduct qualitative market research:

- The Delphi method – this method is used for long term forecasts. The answers and results to the first questionnaire are used to compile the next questionnaire and information is therefore distributed to the other members to answer the next questionnaire. In the end, consensus is reached and a forecast can be done.

- The market research method – this method consists of surveys and questionnaires that are designed to judge specific aspects. These methods of forecasting may not be accurate in the long term as the respondents' opinion may change.

- The method that uses the similarities of related problems in the past – this method is used to achieve a broad perspective with the purpose to do long term forecasting. All relevant aspects that can influence the fact that different time periods are applicable must be considered.

The research method that will be used in this dissertation will consist of a combination of the latter two methods mentioned above.

This chapter will be discussing the construction of the questionnaire that will be supported by the qualitative investigation of this study. The questionnaire is constructed from the derivation of the most important aspects identified from Chapter 2 and 3. The questionnaire will be aimed at potential users, businesses and clients who write URS documents and who is familiar with the process. In order to receive constructive feedback on the advantages of using a URS, identified problems and to gain additional knowledge on company specific information, the questionnaire will be followed up by a personal interview with all the respondents.

The chapter also deals with the analysing and discussion of the results obtained from the interviews with the respondents and typed information in the form of company specific documentation. In the analysis of the feedback from all the respondents, the information was grouped and compiled as indicated in Chapter 5 for the structure and contents of the URS, and the review methodology as indicated in Chapter 6.

From the interviews, certain conclusions could be drawn and recommendations suggested as indicated in chapter.7.

4.2 DESIGN OF THE QUESTIONNAIRE

The questionnaire is divided into two sections. In Section A, particulars are gathered on the current specification practises in the company. In Section B, information is gathered on what the company considers the contents of a URS should be and in what format it should be presented. The purpose of the questionnaire is to collect company specific information, which will be formally presented during the interview with each company. The composition of the questionnaire is discussed under the following sub-sections.

4.2.1 SECTION A: CURRENT PRACTISES

In this section, questions are asked to compose a profile of current structures in use in a specific company, the perceived benefits of using a user requirement specification, and the possible effect(s) this might have during the execution of projects. Different target groups were used, as the involvement in projects of the target group is different according to the type or scale of projects, the different type of product and to what relation the company stands from the view of the end user.

4.2.2 SECTION B: CONTENTS AND STRUCTURE OF A URS

In this section, an indication was sought from the respondents on what the contents and structure a URS should be consisted of. The questions are based on the complexity of projects, trends in the process production industry and measures required ensuring maintained quality.

4.3 GATHERING OF DATA

After the composition of the questionnaire, it was sent to the respondents for discussion and action. A cover letter was affixed to the questionnaire to give a short informative overview and background as to the objectives of the study.

The target groups identified for the questionnaire included:

- Five major South African process system suppliers. The ranges of products include distributed control systems (DCS), programmable logic controller (PLC) systems, supervisory controlling alarming and data acquisition (SCADA) systems, programmable emergency shutdown (PES) systems, field equipment such as valves, transmitters and switches.

- End users of the above mentioned systems. This includes a population of process engineers and managers from strategic business units, and plant maintenance and development engineers or technicians situated and are employed by the above mentioned industries.

- Construction companies doing the physical installation, erection and construction work.

- Implementers, integrators, engineers, developers, programmers and configurators of these systems.

Within these companies, relevant line managers, project managers and end users were targeted.

To ensure that the composition of the questionnaire was relevant and understandable, it was given to a number of people with applicable background for commentary and feedback. The questionnaire was adjusted according to the feedback received. A copy of the introduction letter and final questionnaire that was sent out and discussed with the formal interview, is included in Annexe A.

4.4 FEEDBACK FROM INTERVIEWS

The composition of the interviews was in the form of a questionnaire as discussed previously. The questionnaires were sent out in the first quarter of 1997 to the identified companies and individuals. After two weeks, these companies and individuals were contacted to arrange for the interview session. The interviews were done over a period of three months. The co-operation and feedback was excellent in the sense that all the respondents were interviewed.

An enormous amount of company specific material and documentation were received that varied from quality procedures, project management specific information, business and strategy documents, installation and design methodologies, general and specific guidelines and instructions. The formal interviews were also well received with discussions that went most of the time over the allowed time schedule.

4.5 PROCESSING OF THE INFORMATION

4.5.1 CURRENT SPECIFICATION PRACTISES

Many discussions were presented on what practises are in use, what the advantages and disadvantages were, and the relationship of the URS with the project life cycle. A very remarkable issue that was picked up with the interviews, was the fact that companies and individuals recognise the importance of a URS, but no one actually uses such system! They all rely on the known basis and generalisation of "project scope document", "scope of supply", or simply "scope".

4.5.2 STRUCTURE AND CONTENT OF THE URS

The information received on the content and structure of a typical URS was divided into the following main sections:

- Introduction section.

- Overview section.

- Scope of the project section.
- Business requirement specification section.
- Process requirement specification section.
- Operational requirement specification section.
- Control and automation requirement specification section.
- System flexibility section.
- Testability section.
- Constraints and assumption section.
- Key performance parameter section.

These main sections mentioned above will also form the foundation of the structure that is recommended in Chapter 5. The additional information received from the interviews and personal experience will be slotted into each of the applicable sections. The sequence order in which the above is presented is not critical. The information of the review section to check the completeness of the URS was compiled in the order presented in Chapter 6.

4.6 SUMMARY

In this chapter, the intention and composition of the qualitative research method used in this dissertation was discussed. Questionnaires were sent out to form the foundation of the formal interviews held with each respondent. The questionnaire consists of two sections: firstly, to gather an appreciation of the current practices and procedures within the companies and secondly, to seek information on the structure, contents and maintainability of a typical URS document. Useful information was received during the discussions, which was substantiated by company specific documentation.

The results of the interviews were analysed and many similarities were found which forms the basis for a process control system project. Most companies and individuals presented a large number of specific problems and issues they experienced during the execution of projects. All the information was sorted and the issues addressed in the recommended structure and contents of a URS compiled in Chapter 5 and 6. Additionally, conclusions and recommendations will be made in Chapter 7 based on the interview feedback.

CHAPTER 5

STRUCTURE AND CONTENT OF A URS

5.1 INTRODUCTION

From the interviews, theoretical information and own experience, the recommended structure and content of a user requirement specification was derived and is outlined in this chapter of the dissertation. This does not mean that all URSs should contain that is described here. **It is for an individual client to determine the content and detail appropriate to his or her situation**. However, it is preferable to explain the reasons for the absence of any sections or sub-sections.

Annexe C gives a checklist of the main sections, sub-sections and sub-headings or important aspects described in the following pages to assist the author of a URS in checking the completeness of the document.

It is recommended that a user requirement specification should contain the following main sections and will be described in more detail:

- Introduction - describing the purpose, scope, organisation, structure, legal and contractual aspects of the URS.

- Overview - providing overall descriptions and outlines of processes, outline of the existing control system(s) and proposed project site.

- Scope of the project - including aspects such as hardware, software, construction and commissioning issues to the project, excluded items from the project, constraints and client preferences should be detailed.

- Business requirement specification - specifying all business related items such as technology, capital programme, new products and policies.

- Process requirement specification - process specifications defining process fluids, materials, hazards, and processes. Environment requirements defining the requirements made on the system by its operating environment.

- Operational requirement specification - human interface requirements, alarm handling, data handling requirements explaining data handling such as reporting, logging and trending, manning levels, accounting and management information, and performance and special requirements defining overall system performance and special requirements.

- Control and automation requirement specification - control aspects explaining philosophy, features and logic overview, development project requirements. Quality assurance defining proposed life cycle, times scales and quality assurance requirements, safety and reliability describing safety and reliability requirements, plant control systems explaining interlocking systems, batch systems, continuous control, advanced control and supervisory control.

- System flexibility section - identifying the likely areas of upgrade and expansion.

- Testability section - describing customer requirements in system testing.

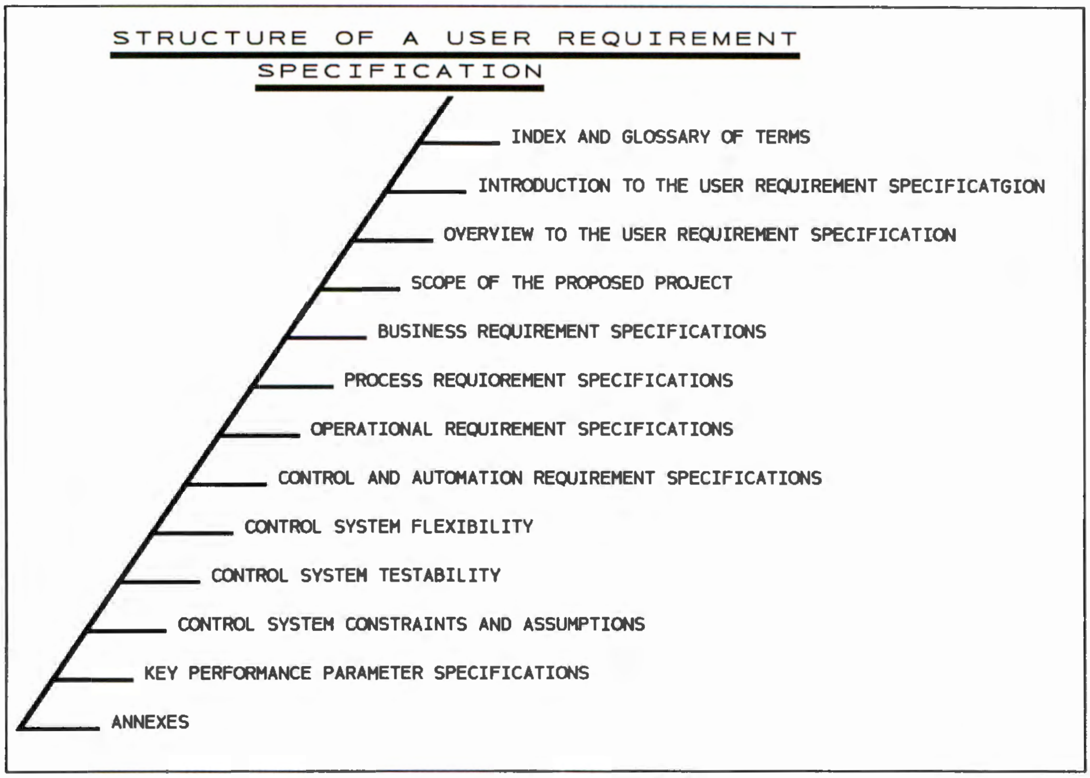
- Constraints and assumptions section - identifying constraints to be applied to potential suppliers and any client assumptions.

- Key performance parameter specification - specifying any critical parameters to which the system must conform. Success of the project will be rated on conformance to these issues.

In addition, a URS should contain annexes containing information which "does not fit" into one of the other sections and **including a full index and glossary of terms.**

Figure 5.1 below represents a pictorial summary of the structure of a typical URS.

Figure 5.1: Summary of the Structure of a URS



Some of the main sections detailed in this chapter will be summarised in summary tables listing the sub sections and information described in the particular section.

5.2 INTRODUCTION SECTION

This section of the URS details the purpose, scope and structure of the specification. In particular, it specifies the relationship to other documents and the project life cycle in general and should cover each of the following areas:

- A concise explanation of why the document has been produced. This needs to state briefly the system(s) objectives, purpose of the project, time frame and perceived benefits.

- Any legal or contractual constraints both on the use of the document and by the existence or contents of the document (which may include ownership, responsibility, circulation in addition to any security classification or restriction markings).

- How the document is to maintained throughout the life cycle including change control procedures to be followed.

- The relationship to internal and external documents and standards.

5.3 OVERVIEW SECTION

This section of the URS should contain a description of the process and application environment itself. It should be unambiguous and capable of being understood by members of multi-disciplined teams (software, hardware, electrical, instrumentation, mechanical and process). Liberal use should be made of diagrams and descriptive text. It will therefore include a description of the physical process, plant and environment characteristics before the introduction of the new system. This may contain parts that will be serviced, replaced or upgraded by the new system.

A detail explanation of the existing control system, if present, should be given. Aspects to be specified should include software, hardware, maintenance, process, electrical and instrumentation.

The geographical location of the proposed project site should be given.

5.4 SCOPE OF THE PROJECT SECTION

This section should describe all aspects and items that the project will encompass to meet the client requirements and is summarised in Table 5.4.

5.4.1 ITEMS INCLUDED IN THE PROJECT SUB-SECTION

Traditionally, the project needs and wants will be specified by the client and will normally exclude the "must have" requirements, include some of the "should have" requirements, and lastly, totally include all the "nice to have" requirements. What is important in this section is that **all** these wants should be listed. The different categories of "must have", "should have" and "nice to have" requirements will be separated during the detail design phase in full co-operation with the client.

This sub-section should contain a list of all the client's required items to be included in the project:

- Project management - planning and scheduling, controlling, estimating, reporting.

- User Requirement Specification. This should list the complete scope or client requirements.

- Feasibility and Hazard Operability studies to identify safety and hazard requirements.

- Contract and contract management. This should be stipulated fully if it is required by the client.

- Functional or conceptual design package to meet the requirements of the client. This will include all discipline engineering.

- Hardware and firmware package - include all new field, control room, peripheral, electrical, mechanical and civil interfaces, cabling, power equipment, upgrading of systems and subsystems.

- Software package - includes all supplier packages, development, application, information management, and communication, programming tools and advanced control software.

- Product development package. If any special product development is required, it should be completely specified.

- Construction activities - installation, cabling, powering, connecting, configuration and programming, erection, quantity surveying and reservation checks.

- Quality standards and procedures package - to be complied with by the project team.

- Purchase and expediting package - ordering of equipment, contractual agreements, quotations, and expediting of orders.

- Commissioning package - include cut-over and changeover from the existing to the new, cold, dry, and hot commissioning of pieces of equipment first, then systems, and then the project as a whole.

- Documentation package - this should include all engineering and design packages, training, operational and maintenance manuals, civil and mechanical packages.

- Training package - of project, process and maintenance personnel on the new system(s).

- Special investigations package - any additional investigations to be carried out by the project team should be declared.

- Acceptance tests - this includes all factory acceptance tests (FAT) and site acceptance tests (SAT).

- Performance trials - high performance tests should be done once the system(s) are on line and fine tuned in order to measure against client specifications.

- Demolishing - of old and redundant equipment.

- Hand-over - relevant hand-over procedure requirements from contractors to project team and from project team to client should be clearly stipulated.

- After start-up support - this should be clearly defined and terms and conditions explained.

5.4.2 ITEMS EXCLUDED FROM PROJECT SUB-SECTION

Specific items that are excluded from the project scope should be described in this sub-section. These can include:

- Specific equipment.

- “Nice-to-have” items that are not really required.

- Re-using of certain existing systems or replacement of certain sections of systems due to new age, cost or functionality, or philosophies regarding re-use of site equipment.

- Equipment to be supplied by the client.

- Services to be supplied.

- Specific civil works.

- Specific mechanical structures.

5.4.3 PROJECT CONSTRAINTS SUB-SECTION

Specific constraints that the client wants to put on the project should be clearly defined. These can typically include:

- Manning levels - increase or decrease of work force complement.

- Costs of the project - this will be determined by the budget.

- Timing and duration of project, which can include certain milestones to be met.

- Availability of client documentation. On old plants, documentation is usually non-existent.

- Availability of client resources as the client usually has only enough resources to maintain the day-to-day ongoing activities.

- Excluding of the use of certain contractors. Black lists, bad experience with certain contractors or the bad reputation of workmanship, quality and co-operation are usually the norm.

Some companies require that the contractor needs to be audited before signing any contracts with him.

- Excluding of certain people from site - black lists, ex employees and fired employees are examples.

- Technology constraints. It could be that the client wants to retain his current technology and this should be stated clearly in this section.

5.4.4 CLIENT PREFERENCES SUB-SECTION

Sometimes, clients have specific preferences or can submit valuable advice regarding equipment or systems to be used. The benefits of specifying this sub-section in detail will be realised in the compilation of the functional specification and during the detail design phase of the project. These preferences should very clearly be defined with reasons and would include:

- Type of equipment already in use on the rest of the plant or site. This would eliminate the spending of capital on additional equipment and spares.

- Equipment of which store spares-levels already exists.

- Selection of equipment on which tests have successfully been done.

- Equipment, which is locally available with short delivery times.

- Personal preferences of equipment or systems.

During the conceptual or functional specification phase of the project, these preferences should be challenged by the developer, supplier and designer and will finally be clarified during the course of the phase.

Table 5.4 below summarises all the aspects and items to be included in the project scope.

Table 5.4: Summary of the Scope of the Project Requirements

ITEMS INCLUDED IN THE PROJECT	**ITEMS EXCLUDED IN THE PROJECT**	**PROJECT CONSTRAINTS**	**CLIENT PREFERENCES**
Project management package	Specific equipment	Manning levels	Type of equipment already in use
User requirement specification	"Nice-to-have" items	Costs of project	Equipment of which stores-levels exists
Feasibility and HAZOP studies	Certain existing equipment	Availability of client documentation	Selection of tested equipment
Contract and contract management	Certain sections of systems	Excluding the use of certain contractors	Locally available equipment
Functional or conceptual	Equipment to be supplied by client	Excluding of certain people from site	Personal preferences of equipment
Design package	Services to be supplied client	Technology constraints	
Hardware and firmware package	Specific civil works		
Software package	Specific mechanical structures		
Construction management and activities			
Quality standards and procedures			
Purchasing and expediting			
Commissioning package			
Documentation package			
Training package			
Special investigations			
Acceptance tests			
Performance trails			
Demolishing			
Hand-over package			
After start-up support			
Support engineering			
Product development			

5.5 BUSINESS REQUIREMENT SPECIFICATION SECTION

The business department is responsible for assessing the business and commercial aspects of a project and for including an adequate provision in the future capital programme. After commissioning of the project, a technical and financial audit should be carried out. The department should also be responsible for the business specification inputs to the URS.

In this section, specifications of the business or plant in which the new system(s) will operate must be given. Typical parameters that can be specified include:

- Amplification of initial business and technology statement including statement of business strategy.

- Business analysis in terms of financial indicators, exports, profits, imports, pricing philosophies and raw material usage. These figures should be used with discretion.

- Products to be manufactured.

- Preliminary costing capacity and phasing - capital, operating and maintenance costing allocations.

- Proposed plant capacity and pattern of demand.

- Fundamental plant concepts.

- Plant on-line time specifications.

- Capital constraints, for example the phasing of the project over several financial years.
- Future business forecasts, market developments and manpower philosophies.
- Quality specifications. Typical any ISO9000 quality or company internal quality checks and standards to be used.
- Expected maximum gross new make or production.
- Raw material efficiency.
- Overall production efficiencies.
- Quality consistency throughout the business.
- Market requirements including local, sub continent and overseas markets.
- Product and material specifications.
- Preliminary siting options.
- Resourcing of critical materials, which includes local and overseas resourcing.
- Chemical routes and process options.
- Process and engineering development requirements.
- Preliminary assessment of product and process hazards.

- Preliminary assessment of environmental and safety aspects.

- Overall key target dates.

- Interaction with other manufacturers and services.

Table 5.5 below summarises all the items to be considered when the user compiles the Business Requirement Specifications:

Table 5.5: Summary of Business Requirement Specifications

BUSINESS REQUIREMENT SPECIFICATIONS
Business and technology statements
Business analysis parameters
Manufacture products
Preliminary costing capacity and phasing
Proposed plant capacity
Fundamental plant concepts
Plant on-line time specifications
Capital constraints
Future business forecasts
Quality specifications
Expected maximum new gross make of production
Raw material efficiencies
Overall production efficiencies
Quality consistency requirements
Market requirements
Product and material specifications
Preliminary siting options
Resourcing of critical materials
Chemical routes and process options
Process and engineering development requirements
Preliminary assessment of product and process hazards
Preliminary assessment of environment and safety aspects
Overall key target dates
Interaction with other manufacturers and services

5.6 PROCESS REQUIREMENT SPECIFICATION SECTION

This section is important in that it identifies all the aspects of the existing and proposed process and environment upon which the new system will impinge. This section should also be concerned with defining the requirements made on the system(s) by the operating environment and should include the following sub-sections:

5.6.1 PROCESS SPECIFICATION SUB-SECTION

In this sub-section, product specifications, background detail of process fluids, materials of construction and hazard processes should be given to the developer or supplier. It should further includes:

- Explosion classification of the plant or areas.
- Corrosivity of process fluids and the environment.
- Errosiveness of the process fluids.
- Product cross-contamination issues.
- Pollution of the air and surroundings with toxic gasses.
- Flammability of process fluids.
- Pyrophoric characteristics of the fluids.
- Carcinogenic and mutagenic effects on personnel.

- Special control activities of the process such as start up, operating and control philosophies.

- Complexity of the technology used in the process.

- Capacity and phasing proposals.

- Preliminary siting layout.

- Battery-limit definitions.

- Process development targets.

This sub-sub-section is important as it may contain information that will effect the legal design aspects of the system(s) such as Intrinsically Safety (I.S.), explosion and flame proofing, and human health aspects.

5.6.2 ENVIRONMENTAL DESCRIPTION SUB-SECTION

This sub-section should give a general description of the environment in which the systems are to be operated. It includes the physical locations of the components of the system(s), since these have an impact on the possible cost and design of the system(s).

Brief details of the available services should also be given, thus enabling the developer or supplier to design the system(s) to meet their capacity.

Typical specifications should include:

- Regulations regarding smoking in the vicinity of the new system(s).

- Vibration from mechanical equipment such as compressors, pumps and large motor drives.

- Vibration and gas emissions from the process. Toxic and corrosive gasses will influence the design and increase project costs.

- Presence of an air conditioner as equipment are normally specified and designed to operate at room temperature.

- Physical and chemical filtration of the air conditioner inlet air - quality of the air as corrosive gasses will drastically decrease the life span of equipment.

- Static generation caused by air dryness during winter months, as certain equipment is sensitive for static currents.

- Eating and drinking habits of operating personnel close to the new system(s).

- Radio communication close to the system(s) as systems can be influenced by the transmitted waves.

- The use of cell phones in the vicinity of the system(s) due to the influencing of transmitted signals.

- Illumination specifications required for inside the control room and outside on the plant. Emergency lighting should also be specified in case of a total power failure.

- Normal power supply, emergency power supply and uninterrupted power supply availability specifications for the new system(s) should be specified.

- Access to and from the building - sizes of doors and passages should be specified in order to design the cabinets of the system(s).

- Availability of cable ducting.

- Suspended computer floor availability or requirements.

- Preliminary external authority approvals.

- Required process audits.

- Site and plant energy balances.

- Safety and fire fighting. This would include fire-extinguishing systems outside on the plant and inside for the control room and control systems. Fire sensing or fire detection systems and alarming should be clearly stated.

- Non process facilities, for example laboratory, offices, kitchens, toilets, amenities, and training and development rooms.

5.6.3 PASSIVE ENVIRONMENTAL REQUIREMENTS SUB-SECTION

This sub-section should describe the requirements for the system during staging, storage and transportation and may includes:

- Vibration and shock specifications during loading and off loading.

- Rain and moisture aspects, especially during transportation in containers at sea.

- Dust and contamination specifications.

- Humidity specifications.

- Corrosive and explosive atmosphere.

- Storage temperature range and gradients.

- Size and weight considerations - provision of eyebolts for rigging and slinging of cabinets.

- Electromagnetic radiation specifications.

- Insurance coverage during transit and storage.

- Specifications for the protection against mechanical damage.

5.6.4 ACTIVE ENVIRONMENTAL REQUIREMENTS SUB-SECTION

This sub-section should describe the requirements that the system should meet during on-line operation and may include:

- Mounting of cabinets to the suspended floor. Strength of the floor design should be taken into consideration.

- Specifications against continuous or intermittent high levels of vibration and shock.

- Protection against rain, lightning, moisture, dust and contamination.

- Protection against humidity variations.

- Protection against corrosive and explosive atmospheres.

- Storage temperature range and gradients.

- Electrical noise immunity.

- Electrical noise generation.

- Electromagnetic radiation immunity.

- Electromagnetic radiation generation.

- High and radio frequency wave immunity.

- High and radio frequency wave generation such as cell phones transmitting, and plant two way radios and portable or base stations transmitting and receiving.

- Power supply frequency and voltage stability.

- Maximum allowable acoustic noise generated.

- Heat dissipation of all sources of power.

- Use of hazardous materials in components that are exposed to the environment or in contact with the process fluid.

- Size and weight considerations of all equipment.

- Safety, health and environmental (SHE) considerations.

- Static caused by humidity variations.

5.6.5 ENVIRONMENTAL CONDITIONS SUB-SECTION

This sub-section should specify the environmental conditions in which the system will operate. Issues that can be considered include:

- Enclosure rating, for example Ingress Protection rating 54 or 64 (IP54 or IP64).

- Access to the enclosure - lockable doors, see-through panels.

- Fixed gland plates or sliding plates to be use for cable entry.

- Bottom or top entry of cables.

- Enclosure power distribution to be specified.

- Earthing of the cabinets - intrinsic safety earth and cabinet earth should be separated.

- Average, minimum and maximum temperature specification.

- Relative humidity.

- Altitude above sea level.

- Average barometric pressure.

Table 5.6 below summarises all the aspects that should be taken into consideration when the user compiles the Process Requirement Specifications.

Table 5.6: Summary of Process Requirement Specifications

PROCESS SPECIFICATIONS	ENVIRONMENTAL DESCRIPTION	PASSIVE ENVIRONMENTAL REQUIREMENTS	ACTIVE ENVIRONMENTAL REQUIREMENTS	ENVIRONMENTAL CONDITIONS
Explosion Classifications Corrosivity of process Errosiveness of process Contamination Requirements Pollution of Atmosphere Flammability of fluids Phyrophoric Characteristics Mutagenic Characteristics Special control Activities Complexity of Technology Capacity and phasing Preliminary siting Layouts Battery limit Definitions Process development Targets	Smoking regulations Vibration Gas emissions Air conditioning Air filtration Static generation Eating and drinking habits Radio communication Use of cell phones Illumination specifications Power supply specifications Access requirements Availability of cable ducting Suspended flooring specifications Preliminary external approvals Process audits requirements Site and plant energy balances Safety and fire fighting Non process facilities	Vibration and shock Rain and moisture Dust and contamination Humidity specifications Corrosiveness and Explosion Storage temperature Specifications Size and weight Considerations Electromagnetic Radiation Insurance coverage Mechanical damage Protection	Mounting of cabinets Vibration and shock protection Weather protection Humidity variations Corrosive and explosive protection Storage temperature Electrical noise immunity Electrical noise generation Electromagnetic radiation immunity Electromagnetic radiation generation Radio wave immunity Radio wave generation Power supply stability Acoustic noise generation Heat dissipation Use of hazardous materials Size and weight considerations Safety, health and environmental Static generation	Enclosure rating Enclosure access Cable glanding Cable entry Power distribution Earthing of cabinets Temperature Specifications Relative humidity Altitude above sea level Barometric pressure

5.7 OPERATIONAL REQUIREMENT SPECIFICATION SECTION

This section should specify all the requirements of the end user(s) of the system(s) that is to operate or to use the system(s). These are the criteria that will fulfil the expectations of what the system is capable of doing. This section is also critical, as the final system(s) will provide to the user the tools to perform his daily task. Of significant importance is that system compliance to this section is the breaking point of project succession on the one hand or failure and the resultant rejection on the other hand. The recommended operational requirement specifications required for the URS are specified in the following sub-sections:

5.7.1 HUMAN MACHINE INTERFACE SUB-SECTION

This sub-section of the URS should be concerned with defining the customer requirements for the human machine interface to the system in the following sub-sub-sections:

5.7.1.1 Human Machine Interface Equipment sub-sub-section

This sub-sub-section should specify the equipment necessary for the human machine and system interfaces with particular attention being given to the following:

- Types and numbers of interfaces, for example video display units, servers, recorders, and terminals.

- Size of the video display units.

- Location and environmental conditions affecting this equipment.

- Facilities to plug in an operator and engineering keyboard. Membrane keyboards should be considered to eliminate dust, dirt and spillage of coffee, tea and soft drinks.

- Colour Laserjet and Laser mono colour printer specifications for screen dumps, events, alarms, reports, programme listings and engineering documentation.

- Operator console desk requirements. Modern and ergonomic design desks should be considered. This facility should also have additional space for a telephone, radio base station, plant operating push buttons, signal recorders, and emergency push buttons.

- Special ergonomic considerations required to optimise personnel effectiveness, thereby promoting safety, operability and reliability for example area illumination, anti-glare devices for the screens, operator chairs, and background music system.

5.7.1.2 Human Machine or System Interaction sub-sub-section

This sub-sub-section should contain a broad description of the perceived interaction requirements between operators, engineers and the system.

It is important to include any areas that could induce incorrect or unsafe actions because of misinterpretation or assumption by operational staff so these can be clarified in the subsequent functional specification.

Particular attention should be given to the following:

- Presentation of data – group- and mimic displays, schematics, overviews, detail tuning, real time and historical trends, and alarms.

- Diagnostic displays for maintenance.

- On-line help functionality on product and software information.

5.7.1.3 Security and Integrity sub-sub-section

This sub-sub-section should contain the client's ideas on the security and integrity of the human interface under the following headings:

- Integrity - functions and data to be protected against general access or accidental or voluntary misuse.

- Access or protection - types of protection or access control required and acceptable probabilities for breaches of security.

- Data retention and recovery - retention and recovery requirements should be specified in terms of target software to be used for recovery and media to be used for retention.

- Security methods - including security control terminals, environmental access control, passwords or key locks and codes, authority and procedures, surveillance, management aspects and data protection legislation requirements.

- Environment of security required - engineering or configurator (all data), supervisor, and operator.

- Event logging of system software configuration changes.

5.7.2 DATA HANDLING REQUIREMENTS SUB-SECTION

This sub-section should contain descriptions of how the system(s) are embedded in the physical environment, with particular emphasis on the interface or "points of contact" with the environment. The level of detail in this section will be dependent on whether the process is totally new or already exists. For the latter, numbers and types of inputs or outputs should be available whereas for the former, they will probably be estimates. Where estimates of numbers are given, it is advisable to err on the high side. Appropriate sub-sub-sections for this section include the following:

5.7.2.1 Interfaces sub-sub-section

This sub-sub-section should describe the interface (inputs and outputs) under the following headings:

- Inputs - should be described as fully as possible to include the sources and purposes of the inputs.

- Outputs - should also be described as fully as possible to include the destinations and uses of the outputs.

- Derived inputs or outputs - descriptions of derived inputs or outputs with the derivation formula and origin.

- Inter-relationships - descriptions of process area relationships with diagrams where possible.

5.7.2.2 Plant Hardware sub-sub-section

This sub-sub-section should contain as a minimum the determining parameters on critical plant hardware and list of such hardware. In addition, descriptions and lists of each of the following should be included (the list is not exhaustive):

- Isolating control valves (ICVs).
- Control valves (CVs).
- Motors and agitators.
- Compressors, blowers and fans.
- Diverting valves.
- Pumps.

5.7.2.3 External Information Transfers sub-sub-section

This sub-sub-section should identify information exchanges between the system(s) and external system(s) with as much detail as possible and includes:

- Data throughput of systems.
- Frequency of information transfer.
- Any protocol or transfer specifications.
- Format of the received data.

5.7.2.4 Alarms, Interlocks and Trips sub-sub-section

This sub-sub-section should describe any requirements in the following areas:

- Alarms and alarm handling including categories, prioritising and suppression.

- Audibility and visual presentation to operator or user.

- Silencing, acknowledging and clearing of alarms internally generated or externally from peripheral equipment.

- Logging of alarms and trips.

- Displaying in sequence order of occurrence.

- Distinguishing of alarms both in terms of display and audibility.

- Levels of priority - critical, advisory, and event.

- Sources of alarms - controllers (process variable High, Low, High-high, Low-low, deviation High or Low), indication (process variable High or Low, and High-high or Low-low), on or off control, status's, system software and hardware alarms.

- Time resolution for the scanning of the alarms.

- Printing and software logging of alarms.

- Interlocks and defeating criteria.

- Trips including categories and defeating criteria.

5.7.2.5 Data Storage sub-sub-section

The data storage sub-sub-section should indicate any and all client requirements for the information storage in the system. In particular where possible, the following should be stated:

- Volume and capacity of data storage required.
- Frequency of access to information such as update periods.
- Duration of retention, security, archiving and backups.

5.7.2.6 Special Interfaces sub-sub-section

This sub-sub-section should describe as fully as possible any interfaces internally in the system or from the system to foreign equipment and can be of a new or novel type such as:

- Modbus.
- Profibus.
- Novell.
- Ethernet.
- Fieldbus.
- Data highways.
- TCP IP/Token Ring.

The interface can be to peripheral equipment such as:

- Programmable logic controllers (PLCs).

- Programmable emergency shutdown (PES) systems.

- Analyser systems.

- Multiplexing units.

- Other computers and computer equipment such as printers and recorders.

- Supervisory systems or supervisory controlling alarming and data acquisition systems (SCADAs).

5.7.2.7 Reporting and Logging sub-sub-section

The following data may be logged either by the system as files or by a spool printer:

- Alarms – new alarms, acknowledged alarms, alarms returned to normal, process and system alarms.

- Operator messages.

- Data entries by the operator - control loop changes in mode, changes to set points, and changes to alarm limits.

The following reports should be spooled to a printer:

- Log reports.

- Daily-, shift-, weekly- and monthly logs with averages.

- On operator demand logs.

The system should allow the format of log reports to be configured by the user.

5.7.2.8 Trending sub-sub-section

Historical and real time trend information could be of vital importance to operations to control the plant, trip and fault diagnostics, and for plant and system optimisation. The following system embedded functionality may be specified:

- Amount of process signal variables per trend.

- Capacity of the system for trending data.

- Number of signals to be trended.

- Duration of trends.

- Sample period of signals.

- Trending of averages.

- Display of trends - zooming and panning both in the time axis (x-axis) as well as in the value axis (y-axis).

- Archiving and retrieving of trend data - frequency of archiving and hardware to be used should be specified.

5.7.3 MANNING LEVEL REQUIREMENTS SUB-SECTION

This sub-section should specify the following with regards to the existing manning levels that are being used and the future requirements:

- Identification of the personnel and their day-to-day tasks.

- Qualifications of personnel that will work with the new system(s).

- Past experience of personnel with similar systems.

- Company policy to increase or decrease manning levels.

- Total number of personnel required.

This sub-section is important in that the level of activity automation can be determined by the past experience of personnel employed.

5.7.4 ACCOUNTING AND MANAGEMENT INFORMATION SUB-SECTION

This sub-section should fully describe in what format the management information should be represented, what software is to be used and what information is required. Special attention should be given to the following important and critical issues:

- Hardware layout, and software set-up and configuration of the management system.

- Maintenance of the system.

- Training of the end users.

- Documentation on the system hardware and software.

- Security and access control.

- Back-up frequency, responsibility for back-ups, and back-up procedures.

In addition special caution should be taken against "nice-to-have" requirements. The use or appointment of a system manager with an assistant or alternative is advised.

5.7.5 PERFORMANCE AND SPECIAL REQUIREMENTS SUB-SECTION

This sub-section of the URS should be concerned with defining specific performance requirements of the system(s) and any "special" requirements envisaged and should include the following sub-sub-sections:

5.7.5.1 Operational Description sub-sub-section

This sub-sub-section should describe the way in which the system will be operated. Such a description places the performance requirements in context to allow developers to arrive at an optimum solution. Particular aspects to be considered in the operational description sub-sub-section are:

- User start-up of system and plant.

- Shutdown of system and plant - specifications of safe and orderly shutdown of the system should be considered.

- Normal running of system and plant.

- Availability - this could be specified as a percentage on-line time of all the systems or specified in terms of days per week or hours per day.

- Operational staff requirements.

5.7.5.2 System Performance sub-sub-section

This sub-sub-section should state the performance requirements for the system(s). These can be many and varied, but where stated, should be **in measurable terms** and not be open-ended. Here, liaison with engineering and development staff to determine what is possible is vital. Amongst aspects to consider are (the list is **not** exhaustive):

- Response times to external events.

- Human interface response - response time **must** be fully specified. For example, the response time from entering or pressing the keyboard for a specific effect to the complete display of such desired effect on the screen.

- Critical sequence, process, interlock or trip timing - the response time of the system executing the complete sequence programme should be specified, and not just the execution per programme step.

- Storage capacity and access time.

- Calculation requirements.

- Communication link capacity and frequency of data transfer.

This sub-sub-section is also critical, as the performance of the project in terms of deliverables will be measured. Performance criteria should be specified clearly and in detail as to avoid any loopholes, contractual issues, court settlements and non-conformance.

5.7.5.3 Maintenance Requirement sub-sub-section

This sub-sub-section should contain the client's maintenance and availability requirements for the system. These requirements will impact heavily on the eventual solution and should include:

- Statement of hardware and software maintenance required.
- Statement of projected availability requirement.
- Proposed planned process maintenance and requirements for degraded operation.

Sufficient supplies of spares should be maintained to do first line maintenance by the plant maintenance team. Some support agreement should be reached with the supplier(s) of the control system(s) to make spares available within a certain period (for example 8 hours) during weekdays and weekends and public holidays (for example 48 hours).

After sales support and upgrade agreements should also be considered to maintain the latest system technology and to benefit from the newest software developed. As part of the support, the use of telephone and satellite modems could be considered to give the supplier direct access to the system under controlled conditions.

Some of the spare equipment could be set up for training purposes and should be linked to the main system. Spare equipment should be installed with power as an integral part of the on-line system. The advantage of on-line spares is that the integrity of the spares will be monitored continuously by the main system to ensure 100% serviceable spare equipment.

Special software application and plant simulation packages such as Reliability Centred Maintenance (RCM) could be considered.

5.7.5.4 Development Environment Requirement sub-sub-section

This sub-sub-section should specify the development and engineering hardware and software required. Consideration should be given to the usage of the spare equipment as the development system. The displaying of on-line information on the development system is advised.

5.7.5.5 Other Special Requirement Sub-sub-section

This sub-sub-section should detail other special client requirement specifications that are not covered elsewhere in the URS.

Table 5.7 below gives a summary of all the requirements to be considered during the compilation of the Operational Requirement Specification.

Table 5.7: Summary of Operational Requirement Specifications

HUMAN MACHINE INTERFACE	DATA HANDLING REQUIREMENTS	MANNING LEVELS REQUIREMENTS	ACCOUNTING AND MANAGEMENT INFORMATION	PERFORMANCE AND SPECIAL REQUIREMENTS
Human Machine Interfaces	**Interfaces**	**Manning Levels**	**Accounting and**	**Operational Requirements**
Types and number of	Inputs and outputs	Identification of personnel	**Management Information**	User start-up of system and plant
Size of video displays	Derived inputs or outputs	Qualifications of personnel	Presentation of management	Shutdown of system and plant
Location and environment	Inter-relationships	Past experience	information	Normal running of system and plant
Keyboard specifications		Company policy regarding	Software requirements	Operational staff requirements
Printer specifications	**Plant Hardware**	manning	Information requirements	
Console desk requirements	Isolating control valves	Number of personnel	Maintenance of information	**System Performance**
Ergonomic requirements	Control valves		systems	Response times to external events
	Motors and agitators		Training of users	Human interface response
Human Machine and	Compressors, blowers & fans		Documentation of system	Critical sequence timing
System Interaction	Diverting valves and pumps		Documentation of software	Interlock timing
Presentation of data			Security requirements	Critical trip timing
Diagnostic displays	**External Information Transfer**		Back-up requirements	Storage capacity
On-line help facilities	Data throughput of system			Storage access time
	Frequency of information transfer			Calculation requirements
Security and Integrity	Protocol of transfer specification			Communication link capacity
Integrity	Format of the received data			
Access or protection				**Maintenance Requirements**
Data retention	**Alarms, Interlocks and Trips**			Software maintenance requirements
Data recovery	Alarms and alarm handling			Hardware maintenance requirements
Security methods	Audibility and visual presentation			Projected availability requirements
Environment of security	Silencing and acknowledging			Process maintenance requirements
Event logging	Clearing of alarms			
	Logging of alarms			**Development Environment**
	Display in sequence order			Use of spare equipment for
	Distinguishing of alarms			Displaying of on-line information
	Levels of priority			
	Sources of alarms			**Other Special Requirements**
	Time resolution of scanning			
	Printing and logging of alarms			
	Interlocks and defeating criteria			
	Trips			
	Data Storage			
	Volume and storage capacity			
	Frequency of access			
	Duration of retention			
	Security, archiving and back-ups			
	Special Interfaces			
	Modbus, Profibus, Novell,			
	Fieldbus, Data highways, TCP/IP			
	and Token Ring.			
	Reporting and Logging			
	Alarms			
	Operator Messages			
	Data entries by operator			
	Log reports			
	Daily, shift, weekly and monthly			
	On operator demand logs			
	Trending			
	Amount of variables per trend			
	Capacity of the system			
	Number of signals			
	Duration of trends			
	Sample period of trends			
	Trending of averages			
	Display of trends			

5.8 CONTROL AND AUTOMATION REQUIREMENT SPECIFICATION

5.8.1 CONTROL REQUIREMENTS SUB-SECTION

This sub-section of the URS should be concerned with describing the requirements of the system in terms of sequence and or regulatory control of the process or plant. The extensive use of logic diagrams and control schematics is recommended. Appropriate sub-sections for this section should include:

5.8.1.1 Strategy and Plant Control Philosophy sub-sub-section

This sub-sub-section should describe the objectives of control, degree of dependency on the system, constraints of the process and product and distribution of control. In the case of revamping an existing system or installation of a new system, the desired control philosophy should be described to include:

- Identification of the areas in which the plant is divided into.
- Description of the subsystem(s) used for the control of each area or groups of areas.
- Location of the control system(s) – control- and satellite control rooms or local control panels.
- A detail description of what the control systems should consist of. Generous use of diagrams and drawings is advisable.
- Detail information on the quantity of input and output signals to the system(s) in use.

- Identification of peripheral equipment, programmable logic controllers (PLC) systems and interfaces should be detailed.

- Redundancy of the system(s). This is to determine the operating integrity whereby the failure of one control subsystem will not cause more of the plant to shut down than would have the case because of process related interdependence.

- Human interface equipment in use.

5.8.1.2 Boundaries Requirements sub-sub-section

This sub-sub-section should define the control system boundaries, including interface requirements to both complimentary control systems and any hierarchical control systems (if applicable).

5.8.1.3 Sequencing Requirements sub-sub-section

This sub-sub-section should include, if available, process and sequence flowcharts describing the process control logic. These should not be related to specific process control hardware and software. The complete process and sequence flowchart with full references to system addresses, programme routines and derived tags should be included as part of the documentation package. Typical software standards to which the programming must be adhered to should be specified, for example SP88 or NAMUR.

5.8.1.4 Regulatory Control Requirements sub-sub-section

This sub-sub-section should include, if available, a description of each control loop or scheme specifying:

- Plant object (vessel, compressor, distillation column, or autoclave).

- Tag names and full description.

- Input signals required.

- Output signals required.

- Type of signal whether pressure, flow, temperature, level, or analysis.

- Ranges of variables and units of measurements.

- Special control algorithms.

5.8.1.5 Manual and Automatic Requirements sub-sub-section

This sub-sub-section should indicate the manual, local, standby, automatic, ratio, cascading or split range control features required. A complete specification should be given on the level of automation required as well as the quality of controller tuning. A complete signal and tag list should be submitted.

5.8.1.6 Interlocking Requirements sub-sub-section

The interlocking of equipment should be fully specified in terms of independent systems such as a relay logic network and programmable emergency shutdown (PES) systems or if the interlocking should be done in the distributed control system (DCS). Redundancies of these interlock systems should be defined. Interlocks to be considered should include:

- Electrical motor control on pumps, compressors, fans, agitators, blowers, conveyors and extruders.

- Between computer systems and computer subsystems via hardware connections or interfacing communications.

- Between computer systems and external independent systems.

- Interlocking to be done by programmable emergency shutdown (PES) systems.

- Software interlocking within system programmes.

A complete motor tag specification should be included in the URS.

5.8.1.7 Batch Control Requirements sub-sub-section

Any batch control requirements that the system must perform must be fully specified. This should include:

- Whether the system should perform sequence control.

- The necessity for recipe management systems and the handling of recipe parameters.

- The interaction of batch operations with the operator schematic diagrams.

- The language or media in which the batch programmes should be written.

- The manual stepping of the batch execution programme.

- The standards to which the batch programmes should comply for example NAMUR or SP88.

- Product tracking throughout the entire production and storage process.

5.8.1.8 Continuous Control Requirements sub-sub-section

This sub-sub-section should specify the control specifications and control algorithms such as:

- Proportional, integral and derivative control or any combination thereof.

- Ratio control.

- Cascade control.

- Arithmetic calculations (multiplication, divisions, additions, subtractions, square root, pressure and temperature compensation).

- Self tuning of controllers.

The sampling times of all controllers should be selectable and the degree of redundancy of the controllers should be specified.

Any interventions in regulatory control from supervisory computers, supervisory controlling alarming and data acquisition (SCADA) systems, programmable logic controllers (PLC) systems and advanced control applications should be fully specified.

References of each control loop or scheme should be indicated on the plant engineering line diagrams (ELDs), piping and instrumentation diagrams (P&IDs) and process flow diagrams (PFDs), specifying the plant object, input, output, type (temperature, flow control), interlocking and algorithm.

5.8.1.9 Advanced Control Requirements sub-sub-section

Requirements for the control system to perform applications written in a real time multitasking level language should be fully specified. These advanced control functions and associated hardware control requirements must be defined. A full benefit analyses study should be carried out to identify all opportunities for optimising the system or plant. These opportunities should then be categorised in priorities to establish the urgent functions with high rate of return and to be implemented as a matter of priority, and the long list of opportunities to be implemented as time and funds become available.

The timing of the implementation of these advanced control functions is also critical:

- Implementing the advanced control at the same time as the new system and train the users accordingly. The advanced control will then be based on theoretical calculations.

- Allow the operator or user to get familiar with the new system and then implement the control functions. Control will be based on calculations substantiated by system or plant measurements and performances.

Documentation on the advanced control functions should be fully completed by the developer or supplier with calculations, comments, programme steps and necessary diagrams. Typical advanced control functions could include:

- Multivariable control and optimal control.
- Implementation of dead band controllers.
- Improvements of operations such as distillation column control and compressor surge control.
- On-line procedural support for the operators or users.
- Improvement of measurements.
- Minimise vibrations.
- Solving of spurious trips.
- Provide on-line operator information.
- Implementation of expert functionality.
- Neural networks.
- Rigorous on-line monitoring and control.
- Process optimisation.
- Process synthesis and pinch technology for energy and water minimisation.
- Dynamic Matrix Control (DMC).

- Non-linear control.
- Model based predictive control.
- Batch control.
- Operations planning support.
- Stochastic modelling.

5.8.1.10 Supervisory Control Requirements sub-sub-section

The use and necessity of supervisory computer systems should be defined. Typical functionality required can include:

- Additional and improved trending, logging and reporting.
- Management information systems.
- Scheduling and planning (SAP) and material and resource planning (MRP) application systems.
- Special and complex plant control and modelling application or licensed third party software.
- Link to a typical office local and wide area network (LAN and WAN) systems.

The integration and communication to the main system should be fully specified in terms of redundancy of interface, speed of data transfer, and functionality of the supervisory system without influencing the main control system negatively.

5.8.2 PLANT CONTROL SUBSYSTEM REQUIREMENTS SUB-SECTION

Most plant control systems consist of a variety of subsystems integrated together by means of a communication link using standard protocol or customised drivers specially developed for the application. Typically, the plant control subsystems requirements section will include the following sub-sub-sections:

5.8.2.1 Communications Requirements sub-sub-section

Communication to foreign devices should be specified fully in terms of the following:

- Protocol to be used - Modbus, Profibus, or Fieldbus.
- Master and slave relationship.
- Multi-dropping of devices.
- Redundancy of communication link.
- Access time and transfer rate of data from the host computer to the slave device.
- Type of data transfer - single point to point, files, blocks, analogue, or digital.
- Complete documentation on communication links in use is critical for the user to upgrade or change in the future.

5.8.2.2 Marshalling and Equipment Rack Requirements sub-sub-section

This sub-sub-section should detail the requirements of the control system components to be housed in the system equipment cabinets while the termination to the field is to be done in marshalling cabinets. The marshalling cabinets should also contain the safety barriers if the inputs or output (I/O) signals are not intrinsically safe (I.S.) and should allow for cross marshalling between field signals and signals entering the input output modules of the control system. The equipment racks and the marshalling cabinets should be as far as possible be connected by means of cables with plug-and-sockets to facilitate quick assembly on site.

Top or bottom cable entry into the cabinets should be specified. In case of bottom entry, 150mm from the cabinet bottom is required for making off of cables. The colour of the equipment and marshalling racks as well as physical dimensions should be specified. Each cabinet should be supplied as far as possible with its own 220-Volt alternating current (AC) and 24-Volt direct current (DC) distribution circuitry.

Sufficient earth points for both the cabinet earth and or the intrinsic safe (I.S.) earth should be provided. All cabinets should be supplied with its own cooling system. Removable filters should be fitted in front of ventilation louvers. Mounting of these cabinets should be on sub frames within a false (computer type) floor. Lockable doors should be included. Internal lights can be useful for maintenance and fault finding during night.

5.8.2.3 Instrument Electrical Interface Panel Requirements sub-sub section

In general, the control philosophies must specify how the low voltage interface to control equipment should be handled. This interface is required for the control system to start or stop electrical drives, feedback on the running or stop status of the motors, speed, and tripping conditions. Depending on the supplier or type of the control system, it is good practice to separate the 220-Volt alternating current (AC) system from the 24-Volt direct current (DC) system. In some cases, the plant maintenance teams are also split into Electrical (responsible for the 220-Volt system) and the Instrument Section (responsible for the control and the 24-Volt system). With this interface, a clear battery limit is identified between the two disciplines. Factors to be included in this sub-sub-section should be:

- Use of interface relays.

- Routing of 220 VAC signals to the control system

- Philosophies on the stopping and starting of motors and drives.

- Feedback signals from the motors or drives in terms of stopped or running, overload indication, general fault indications, thermal trip indication and auto, manual or local control status.

5.8.2.4 Operator Console Requirements sub-sub-section

This sub-sub-section is also important to specify as complete as possible. This will define the working environment to the operator for a large portion of his or her working life. The physical environment must therefore be carefully selected and set up to realise any benefits such as efficiency, better performance and satisfaction in the working environment. Factors to be included should be:

- Working space on console.
- Amount of visual display units (VDUs).
- Ergonomic factors such as leg space, type of chairs, and incline of console desks.
- Anti glare devices on visual display units (VDU) screens.
- Illumination of background and working area.
- Communication facilities such as plant radio systems, intercoms and telephones.
- Additional plant-control equipment such as recorders, printers, emergency buttons, stop or start pushbuttons for motors.

5.8.2.5 Power Supply Requirements sub-sub-section

The two main power sources to control equipment should be fully specified:

- Mains supply of 220-Volt or 110-Volt alternating current (AC) - the voltage and frequency including upper and lower tolerances as well as the current requirements.
- 24-Volt direct current (DC) supplies - voltage and upper and lower tolerance as well as the current requirements.

Power supply backup requirements should also be detailed as follows:

- Uninterrupted power supply (UPS) supply of the mains - specifications of the backup time to be given.

- Requirements for constant voltage transformers (CVTs) to be given.

- Connections of the mains to the factory emergency supply.

- Battery backed systems for the 24-Volt system.

- Availability of normal, shutdown and standby 24-Volt direct current supply systems.

5.8.2.6 Shutdown System Requirements sub-sub-section

Emergency shutdown of plant and control systems is critical for the safe well being of capital equipment and human lives. Careful considerations should be given to the specifications of such systems and may include the following:

- What for and where will the system be used.

- Types of system - hardwire relay or programmable emergency shutdown (PES) system.

- Approval authority of the system.

- Interface of the system to the main control system. This interface should only be unidirectional - no software shutdown commands should be sent across the communication link.

- Event recordings of trips and the alarms. Resolution of the alarm and trip events in terms of date and time should be carefully specified.

- Historic logging on hard disks for later retrieval and research work.

- Input and output (I/O) cards to be able to fail to a safe condition.

- On-line software changes and card replacements of redundant central and input and output (I/O) cards must be possible.

- Self-documenting of programme and logic's should be possible.

- Each central processing unit (CPU) should be installed with at least 20% spare capacity to allow for future changes.

- Comprehensive self-diagnostics must be available to guide the maintenance personnel to pinpoint the failed sub module.

- The system must be able to react on external hardwired signals i.e. emergency stops, reset buttons, overrides.

- Soft overrides of input and output signals should be possible only in the shutdown system.

- Alarms should be available for the operator and must be logged.

- System printers for alarm or event and system error logging should be specified.

- On-line card additions and removals.

5.8.2.7 Expert System Requirements sub-sub-section

If an expert system will be required, consideration should be given to the following aspects:

- Type of expert system should be specified - Gensym G2, or DCM.
- Hardware platform required for running the expert system.
- Development requirements such as training and time schedule.
- Availability of resource personnel to assist in the development of the expert system.
- Level of complexity and human interaction between normal operation of the plant and the expert system.
- Testability of performance and accuracy.
- Readiness of the plant in terms of level of instrumentation, level of maintenance of equipment, accuracy and reliability of measurements.

5.8.2.8 Input Output Signal Requirement sub-sub-section

The control system should have the capability and compatibility to connect to various types of input and output signals. For analogue signals, linearisation functionality of at least square root, resistance temperature devices, and thermocouples is required. The system must be able to alarm at least four set points on all types of analogue signals.

Indication of binary or digital status should be derived from voltage free contacts. These contacts must be configurable for either normally open or normally closed contacts.

The following type of input and output signals should be considered and fully listed on the engineering line diagrams (ELDs), process flow diagrams (PFDs) or piping and instrumentation diagrams (P&IDs):

- Proportional, integral and derivative (PID) control loops - these are conventional 3 term control loops with 1 off 4-20mA analogue input and 1 off 4-20mA output. The main sources of 4-20mA input signals are normally field-mounted transmitters and converters. They are either self-powered or externally powered. The output 4-20mA signals will be used for driving current to pressure converters for use on control valves and variable speed drives.

- Cascade control loops - these consist of 2 off 3-term control loops with 2 off 4-20mA analogue inputs and 1 off 4-20mA analogue output.

- Data acquisition analogue signals - these inputs are mainly used for data acquisition such as trending and monitoring, and include 4-20mA, 0-20mA, 1-5 Volt, 1-10 Volt, resistance temperature device (RTD) and thermocouple signals.

- Manual loader analogue output signals - are used for manual control by the operator.

- Digital input signals - these are potential free contacts or 24-Volt direct current (DC) switch signals from contacts in the field and are used for alarms, sequencing, interlocking, and position indication. These signals are generated by field devices such as switches, auxiliary contacts, and relay contacts.

- Digital output signals - these are 24-V direct current (DC) output signals which are driven from the system individually or from the sequencing and interlocking software and are used for starting and stopping of motors, isolation control valves (ICVs), and remote alarms.

5.8.2.9 System Configuration and Programming Requirement sub-sub-section

This sub-sub-section should be carefully specified to minimise rework, redesign and eventually re-configuration or programming of the control system. Although this section is very supplier specific, certain specifications can however be specified for general use in the industry. The flexibility and the capability of the systems make it difficult to be rigid on these specifications. Some specifications that can be included are:

- Colour philosophies of displays, schematics, alarms, and process plant presentations.

- Operator guidance through different levels of the plant control structure.

- Screen sizes of pipes, equipment, dynamic movements of machinery, and 3-dimensional representation of equipment.

- Level of detail required to effectively **running** and **operating** the plant. Most systems have magnificent graphics capabilities, but all that is not always required to operate the plant. However, it can cause some distraction to the operator - critical information is lost between the detail.

- Tag descriptions - different names should not be given to the same equipment.

- Database structures - similar signals should be grouped together, character length of tags, engineering units, ranges and span of values.

This section is critical as it defines the working environment of the operator or user. Total acceptation, willingness to co-operate or rejection of the system is at stake.

5.8.3 PROJECT DEVELOPMENT REQUIREMENTS SUB-SECTION

This sub-section is concerned with any factors relating to the design of the system(s) and conduct of the development life cycle. The following sub-sub-sections should be included:

5.8.3.1 Project Control Requirements sub-sub-section

The project control sub-sub-section should describe methods to be employed to ensure proper project control during the life cycle and include:

- Quality control - what design methods and tools are to be followed by the developer and supplier.

- Standards - to be applied to development (for example, BS 5750, AQAP-13, or SABS 9002).

It is possible that much or all of this information will be incorporated within the project quality plan.

5.8.3.2 Deliverable Documentation sub-sub-section

This sub-sub-section should specify any and all documents to be supplied to the client during development and testing phases of the project. Estimates of required availability dates should be specified. All post-installation documentation to be handed over by the supplier or software developer should also be specified. A typical deliverable documentation package should include:

- Detailed system hardware design list giving all items of software and hardware.

- A set of as built drawings for the control system(s) and subsystems.

- Operating manuals containing operating instructions for the systems.

- Training manuals including system overview and general system information, and description of all the functions of the system(s).

- Maintenance manuals describing general specifications for each item of equipment, troubleshooting, maintenance, calibration, test and adjustment instructions for each item of equipment.

- Process flow sheets, engineering line diagrams (ELDs), process data sheets for all plant items, and site and plant layouts.

When the developer or supplier is using a sub-contractor, the documentation on the equipment should be as comprehensive as that for equipment supplied directly by the suppliers.

5.8.4 SAFETY AND RELIABILITY REQUIREMENT SUB-SECTION

The reliability and safety sub-section of the URS should be concerned with the identification of safety and reliability requirements of the system(s). It needs to appear for all systems where intervention in or control of a hazardous process is to occur (even when protection is ultimately afforded by independent safety or trip systems). This section will usually be a starting point for a hazard and operability study on any computer system.

Before preparing this section, **the client shall be aware of company, divisional, and departmental policies on the safety of programmable systems as detailed in various company documents, the Occupational, Safety and Health act (OSH Act), and the report of the process hazard and operability study**. In the text of this section, cross-reference to the appropriate company documents and the OSH Act guidelines should occur and to the process hazard and operability study.

Parts of the plant could be classified as hazardous areas in terms of SABS 0108. All plant signal inputs and outputs affected by this classification should be listed for the supplier or developer as major cost and hardware implications are involved to comply to the legislative design rules. All hardware to make the analogue, digital and communication loops intrinsically safe, should be specified. SABS approved drawings. The supplier or developer of all intrinsically safe loops should also obtain certification. These should be included in the documentation package to be handed over to the client.

In preparing this section, due consideration should be given to the following which will require close liaison with engineers or developers and other engineering disciplines (this list is not exhaustive):

- Hardware and software failures - precautions are to be taken by the supplier to reduce the probability of failure of any component part of the system. Using modern automated test equipment, the manufacturer should test all electronic circuit boards. Boards should be subjected to a suitable period of operation with temperature cycling in order to eliminate infant mortality of components.

- Data and human errors or violations - internal and application software should be done in such a way that that no human and data errors or violations occur.

- Failure identification and isolation - on board failure identification as well as a sounded alarm should be available from the system. Isolations, lockouts and overrides should be displayed and alarmed as far as possible.

- Remedial and system recovery procedures - recovery procedures for systems and subsystems should be compiled and must form part of the documentation package.

- Security standards - access requirements to the system and to the physical environment of the system must be specified.

- Mean time between failures (MTBF) and mean time to repair (MTTR) requirements of components - calculated or measured data on the reliability of the system should be given. This should include a calculated overall percentage availability of the system and a per loop availability.

  Definition: *MTTR is the average time to diagnose and to rectify the fault. It is accepted that the MTTR will be dependent upon spares holding.* Blanchard and Fabrycky (1981:375).

  Definition: *Availability is defined as the ratio of mean time between failures (MTBF) and the sum of MTBF and the mean time to repair (MTTR).* Blanchard and Fabrycky (1981:375).

  A quantity of spares necessary to achieve the quoted percentage availability shall be required to qualify the calculations.

- Redundancy of hardware and or software - degree of redundancy of controllers, 24-Volt power supplies, 220-Volt power, emergency supplies, and hardware of the system(s).

- Fail-safe operation - the fail-safe position of input and output card channels in event of a power failure should be specified. This can include hold last value, upscale drive and down scale drive.

- Standby and manual control operation - all operation or software intervention to change from auto, cascade and ratio to manual or local should be logged and displayed.

- Start-up and shutdown procedures - procedures on system start-up, shutdown and software version upgrading should be included in the documentation package.

- System reaction to process events - speed of reaction of the system on any input should be specified. Tuning of controllers to allow upsets in the process conditions should be requested.

- Demand on independent trip systems - philosophies on independent relay shutdown systems, programmable emergency shutdown (PES) systems, and shutdown by distributed control system (DCS) systems should be specified. Communications to such system and the main control system should also be specified.

5.8.5 DESIGN PROVISIONS SUB-SECTION

This sub-section should define any measures necessary to meet the foregoing requirements and may include:

- Coating of equipment - this should be included in the equipment specifications for valves, transmitters and colour of equipment. The RAL colour codes should always be specified.

- Encapsulation of components - this may be a standard used by some suppliers, but should not be specified. No on-board repairs can be done on an encapsulated circuit board.

- Cooling systems on components, printed circuit boards, cabinets, and control rooms.

- Electronic or software damping of measured variables, controller outputs, inputs and set points.

- Filtering of measured signals to eliminate noise generated by radio signals, power dips, static, electromagnetic waves, and induction during the starting of large motor drives.

- Screening of cables to prevent the generation of earth loop currents, and video screens to eliminate static.

- Heat resistance specifications.

- Flame proofing of cables, equipment and floors.

- Soldering specifications.

- Power stabilisation with uninterruptable power supplies, constant voltage transformers and inverters.

- Spark suppression by means of special earth mats and braided cables.

- Packaging of equipment during transportation.

- Fire fighting equipment and facilities to be used.

- Earth and lightning protection of equipment and structures.

5.8.6 IDENTIFICATION AND MARKING SUB-SECTION

All requirements for identification and marking should be clearly defined which may include:

- Nameplates and labels.

- Software listing headings.

- Classification numbers.
- Part numbers.
- Version numbers and dates.
- Release numbers and list numbers.
- Change and modification numbers.
- Serial numbers.
- Drawing specifications and references (headings, markings, and conventions).
- Report headings.
- The preferred means of fastening labels should be specified.
- Instrument and Electrical specifications

Table 5.8 below summarises all the aspects that should be taken into consideration when compiling the Control and Automation Requirement Specifications.

Table 5.8: Summary of Control and Automation Requirement Specifications

CONTROL REQUIREMENTS	PLANT CONTROL SYSTEM REQUIREMENTS	PROJECT DEVELOPMENT REQUIREMENTS	SAFETY AND RELIABILITY REQUIREMENTS	DESIGN PROVISION REQUIREMENTS	IDENTIFICATION AND MARKING REQUIREMENTS
Strategy and Plant Control Philosophy Identifications of plant divisions Area allocation Location of control system Detail system description Quantities of inputs and outputs Identification of peripheral equipment Redundancy of the systems Human interface equipment in use **Boundaries Requirements** Control system boundaries Interface requirements **Sequencing Requirements** Process and sequence flowcharts **Regulatory Control Requirements** Plant object description Tag names and full descriptions Input signals required Output signals required Types of signals Ranges of variables Special control algorithms **Manual and Automatic Control Requirements** Manual, local, automatic, standby, ratio, cascade, or split range control Complete signal and tag list **Interlocking Requirements** Electrical motor control Computer to computer control Computer and external systems Interlocking by shutdown systems Software interlocking	**Communication Requirements** Protocol to be used Master and slave relationship Multi-dropping of devices Redundancy of communication link Access time and data transfer rate Type of data transfer Documentation on communication link **Marshalling Rack Requirements** Safety barriers Allow for cross marshalling Plug-and-socket type cables Top or bottom entry of cables Colour of cabinets Physical dimensions Power distribution circuitry Earthing points Cooling system Removable filters Mounting on sub-frames Lockable doors Internal lighting **Instrument Electrical Interface Requirements** Low voltage interface signals Start and stop signals Feedback signals Identification of battery limits Use of interface relays **Operator Console Requirements** Working space on the console Amount of display units Ergonomic factors Anti glare devices Background illumination External communication facilities Additional plant control equipment **Power Supply Requirements** Mains supply of 220- or 110-volt Low voltage supply of 24-volt Uninterrupted power supply Constant voltage transformers Emergency supply Battery backed systems Availability of normal, shutdown and standby supplies	**Project Control Requirements** Quality control Standards to be used **Deliverable Documentation** Detail system hardware design Set of as-built drawings for control system Operating manuals Training manuals Maintenance manuals Process flow sheets Engineering line diagrams Process data sheets Site and plant layout drawings	**Safety and Reliability Requirements** Definition of hazardous areas Intrinsically safe installation SABS approved drawings Hardware and software failures Data and human errors violations Failure identification and isolation Remedial and system recovery procedures Security standards Mean time between failures Redundancy of hardware and software Fail-safe operations Standby and manual control operation Start-up and shutdown procedures System reaction to process events Demand on dependent trip systems	**Design Provision Requirements** Coating of equipment Encapsulation of components Cooling systems on equipment Damping of measured variables Filtering of measured signals Screening of cables Heat resistance specifications Flame proofing of equipment Soldering specifications Power stabilisation Spark suppression Packaging of equipment Fire fighting equipment Lightning protection equipment	**Identification and marking Requirements** Nameplates and labels Software listing headings Part numbers Version numbers and dates Release numbers List numbers Change control numbers Modification numbers Serial numbers Drawing specification numbers Reference numbers Report headings Preferred means of fastening labels Instrument equipment specifications Electrical equipment specifications

Table 5.8: Summary of Control and Automation Requirement Specifications (Continued)

CONTROL REQUIREMENTS	PLANT CONTROL SYSTEM REQUIREMENTS	PROJECT DEVELOPMENT REQUIREMENTS	SAFETY AND RELIABILITY REQUIREMENTS	DESIGN PROVISION REQUIREMENTS	IDENTIFICATION AND MARKING REQUIREMENTS
Batch Control Requirements Sequence control Recipe management Interaction to operator schematics Language of programs Manual stepping Standards of compliance Product tracking **Continuous Control Requirements** Proportional, integral and derivative control Ratio and cascade control Arithmetic calculations Self tuning of controllers **Advanced Control Requirements** Multivariable control Dead band control Surge control On-line procedural support Improvement of measurements Minimize vibration Solving of spurious trips On-line information Expert functionality Neural networks On-line monitoring and control Process optimization Process synthesis Pinch technology Dynamic Matrix Control Non-linear control Model based predictive and batch control Operations planning support Stoichastic modeling Production coordination and scheduling **Supervisory Control Requirements** Trending and logging Management information Scheduling and planning Special and complex Link to office LAN Plant control	**Shutdown System Requirements** Purpose of use Types of systems Approval authority Interfaces to the control system Event recording of trips and alarms Historic logging Input and output card specifications On-line software changes Self-documenting of programs Spare capacity of processors System self-diagnostics External hardware signal control Soft overrides of input and output signals Logging and displaying of alarms Use of system printers On-line hardware addition and removal **Expert System Requirements** Preferred type of system to be specified Hardware platform requirements Development requirements Availability for resource personnel Level of complexity Testability of performance and Accuracy Evaluation of plant instrumentation level **Input Output Signal Requirements** Proportional, integral and Derivative cascade control Data acquisition signals Manual loader signals Digital input signals Digital output signals **System Configuration and Programming Requirements** Colour philosophy of displays Operator guidance Screen sizes of pipes and equipment Level of detail on displays Tag description and database Structures				

5.9 SYSTEM FLEXIBILITY SECTION

The system flexibility section of the URS should be an attempt by the client to specify the likely areas of expansion of the system(s) which should contain a statement of the life expectancy of the system(s) and may also include:

- Software expansions and enhancements. An undertaking from the developer or supplier should be obtained for the upward upgrading of the system(s).

- Hardware expansions and enhancements and if there are any short to medium term plans to introduce new systems.

- Capacity of the system in the short and long term.

- Performance tuning.

- Storage capacity enhancements.

- Interfaces to and impact on other systems or environment in the future.

- Long term support from supplier.

5.10 TESTABILITY SECTION

The testability section should contain the client's requirements in the testing and validation of the system and should include the following sub-sections:

5.10.1 GENERAL SUB-SECTION

Performance tests should be done on all systems. Tests should also be carried out on site before and after installation. These tests must be defined in a series of Acceptance Certificates, which individually describes each of the separate activities to be demonstrated. Work acceptance tests shall not be deemed complete until all certificates have been signed by representatives of all parties concerned (client, developer, and supplier).

5.10.2 WORKS TEST SUB-SECTION

Work tests should only commence after the supplier has performed his own testing to ensure that the requirements of this specification have been met. All components of the system(s), including cables supplied as part of the system(s), shall be connected in the operating arrangement. The tests as defined by the works acceptance certificates should generally include the following:

- Hardware physical inspection for completeness, safety, finish and conformity with arrangement and layout drawings.

- Demonstration of the correct operation of all inputs, outputs, and control loops.

- Demonstration of the complete software system. This should include individual tests of each software routine when running concurrently with all other software routines and utilising peripheral devices.

- Complex software and application software should be thoroughly tested by a plant representative with assistance of a control engineer.

Non-exclusive examples of aspects which may be defined include:

- Availability of test data.
- Preferred duration of testing.
- Simulation methods - this may affect manning and production of simulation software.
- Re-testing.

5.10.3 SITE TESTS SUB-SECTION

On completion of the installation, pre-commissioning of the systems should be done to prove the correct operation of all related system hardware and software in terms of the provisions of these specifications.

5.11 CONSTRAINTS AND ASSUMPTION SECTION

This section should identify the major constraints, which the client wishes to impose on potential developers and suppliers and any assumptions made during the writing of the URS.

Typical the constraints might include **time, cost, major restriction on choice of interface hardware, and any preferences**.

All assumptions should be clearly identified since they may affect the whole perspective in which the URS is considered by the supplier and can impact heavily on life cycle costs.

5.12 KEY PERFORMANCE PARAMETERS SECTION

All issues and specifications that are critical for the process, operator or user or for the business should be listed. This will be heavily dependent on the plant or business to specify their critical parameters. Compliance to this section will also be used to measure the success of the completed project. The following could be considered:

- Response times of screen updates.
- Alarming of signals and handling of alarms.
- Data transfer to specific foreign equipment.
- Additional facilities for training and laboratory systems.
- Overall project cost and schedule.
- Plant high performance trails after implementation of the project.

5.13 ANNEXES

A number of annexes to the user requirement specification will normally be required. In these the following should appear:

- Internal standards and guidelines - where a standard or guideline internal to the client is to be adhered to which is not publicly available this should be included as an annexe.
- A full index.

- Glossary of terms.

- All relevant technical and process drawings, schedules, descriptions and documentation.

5.14 SUMMARY

This chapter contains the recommended structure and contents of a user requirement specification. It forms the kernel of this dissertation, as the primary objective of the study was to conclude a specific structure for compiling URSs. This recommended structure was compiled from the interviews with the respondents as outlined in Chapter 4 and can be summarised in the following:

- Introduction section
- Overview section
- Scope of the project section
- Business requirement specification
- Process requirement specification
- Operational requirement specification
- Control and automation requirement specification
- System flexibility section
- Testability section
- Constraints and assumptions section
- Key performance parameters section
- Annexes

The specific order in which these items are used in the URS is not important. Much detail has been given with-in the sub-sections, which was derived from the large amount of information received during the interviews and from the company specific information. Pictorial diagrams have been included at the end of some of the sections to summarise the detail stated in that specific section.

The above sections can be used as a guideline to compile a URS for a project in the process control industry and these guidelines must be flexible to suit individual URSs. To be able to check that the compiled URS consists of all the required elements, a URS review should be undertaken which is the subject of the next chapter.

CHAPTER 6

PRODUCTION AND REVIEW OF THE URS

6.1 INTRODUCTION

The production of a URS in a specific format or according to the recommended structure as discussed in Chapter 5, is no guarantee that all the aspects are included in the final document. In Chapter 3 of the dissertation, it has been stated that a URS document should, apart from the technical detail, also adhere to certain quality specifications such as stability, unambiguity, completeness, consistency, verifiability, modifiability and traceability.

The URS forms the foundation of all the other phases of the project, and provides a measurable indication of success at the end of the project. It is therefore critical that the produced document is subjected to formal change, control and review procedures in order to ensure the above mentioned quality characteristics are maintained.

This chapter of the dissertation proposes recommended guidelines for the production and review of a URS, the personnel to be involved in the process and control measures designed to ensure the following:

- The supplier and developer **know** what is required of him and has the necessary information to proceed to the next stage in the life cycle namely the **functional specification or conceptual design phase**.

- All major areas of technical functionality have been specified.

- Control the accuracy and completeness of the URS document throughout the entire project life cycle.

Similar to the description of the structure discussed in Chapter 5, very little literature exists and so much of what is detailed here, is derived from information received during the investigation research and from experience.

6.2 PRODUCTION OF A URS

Prior to the production of any URS, the following should ideally be agreed between the client or user, and developer or supplier:

- Contents - a list of the sections, sub-sections and headings should be derived.

- Time scale - a schedule for the production of the complete specification and individual sections of it should be planned, together with dates for review sessions.

The production can then commence and progress measured against the planned schedule. Reviews may commence as soon as any part is ready, although reviews may have to be repeated subsequently to ensure consistency across the document as a whole.

Some guidelines which may reduce difficulty later are:

- Format, layout and style should be agreed upon and the producing personnel or secretarial services informed - attention should be paid to titling, section, page and paragraph numbering **(consecutive page numbering is recommended),** identification and spacing, capitalisation, tense, abbreviations, technical terms, synonyms, and grammar.

- Method of production – word-processing package, access to editors and the use of spelling checkers.

6.3 SECTIONS PRESENTED FOR REVIEW

As each section of the specification is produced for review, the following should be clearly indicated:

- The author(s) and originator(s) of the section.

- The date of production.

- A pre-issue identifier (example pre-issue 1,2,3).

6.4 PERSONNEL INVOLVED IN REVIEW

It is preferable to split the review process into a series of sessions over a period of days or weeks. The choice of personnel in such circumstances is therefore crucial to ensure:

- All parts of the URS are reviewed to the same standard.

- The implementor(s) are aware of what is being proposed and can influence the requirements using their detailed technical knowledge of what is possible and most economic.

- Safety critical proposals are **fully considered**.

For these reasons, the following personnel should be involved at the review sessions:

- The originator(s) and author(s) of the area under review.

- A technical knowledgeable representative of the user or client with the authority to take decisions.

- The supplier or developer's representative.

- Persons from other engineering disciplines (particularly in safety critical areas).

- Quality assurance personnel on a part-time basis.

6.5 CONDUCT OF THE REVIEWS

The review sessions themselves have the following purposes:

- Checking that no areas have been missed.

- Ensuring that what is proposed is feasible and testable.

- Checking that the text is "sufficiently" detailed and yet unambiguous.

- Audit of style and layout of the specification.

Some time before the review, the originator should circulate the section to be reviewed to interested parties and they should read and document their criticisms **prior** to the meeting. By doing this, if they are unable to attend the review meeting, their observations can be considered and discussed.

Annexe C gives examples of detailed checklists for any reviewer and additionally can be used to guide the review sessions itself.

At the meeting, those present should concern themselves **only** with the sections under review and should avoid lengthy discussions of relatively insignificant issues. These should be deferred if necessary for a subsequent session. This is **very important** since time wasted in a review may result in the latter portions of the section under review being "nodded through" without proper discussion because of pressure of time.

One person should maintain a record of issues or points and a specific reference to any and all sections considered. This latter point is very important since particularly in safety critical areas, there should be a record of what was covered. A copy of these records should be circulated after the meeting. The client should ensure that corrections are implemented by holding a further review if necessary.

6.6 APPROVAL AND DISTRIBUTION OF THE FINAL URS DOCUMENT

The final version or issue revision of the URS document should first be circulated for approval. It is important to circulate the document for approval to all parties involved in the production or review. Comments to this document can be implemented in a later revision of the document. The project manager should use his own discretion for the distribution of the signed document but it should at least be distributed to all discipline lead engineers involved in the project.

6.7 URS CHANGE CONTROL PROCEDURE

For each URS generated, a separate change control procedure should be implemented. The purpose for this is to keep a record of changes from the original issue and to maintain the URS as **a live and dynamic document.**

Each change to the URS should be carefully documented with complete references to the applicable section, sub-section or sub-sub-section. The same approval body should then approve the complete document with the updated revisions and changes. The new document should also clearly states the date of issue and the latest revision number.

6.8 SUMMARY

This chapter summarises the external measures to be taken by project personnel to ensure that the produced document is technically complete. It should also adhere to certain quality standards such as stability, modifiability, flexibility, unambiguity, textual completeness, consistency and traceability.

Once the document is approved, it is the responsibility of the project manager to maintain the document and to control all the changes that will be requested during the life span of the project. It is important to establish a separate phase in the project life cycle to manage and control the generation of the URS document.

The above section can also be used as guidelines to review the production of a URS. These guidelines should, as in the recommended guideline for the structuring of a URS, be flexible to suit the particular company and organisational structure of the company.

CHAPTER 7
CONCLUSIONS, RECOMMENDATIONS AND SUMMARY

7.1 INTRODUCTION

From the qualitative research investigation done for this dissertation, the primary objective of producing a recommended structure that can be used for the production of a URS, has been reached in Chapter 5. In addition, a review methodology and control measures have been stated in Chapter 6 to ensure that the produced document conforms to certain quality standards and practices as stated in the literature overview in Chapter 3.

Given the findings and results of the foregoing chapters, and the concepts that were analysed concerning the structure and content of a URS, this chapter of the dissertation will focus on the final conclusions, recommendations and critical success factors that followed from the investigation and interviews. The success of the study will be measured against the stated primary and secondary objectives. There after, the achievements and suggested future fields of the study will be given.

7.2 CONCLUSIONS

The following conclusions can be drawn from the results of the investigation:

7.2.1 CONCLUSIONS ON CURRENT SPECIFICATION PRACTICES

- From the analysis of the results from the various groups of respondents, many common facts, issues, problems and presentations surfaced. This is an indication that most companies or individuals are doing the basic and important things correct. However, most of the time it is the insignificant, unpredicted and unimportant issues that are causing the tripping hazards in the execution of projects.

- No formal structures or guidelines for the compiling of a URS are currently existing in the companies or used by individuals. The respondents recognise the importance of a URS, but nobody has tried within his or her company to document the enormous amount of knowledge and experience of individuals regarding this subject. Individuals tend not to share their knowledge.

- Theory on the subject is non-existent. No publicised articles or computer software on the particular subject could be found. Internal and proprietary company documentation such as quality assurance, standards, procedures, guidelines, contract and tender documents contains certain aspects of specifications, but even these are very incomplete.

7.2.2 CONCLUSIONS ON STRUCTURE AND CONTENT OF A URS

- Within the companies, because no fixed guidelines exist for the specifications of requirements, friction and false perceptions are created between clients, suppliers and designers as the real requirements from the client are not satisfied. This results eventually in a sense of mutually distrust.

- The key to a good requirement specification is planning. Before the specification is written, the whole project should be fully thought through. The specification transforms this planning in words, and will be mush easier with the help of a guideline.

- The structure of the URS should not necessarily be in the same sequence as suggested in Chapter 6 of this dissertation. The most important aspects that should be used form part of the sub-sections.

7.3 CRITICAL SUCCESS FACTORS

In practice, when an idea is formed or a project is launched by a business entity, the first step for the prospective contractor is to evaluate his own business and capability in terms of profitability, technology, and resources. He will then form a project team and set up the communication and liaison channels with the client. The next step or phase in the project is the establishing of the exact scope of the project. This is achieved by the production of the User Requirement Specification document, which will be generated in conjunction with the client. Once this document is generated and approved, the actual project work can proceed as per the rest of the project phases.

The importance of the URS document can therefore be seen in the initial stages of the project where the technical terms and conditions for the project are agreed. These aspects and detail can also be considered as the basis to measure the success of the project. Success can not be guaranteed if some items or issues are omitted or overlooked during the preparation of the scope of the project. To ensure complete success of the project, certain success factors should be specified – failure of one or more of the criteria of these factors will result in the failure of or dissatisfaction with the project.

In Section B and in particular, Question 15 of the questionnaire, the respondents' opinion regarding the main sections of the URS was gathered. These aspects can be considered as the critical success factors for the structuring of a URS as it forces the writer or user to consider all global aspects that might influence the successful implementation of a project. In general, these factors can therefore also be used as critical success factors for the entire project and are listed as the following:

- Introduction section.
- Overview section.
- Scope of the project section.
- Business requirement specification.
- Process requirement specification.
- Operational requirement specification.
- Control and automation requirement specification.
- System flexibility section.
- Testability section.
- Constraints and assumptions section.
- Key performance parameter specification.

- Annexes.

7.4 RECOMMENDATIONS

Every project is unique – with its own project personnel, scope of work, environment and associated uncertainties and problems. The uncertainties and potential problems are normally the result of a chain reaction caused by poor defined scope, conceptual design based on a poorly defined scope, detail engineering and construction that went wrong because the conceptual design is wrong. During commissioning, complete re-design is then often required or design is done as commissioning progresses. To summarise, efforts are concentrated mainly to correct deficiencies caused by a poorly defined scope.

This document is aimed to assist the project team and the client in the initial stages of the project where the exact definition and ground rules of the project scope are defined. The following recommendations can be done as followed from this study:

- The guidelines as specified in Chapter 5 and 6 should be used as guidelines only and not be as specifications, standards or procedures. The lists of considerations as detailed in the sub-sections are not exhausted, and can be expanded depending on the type of project.

- The structure of this document consists of the key success factors for any process control project. The detail under each section of Chapter 5 and the items listed in Annexe 3 can be used as a checklist to ensure completeness of the project scope.

- This document should be valuable for a Consultant, specialising in the definition of project scopes, supervising construction, conducting or facilitating preliminary design studies, and hazardous and operability studies. It is also useful for the structuring of design philosophies.

- The checklists in the annexes are only an indication of the type of questions that can be asked. These lists are by far not exhausted.

- The practical application of these recommended guidelines must be flexible. It should be written to the advantage of the company with full consideration of the size and type of project.

- The recommended guidelines are mainly applicable to the process control industry, but could be implemented with success in the computer industry. Some of the sections can also be used in similar documents applicable to other disciplines.

7.5 SUCCESS OF THE STUDY

The achievements of the primary and secondary objectives have been evaluated to determine the success of the study.

- The primary objective has been achieved as the recommended content, layout, preparation and review of a user requirement specification for use in the process control industry are specified in Chapter 5 and 6.

- The first secondary objective to research the literature available in the form of technical manuals has been done in Chapter 3. Unpublished internal and proprietary documentation from various companies was obtained during the formal interview sessions.

- The second secondary objective was achieved in specifying the key success factors of the study and to use these factors as the framework for the recommended guidelines.

- The third secondary objective to ensure continued client satisfaction can be achieved by measuring the final implemented project with the issues listed under the main sections of the guidelines.

- The fourth secondary objective to provide an effective means to manage change and project variations is achieved in Chapter 6.

- The last secondary objective to prove that the URS forms the platform, on which a process control project can be built, is provided in the theoretical background in Chapter 3.

7.6 SUGGESTED FUTURE FIELDS OF STUDY

A good User Requirement Specification is the answer to a successful process control project. Depending on the size and type of project, the scope of the project could include mechanical, civil, and electrical disciplines. Similar studies should be attempted for these disciplines.

7.7 SUMMARY

Any investment, which offers a payback measured in months rather than years, is attractive. To have the engineering and support capability locally, is something to be intensely proud off.

The cost of implementation of technology projects is very high especially in monetary terms and no informed business manager can afford to use the services of inexperienced technologists or engineers to make decisions that effect the future efficiency and reliability of the plant. It is so disheartening to see the well intended but green technologist or engineer make a poor engineering or weak design decision due to the lack of experience that wastes hard earned project funding or does not fulfil the short and long-term technological needs of the business.

These guidelines specified in this dissertation will provide options for the inexperienced and experienced to work together with the end user to provide optimal business solutions and world class technology to compete globally.

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ANNEXE A

QUESTIONNAIRE

USER REQUIREMENT SPECIFICATION

INTRODUCTION:

I, J.J. Botha, an employee of Polifin Limited, am currently enrolled at the PU for CHE as a MBA student. As part of the MBA course, a dissertation needs to be submitted, and to be able to complete this, research work needs to be undertaken.

I have decided to use User Requirement Specifications (URS) as a topic due to the fact that it forms an integral part of the project life cycle and the Polifin Electrical Instrument Technical Section is actively involved in process control projects on all the Polifin sites. The title of my thesis is "Guidelines to structure a User Requirement Specification in the Process Control Industry".

The overall objective of the questionnaire is to extract information form your personnel on the specific subject. Firstly, particular emphasis will be placed on what your company considers the advantages of a formal URS may have on your business and secondly, what do you require as the mandatory elements that such a specification should have. The investigation will be used to provide the required guidelines to formulate the required recommendations.

QUESTIONNAIRE:

A formal appointment will be arranged with yourself or representative(s) of your company and the attached list of questions will be discussed during the interview. To achieve optimal benefits, it would be appreciated if these questions can be discussed amongst you prior to the interview. The questions are divided functionally into the following sections:

SECTION A: Information regarding the current specification practices in your company, the perceived benefits of using a user requirement specifications system and the effect(s) it will have in the execution of projects.

SECTION B: Information on what the contents should be and how the specifications should be presented or structured to form a dynamic and flexible document.

PARTICIPATION IN THE QUESTIONNAIRE:

Your participation in the compilation of the answers will be appreciated. The population size of the investigation is limited to the process control environment. It is therefore important that your feedback is received as part of the population. Company proprietary information in the form of discussions and printed material will be treated as confidential and will not be distributed.

If any problems are experienced with the questionnaire, please contact me at (016) 703 2467 or 082 651 8172.

Thank you

Kobus Botha

INLEIDING:

Ek, J.J. Botha, tans 'n werknemer by Polifin Beperk, is ingeskryf by die PU vir CHO as 'n MBA student. As deel van die MBA kursus moet navorsing gedoen word wat dan as 'n skripsie ingehandig sal word.

Die onderwerp van die skripsie handel oor Gebruikersbehoefte Spesifikasie (GBS), aangesien dit 'n integrale deel vorm van die projek lewenssiklus en die feit dat Polifin se Elektriese en Instrumentasie afdeling aktief betrokke is in proses beheer projekte. Die titel van my skripsie is: "Riglyne vir die strukturering van Gebruikersbehoefte Spesifikasies in die Proses Beheer Industrie".

Die oorhoofse doel van die aangehegde vraelys is om informasie te verkry vanaf u personeel in verband met die spesifieke onderwerp. Spesifieke klem sal in die eerste plek geplaas word oor wat die spesifieke voordele sal wees wat die gebruik van 'n formele GBS vir u maatskappy moontlik sal meebring en tweedens, wat behoort die kritiese elemente te wees waaruit 'n tipiese GBS moet bestaan. Die ondersoek sal gebruik word om die nodige riglyne te veskaf ten einde die gevraagde aanbevelings te formuleer.

VRAELYS:

'n Formele afspraak sal met u of met van u verteenwoordigers gereël word om die aangehegde vraelys te bespreek. Om optimale voordeel te verkry, word u vriendelik versoek om hierdie vrae vooraf onder uself te bespreek.

Die vrae is funksioneel in twee afdelings ingedeel:

AFDELING A: Informasie aangaande die huidige spesifikasie praktyke in u maatskappy, die moontlike voordele wat verkry behoort te word deur die gebruikmaking van 'n GBS en die effek(te) wat dit behoort te hê op die uitvoering van projekte.

AFDELING B: Informasie oor wat die inhoud behoort te behels en hoe die spesifikasies voorgestel of gestruktureer behoort te word om 'n buigbare en dinamies dokument te veseker.

DEELNAME AAN DIE VRAELYS:

U deelname aan die samestelling van die antwoorde sal hoogs waardeer word. Die populasie grootte van die ondersoek is slegs beperk tot die proses beheer omgewing. Dit is daarom belangrik dat u terugvoering ontvang word as deel van die populasie. Vertroulike maatskappy inligting in die vorm van besprekings en gedrukte materiaal sal streng vertroulik hanteer word en nie versprei word nie.

Indien enige probleme ondervind word met die vrae, skakel my by telefoon (016) 703 2467 of 082 651 8172.

Byvoorbaat dank

K. Botha

QUESTIONS/VRAE

SECTION A/AFDELING A

CURRENT PRACTICES/HUIDIGE AKTIWITEITE

1. Is any more additional background information on the purpose of the investigation required? / *Word enige addisionele agtergrond inligting aangaande die doel van die ondersoek benodig?*

2. What do you understand under " URS" ? / *Wat verstaan u onder 'n " GBS" ?*

3. Is your company involved in any project issues and if so, how are your projects executed? / *Is u maatskappy betrokke by enige project aangeleenthede en indien wel, hoe word hierdie projekte hanteer?*

4. What systems are currently in place in your company to address user requirements? / *Wat se sisteme is in u maatskappy in plek om gebruikersbehoeftes te adresseer?*

5. Are you familiar with the project life cycle concept and what role should the URS play in this life cycle? / *Is u vertroud met die konsep van projek lewenssiklus en watter rol behoort die GBS te speel in hierdie lewenssiklus?*

6. How are additional new and variations on requirements from clients handled? / *Hoe word nuwe en veranderde behoeftes vanaf kliente hanteer?*

7. What would you consider as the purpose and benefits of a URS? / *Wat sou u beskou as die doel en voordele van 'n GBS?*

8. How do you experience the trend of total project cost and to what reasons should that be contributed? / *Hoe word die neiging in totale projek kostes ervaar en waaraan sou u dit toeskryf?*

9. Have you lost any tenders to you opposition where the client did not properly specify his needs? Please explain what happen and why? / *Het u al enige tender verloor teenoor u opposisie waar die klient nie sy behoeftes behoorlik gespesifiseer het nie? Veduidelik wat het gebeur en hoekom?*

10. What competitive edge would a good URS gives you? / *Wat se kompeterende voordele sal 'n goeie GBS u bied?*

11. Have you experienced any legal actions taken or threatened to be taken against you by the client, on the dissatisfaction of an implemented project? Please explain. / *Is daar al enige wetlike aksies of beoogde aksies deur 'n klient aan u aanhangig gemaak oor die ontevredenheid van die implementering van 'n projek? Verduidelik.*

12. When a project is completed, what mechanisms are in place to check total client satisfaction? / *Wanneer 'n projek voltooi is, wat se meganismes is in plek om totale kliente tevredenheid te toets?*

SECTION B/AFDELING B

CONTENTS AND STRUCTURE OF THE URS/INHOUD EN STUKTUUR VAN DIE GBS

13. What would you consider as a "good" URS? What quality criteria should such a URS have? / *Wat sou u beskou as 'n "goeie" GBS? Aan wat se kwaliteit kriteria moet so 'n GBS voldoen?*

14. What characteristics should a URS have? / *Aan watter karaktersitieke eienskappe moet 'n GBS voldoen?*

15. What would you consider the main sections of a URS to be? / *Wat sou u beskou as die hoof afdelings waaruit die GBS moet bestaan?*

16. Is the description of the process and the environment, in which the project will be implemented, important? Give reasons. / *Is die beskrywing van die proses en agtergrond waar die projek ge-implementeer word, belangrik? Verskaf redes.*

17. What additional background information is required in the URS? / *Wat se addisionele agtergrond inligting word benodig in die GBS?*

18. What would you consider under the "scope of the project"? / *Wat sou u alles oorweeg onder die "omvang van die projek"?*

19. Which elements would you consider under business specifications? Give reasons. / *Watter elemente sou u oorweeg onder besigheid spesifikasies? Verskaf redes.*

20. Which elements would you consider under process specifications? Give reasons. / *Watter elemente sou u oorweeg onder proses spesifikasies? Verskaf redes.*

21. Which elements would you consider under operational specifications? Give reasons. / *Watter elemente sou u oorweeg onder operasionele spesifikasies? Verskaf redes.*

22. Which elements would you consider under control and automation specifications? Give reasons. / *Watter elemente sou u oorweeg onder beheer en outomatisasie spesifikasies? Verskaf redes.*

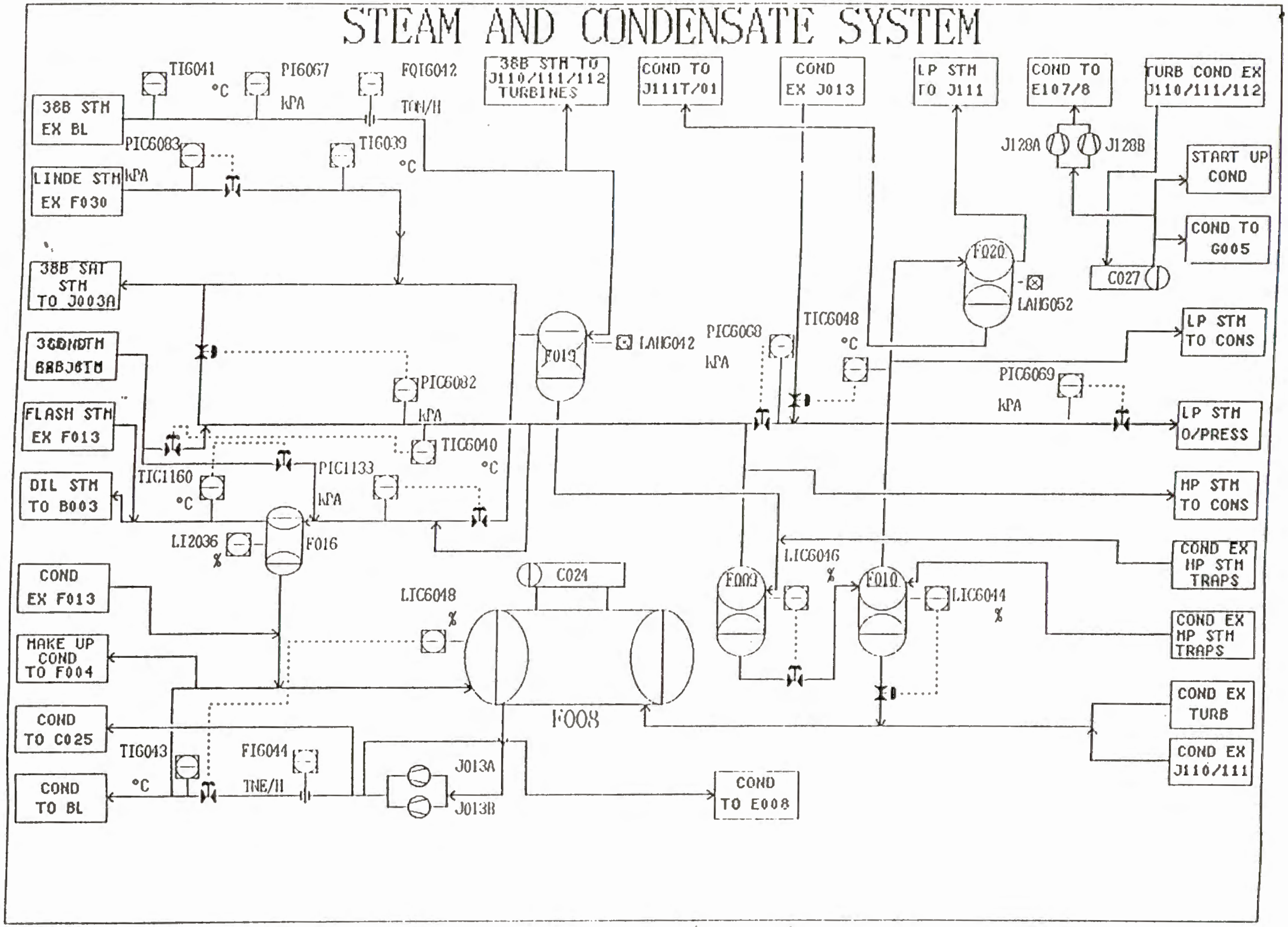
23. Which elements would you consider under key performance parameter specifications? Give reasons. / *Watter elemente sou u oorweeg onder sleutel prestasie spesifikasies? Verskaf redes.*

24. Is there any other valuable information that you can add to the above? / *Is daar enige addisionele inligting wat by bogenoemde bygevoeg kan word?*

25. How would you ensure the completeness of the URS? / *Hoe sou u te werk gaan om die volledigheid van die GBS te verseker?*

26. Any additional questions? / *Enige addisionele vrae*?

Graphics (advanced function type) [Static graphics]



ANNEXE B

ANNEXE C

1. Table of contents checklist

MAIN SECTION	SUB-SECTION	HEADINGS/FROM POINTS
Introduction	Objectives/purposes/time frame/legal	
Overview	Block diagram(s)/ explanatory text	
Data handling	Interfaces	Inputs, Outputs Derived inputs Inter-relationships
	Plant Hardware	ICV's/CV's/etc.
	External Data Transfers	Throughput Frequency Type of data Transfer Security
	Alarms, Interlocks, Trips, Shutdown	Alarms, etc. Interlocks Trips
	Data Storage	Capacity Access etc.
	Special Interfaces	Novell Modbus I/O
Human Interfaces	Human Interface Equipment	Types, Numbers, Location
	Human/System Interaction	Description of Integrity

	Security/Integrity	Access/Protection Retention/Recovery Security Methods
Performance Special requirements	Operational Description System Performance Maintenance Requirements Other Special Requirements	Method of operation Response Timing etc. Requirements Availability Other special requirements
Safety/Reliability	Failures, Errors, MTBF, MTTR, Redundancy, etc.	
Environmental Requirements	Environment Description Passive Environment Active Environment Design Provision Identification & Marking	Description Location Dust, Vibration Heat, Noise, Health, etc. Cooling, screens, etc. Labels, Serial Numbers, etc.
System Flexibility	Expansion, Life expectancy, tuning, support	
System Testability	Availability, testing periods, Testing methods, Re-testing, FAT & SAT	

Development Life Cycle	Project Control Documentation	QA/Configuration control In/after project
Constraints/Assumptions	Client Constraints, Assumptions	
Appendices	Internal standards, Index, Glossary	

2. Review checklists

2.1 Process/Plant/Overview checklist

(This list is not exhaustive)

QUESTION	YES/NO
Is a process description included?	
Is the project start date specified?	
IS THE PROJECT END DATE SPECIFIED?	
Is the process a single product continuous one?	
Is the process a single product batch one?	
Is the process a multi-product continuous one?	
Is the process a multi-product batch one?	
Is the process environment adequately specified?	

2.2 Plant/system inputs and outputs checklist

(This list is not exhaustive)

QUESTION	YES/NO
Is the maximum number of analogue inputs defined?	
Is the minimum number of analogue inputs defined?	
Are the types of analogue inputs specified?	
Is the maximum of types of analogue inputs specified?	
Is the maximum number of analogue outputs defined?	
Is the minimum number of analogue outputs defined?	
Is the maximum number of digital inputs defined?	
Is the minimum number of digital inputs defined?	
Is the maximum number of digital outputs defined?	
Is the minimum number of digital outputs defined?	
Is the maximum number of control sequences defined?	
Is the minimum number of control sequences defined?	
Is the maximum number of analogue control loops defined?	
Is the minimum number of analogue control loops defined?	
Is relay replacement required?	
Is the maximum number of derived variables defined?	
Is the minimum number of derived variables defined?	
Is optimisation required?	
Is the maximum number of open/shut valves defined?	
Is the minimum number of open/shut valves defined?	

Is the maximum number of motors/drives/compressors defined? Is the minimum number of motors/drives/compressors defined? Is the maximum number of control valves defined? Is the minimum number of control valves defined? Is other plant hardware required/present? Is number of links to site/works computers defined? And frequency of transfers? Is number of links to plant/control computers defined? And frequency of transfers? Is number of links to plant control PLCs defined? And frequency of transfers?	

2.3 Operational data/alarms/trips/historical recording checklist

(This list is not exhaustive)

QUESTION	YES/NO
Are analogue alarm functions required?	
Are digital alarm functions required?	
Are derived value alarm functions required?	
Is rate of change alarms required?	
Are deviation alarms required?	
Are alarms to be displayed?	
Are alarms to be printed?	
Are alarms to be logged?	
Has the maximum number of trips been defined?	
Has the minimum number of trips been defined?	
Is the maximum number of values to be logged defined?	
Is the minimum number of values to be logged defined?	
Are the frequencies of logging defined?	
And on-line retention period?	
And off-line retention period?	
Is the maximum number of recipes defined?	
Is the minimum number of recipes defined?	
Is the maximum number of items per recipes defined?	
Are items to be used as set points?	
Are items to be used as alarm limits?	

Are items to be used as outputs? And on-line retention period? And off-line retention period?	

2.4 Human Factors checklist

(This list is not exhaustive)

QUESTION	YES/NO
Has the number of VDU's been defined?	
Has the number of colour graphics VDU's been defined?	
Is the number of colour schematics defined?	
Is the number of non-graphic schematics defined?	
Are industrial VDU/keyboards required?	
Is security/password access required?	
Have the number and types of plotters been defined?	
Have the number and types of printers been defined	
Have the number of mimic panels been defined	
Are alarm annunciators required?	
Are special devices (mouse, tracker ball, bar-code readers) required?	
Is an engineering/training terminal required?	
Have the number and types of displays been defined?	
Have the number and types of reports been defined?	
Have the number and types of logs been defined?	
Is sequence manipulation required?	
Is control loop operation required?	
Are recipe changes required?	
Are alarm displays required?	
Are printouts of alarms required?	

2.5 Special requirements/performance checklist

(This list is not exhaustive)

QUESTION	YES/NO
Are the critical system responses specified? Is required display refresh specified? Does plant control depend on computer? Are there planned stoppages of the process? And if so, has their frequency been specified? Have maintenance requirements been specified?	

2.6 Safety and Reliability checklist

(This list is not exhaustive)

QUESTION	YES/NO
Is the system required to handle safety trips/alarms?	
Is there an independent protection system?	
Have process upsets been adequately specified?	
Have safe and unsafe process states been specified?	
Are critical response times to process upsets defined?	
Is the system required to perform emergency shutdown?	
Have reliability figures been specified?	
Has manual control operation been specified?	
Have critical measurements/control been specified?	
Will the system rely on other systems for recovery?	
Will the system rely on other systems for restart?	
Have environmental stresses been adequately defined?	
Have availability figures been specified?	

2.7 Testing/Project control/Deliverables checklist

(This list is not exhaustive)

QUESTION	YES/NO
Are planning and review procedures defined?	
Are design methods and tools defined?	
Are standards and method of conformance defined?	
Are acceptance testing criteria and conduct defined?	
Are configuration/document/version control defined?	
Has defect reporting system been defined?	
Are change control systems defined?	
Are the deliverable documents defined?	
Can the process be simulated?	
Is tuning/change required?	
Will the client specify any test data?	
Are all likely areas of expansion/upgrade defined?	

2.8 General style/consistency/usability checklist

(This list is not exhaustive)

QUESTION	YES/NO
Is the text readable?	
Does the text/format conform to agreed convention?	
Are all synonyms explained on first use?	
Are synonyms over-used?	
Are naming conventions consistent?	
Are cross references complete and accurate?	
Can the developers understand the specification?	
Can they work from it?	
Can the client/user understand the specification?	
Can a supplier/developer understand the specification?	