ANALYSIS OF THE ENGINEERING DESIGN PROCESS IN AN INDUSTRIAL CONTEXT

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SUMMARY

This dissertation is concerned with the process of engineering design, and the development of ways to improve design quality in industry through more effective management of design activities.

A review of the literature suggests that the way in which needs and ideas are converted into information for manufacturing products and technical systems is not yet fully understood, despite a long history of innovative engineering design in industry. Better understanding of what happens in practice is needed. Participant observation of actual engineering design projects, where the researcher takes an active part, records what happens and analyses the field data collected, is a recommended research approach.

The participant observation of an engineering design project involving the design of a high-pressure, high-temperature system for testing materials in a simulated coal gasification environment is described. A systematic approach was used to structure the design work, and all activities were recorded during the 2.8-year project. In total 1180 pages of field notes, 76 hours of tape-recordings, 116 weekly reports and 6 design reports were accumulated. These covered 1373 separate events or 'interchanges', and detailed the 2368 hours of project effort. 'Interchange data sheets' were compiled for each of the 37 participants, and the 2488 coded records were entered into a computer for sorting and categorizing. The reduced data resulting from this is analysed both quantitatively and qualitatively in terms of the engineering design process.

To clarify the context within which the project took place and to help structure the analysis, a Context Model is described. It represents the phases of the engineering design process in terms of its 'activities' and 'outputs', set in context within the Project, within the Company, within the Market, and within the Environment. The quantitative analysis shows that the engineering design process may be characterized by a set of overlapping phases, each consisting of a particular mix of procedural steps and other general activities. A comparison between the 'phase diagram' of design effort and an 'ideal' diagram indicates ways of assessing progress and identifying problems during an engineering design project. The design 'activities' observed during the project are compared with the procedural design steps referred to in the literature, and six general activities are added. The design 'techniques' used during the project are compared with those suggested in the literature, and thirteen working, communicating and motivating techniques are added. Theoretical and observed design outputs are compared. Work 'type', work location and team 'mood' are discussed.

A tentative list of 103 factors likely to influence the engineering design process is generated from the literature, divided into 20 categories of influence at five levels of resolution. The impact of each factor on the project is assessed. An attempt is also made to assess the effectiveness and efficiency of the design process and the success of the project.

Several recommendations for further research are made, including: the use of phase diagrams; comparative studies of the observed 'activities' and 'techniques' for different projects; assessment of design process outputs; and development of a design terminology acceptable to related disciplines.

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CHAPTER 3: QUALITATIVE ANALYSIS OF AN ENGINEERING DESIGN PROJECT

CHAPTER 4: CONCLUSIONS AND APPLICATIONS

CHAPTER 5: RECOMMENDATIONS FOR FURTHER RESEARCH

PREFACE TO FIRST EDITION

This dissertation was submitted to the University of Cambridge in January 1987 and is the result of work completed in the Cambridge University Engineering Department between October 1982 and October 1986. It is published here in its original form, complete with all the appendices. One or two minor changes have been made to improve clarity.

In 1981, when Ken Wallace and I first discussed the possibility of such a design research project, there was still a certain air of scepticism over what could be achieved by observing a single engineering design project in industry and analysing the data collected. We were not sure of what lay ahead but it seemed an ideal opportunity to confront some of the issues we had found to be important in engineering design over the years. It also seemed that in order to try and find out more about the engineering design process and its management in practice it was necessary somehow to collect data from a real project. It is heartening to note the great change in attitude which has come about since those days. There has been a renewed appreciation of the importance of engineering design and its management in industry, with a realization that we do indeed need to know more about the design process in practice if we are to improve the way it is carried out. Reports have been written and design initiatives set up in a number of countries calling for more research into the engineering design process. These are to be welcomed and supported but in the end it will fall to individual researchers to do the job, and it is not an easy task.

The thesis has been published to make available to researchers some of the results obtained and experiences encountered when analysing field data collected from an engineering design project in industry. The structure of the thesis is simple: a quantitative analysis followed by a qualitative analysis. Supporting this is an extensive and categorized bibliography and a series of appendices which provide further details of the project. In particular a complete summary database is included for researchers who may wish to analyse the same data from a different viewpoint. A brief case history details the technical aspects of the engineering design work and the field research and data reduction methods are discussed in further appendices. For those about to begin their own design research perhaps the thesis offers a foundation to build on and the encouragement to see it through. I certainly hope so.

Crispin Hales
Cambridge
October 1987

PREFACE TO SECOND EDITION

In the four years since the first edition, engineering design research has become more established worldwide, two international journals have been started and a great many papers have been published. However, there is still very little detailed data available from design projects in industry. Without data from a variety of different types of projects it will be difficult for design researchers to develop criteria for assessing the benefits or otherwise of proposed approaches to design. For anyone who is interested, the database from the Gasifier Test Rig project is available in DOS or Macintosh format at nominal cost. More copies of the dissertation were needed to satisfy a small but continuing demand and it was felt that the quality should be improved by changing the typeface and some of the layout. This has been done with the help of Lynn Wallace-Mills in the Graphics Department at Triodyne Inc., and her input is greatly appreciated.

Crispin Hales
Chicago
April 1991

CHAPTER 1

INTRODUCTION AND BACKGROUND

1.1 Introduction

Through the process of engineering design, ideas and needs are converted to the information from which technical systems and products can be made. It is fundamental to all manufacturing industries, it involves complicated factors, changing expectations and the effect of indirect influences, and its effectiveness is difficult to assess. Two critical issues are the *quality of designs produced* and the *management of design activities*. The failure of the Space Shuttle Challenger provides a tragic reminder of what can happen when insufficient attention is paid to these two issues. In its accident report the Presidential Commission was forthright (A25):

> "...the cause of the Challenger accident was the failure of the pressure seal in the aft field joint of the right Solid Rocket Motor. The failure was due to a faulty design unacceptably sensitive to a number of factors." (Conclusion: p.72)

> "The decision to launch the Challenger was flawed. Those who made that decision were unaware of the recent history of problems concerning the O-rings and the joint and were unaware of the initial written recommendation of the contractor advising against the launch at temperatures below 53 degrees Fahrenheit and the continuing opposition of the engineers at Thiokol after the management reversed its position. They did not have a clear understanding of Rockwell's concern that it was not safe to launch because of ice on the pad. If the decisionmakers had known all of the facts, it is highly unlikely that they would have decided to launch 51-L on January 28, 1986." (The Contributing Cause of the Accident: p.82)

Commissioned reports such as this invariably call for better understanding of the engineering design process as a first step towards producing higher quality designs through more effective design management. In Britain, the concerns first raised in the 1850's (A7) were defined in the 1963 Feilden Report for the Council for Scientific and Industrial Research (A1):

> "Britain's share of international trade in engineering goods has been declining. In spite of some notable successes, too many British products are being outclassed in performance, reliability and sales appeal."

> "Design ... determines most and affects all of these factors and is therefore of paramount importance."

> "There is evidence that the importance of design is not sufficiently appreciated by the managements of engineering businesses."

"... it is the responsibility of management to see that the design team work as a unit and that the customers' requirements are fully understood and properly interpreted. In design everything matters."

Thirteen years later the 1976 Moulton Report (A2) on educating engineering designers included the statements:

"The Feilden Report, published more than ten years ago, considered the standards of engineering design obtaining at that time."

"Subsequent reports, notably by the Mechanical Engineering Economic Development Committee have shown no signs that these trends have been halted."

In 1979 the Corfield Report on Product Design (A3) echoed earlier reports:

"British industry is criticised for the poor design of many of its products and this report has illustrated the vital need for improved designs in them if this nation is to survive industrially."

Then the 1983 Lickley Report to the Engineering Board of the Science and Engineering Research Council (A4) added:

"... there is need for a more coherent body of scholarship and knowledge in engineering design."

From the 1984 CNAA report on managing design (A5) came disturbing news:

"Many United Kingdom companies now face their final opportunity to get to grips with design before their markets are dominated forever by foreign competitors who *have* learnt how to exploit design."

In the same year the issues were summarized for the British Government in a Strategy Group Report (A6) which supported action as recommended in the previous reports. A need for better understanding and management of the engineering design process was emphasized. The concern over understanding the engineering design process is not confined to Britain but the emphasis is different in other countries. For example in the United States and in Japan there is great interest in 'expert systems' for engineering design (B17, B41 & B62). In the U.S.A. a National Science Foundation study on research needs (A8) concluded that:

"Research is needed to understand the conceptual process of design and to integrate and expand the capabilities of computers to aid in this creative process."

To gain a better understanding of the engineering design process in actual practice it must be studied in its industrial and commercial context. As the process output is engineering information, rather than a more tangible product, and the concern is with both the quality of this output and the human activities which produce it, such studies are complex. They demand the use of social science field research techniques for collecting data, and practical experience of engineering design for interpreting results.

Few of the studies reported in the literature have resulted in more than a descriptive analysis, and they have led only to marginal improvements in our understanding of what actually happens. As a result the practical benefits for design engineers in industry have been limited, and the call for further research has become increasingly urgent.

The aims of this study were twofold. Firstly, to try and collect detailed data on the activities and outputs during an engineering design project, and secondly, to develop techniques for analysing the data and presenting the results in a more meaningful way. This thesis is based on the results of a study carried out on a single engineering design project in industry; one involving 37 people and the design of a materials testing facility to operate continuously for periods of up to 1000 hours at high temperatures and pressures. A quantitative analysis of the field data accumulated is presented in Chapter 2, and a complementary qualitative analysis of the same data is presented in Chapter 3. Conclusions are drawn and possible applications discussed in Chapter 4, and a number of specific areas for further investigation are recommended in Chapter 5. Detailed Appendices provide supporting evidence and information. Appendix A provides a full set of data together with the project case history and summaries of the six design reports. Appendix B provides a referenced discussion on field research issues, together with a commentary on the fieldwork for this study, and Appendix C provides details of the techniques developed for reducing and analysing the data.

1.2 Engineering Design in Industry

The nature and meaning of engineering design differs according to context. Much has been written on the subject but it is widely dispersed within a variety of disciplines and coherent patterns of thought are difficult to extract. Texts such as those of P.J. Wallace (B70), Asimow (B8), Matousek (B40), Alger and Hayes (B1), Glegg (B26), French (B24), Hubka (B31) and Pahl and Beitz (B47) provide some insight into design practice in industry through technical examples. Collections of case histories, such as those of Whyte (A27, A28), and papers on design projects, such as Ackroyd (A10), Griffin (A15), Hales, Howes and Bhattacharyya (A16) and Horsley (A18), describe real situations in more detail. Biographical and documentary texts with popular appeal, like those of Majdalany (A22), Masefield (A23), Prebble (A24) and Rolt (A26), give accounts of major engineering design ventures set in the context of their times. Historical perspectives are sharpened by documentary studies on particular aspects of design such as those of Booker (A11) and Farr (A13).

Empirical research has helped to clarify some of the issues involved. In 1979 Gregory listed some thirty observation-based studies (C10) considered to provide the "...prime material upon which development of our knowledge about designing can be founded," and those of Marples, Hykin and Bessant and McMahon are of particular interest here:

(i) Marples (C21) described two case histories from industry, analysing them using his 'Decision Tree' approach, which highlights decision-making aspects of the engineering design process. The approach has since been developed by others. For example Tebay, Atherton and Wearne (C31) analysed the decisions made during the course of three design projects and used the data to test existing decision theory. They concluded that while simple quantitative techniques can be useful for handling uncertainty there are time and cost penalties, measurement problems and the often overiding effects of external influences. The value of decision theory was felt to be in helping promote a better understanding of the engineering design process rather than in formulating "...a model of design decision."

(ii) Hykin (C13) observed eleven engineering design projects in industry during the period 1966-1972. Some of the variables and influences involved were identified, and an attempt to measure and categorize these was made. The dominant variable identified was 'production quantity', and so for this study the engineering design process was seen to depend heavily on whether mass production or a 'one-off' exercise was involved [Hykin and Laming (C14)].

(iii) Bessant and McMahon (C4) describe the participant-observation of a major engineering design decision, taken over four years. In their opinion the "...task of theory-building must be to convert specific high-variety empirical information into concepts which are generalizeable and capable of application to different situations with some predictive validity." They see a shift away from prescriptive theories of design (specifying how to do design) towards obtaining empirical evidence for developing more adaptive theoretical models which admit "...multiple iterations, recycles, recursion and other dynamic behaviours." In summary they advocate three changes:

Research methodology away from quantitative and mechanistic studies towards case studies and hybrid qualitative/quantitative analyses;

Theoretical frameworks away from forcing a general theory around increasingly varied empirical data and towards contingency models;

Design practice away from prescriptive approaches more towards ones based on appropriateness and applicability.

These three studies, supported by Gregory's own observations, suggest that the use of participant observation for the collection of empirical case history data, and the development of flexible and adaptive models which take account of the dynamic nature of the engineering design activity (contingency models) are needed for our improved understanding of the engineering design process. As discussed in Appendix B, there exists a 'spectrum' of observational field research techniques, ranging from direct observation where the researcher takes no part in the activites to 'action research' where the researcher not only takes an active part but actually determines how the activities to be observed will be carried out. If the aim is to increase the understanding of what happens in practice, rather than experimenting with new ways of working, then a less directive role than for action research is needed by the researcher, but on the other hand, as Thomas and Caroll conclude (C32), more researcher involvement is needed in design studies than straight observation. A compromise is in the use of participant observation, where the researcher takes an active part in the activities being observed but tries not to influence the outcome more than would be expected from any other participant.

Since Gregory's survey other observation-based studies have been reported including Lera (C15, C16), and Roy, Walker and Walsh (C26) in Britain; Bucciarelli (C5) and Nadler and Peterson (C22) in the U.S.A.; Wiendahl (C35) in Germany; and Lewis (C18) in Australia. The role of such studies in improving the effectiveness of the engineering design process is emphasized by Chatterton and Leonard (A12), Kardos and Smith (A20), Eder (B19) and Topalian (D19), but there is little guidance on how further analysis could best be carried out or coordinated.

1.3 Design Methods and Models

Many design 'methods' and 'methodologies' have been developed, together with conceptual models, as techniques or aids for use in the activities of the engineering design process (B30). For this thesis a design 'method' will be taken to mean 'a prescriptive programme of action describing the way to solve more than one problem' and a design 'methodology' as 'a prescribed procedure containing at least two methods and information on their use'. Early developments were based on technical viewpoints which omitted many influences now regarded as important and the approaches used varied with geographical area. Eder (B18) argues that this stemmed from cultural and historical differences between countries. In Britain the emphasis was on conceptual design, in other European countries (notably Germany) it was more on embodiment and detail design, and in North America on a systems or management approach. Despite these differences, cross-referencing in the literature is common. Archer (B3, B4), Asimow (B8), Dixon (B16), French (B24), Glegg (B26), Gregory (B27), Hubka

(B31), Jones (B36), Krick (B38), Marples (C21), Matchett (B39), Matousek (B40), Rodenacker (B55), Roth (B56) and Wallace (B70) to name but a few, are commonly referred to in publications on design methods and models.

Bishop (B10) reviewed the available design methods or techniques in 1972. Turner (B64) broadened this in 1975, and Finkelstein and Finkelstein (B23) comprehensively reviewed existing design 'methodologies' in 1983. They concluded that design methodology "...provides a useful framework for the structuring of the design process, the generation of design concepts and for evaluation in design," and that the design process in general could be described as:

> "...a sequence of stages starting from the perception of a need and terminating in a final firm description of a particular design configuration. Each stage is in itself a design process and is an iterative sequence of steps."

These stages were commonly referred to as: 'Need'; 'Problem Definition'; 'Conceptual Design' and 'Detail Design', with 'Manufacture' and 'User' put in if a complete product cycle was shown. This simple 'core model', such as the one used by French (B24) and reproduced in Appendix D, was central to the early developments. It was generally accepted that information processing was involved, with a progressive transformation of the abstract into the concrete during the course of the design process as described and modelled by Gill (B25). Finkelstein and Finkelstein found that up to the time of their review there had been no successful attempt to synthesize management and design methodology, and that much more accurate analyses of the design process were needed, to help the manager control the activities and resources more effectively.

In the U.S.A. Asimow (B8) and Woodson (B72), followed by others such as Nadler (B44) and Suireg (B61), developed models which better represented the full life cycle of a product. Ostrofsky's approach (B46) is perhaps typical of these. His 'design morphology', or chronologically structured decision sequence, is intended to aid the 'designer-planner' in efficient use of resources and is divided into three main phases: Feasibility Study; Preliminary Activities; and Detail Activities. Then come the four stages of: 'Production'; 'Distribution'; 'Consumption' and 'Retirement'; with an implied return loop to complete the 'Production-Consumption' cycle [See Appendix D]. Meanwhile in other countries, particularly in Germany, the approach was to refine the 'core model' by adding intermediate steps within each stage or 'phase', to provide the design engineer with a well-structured procedure and help in applying available design techniques. The Pahl and Beitz approach (B47) is one of the most comprehensive, with a set of secondary models and design guidelines which have evolved from years of European development. [See Appendix D]. These form the basis for German Standards such as VDI 2221 (B65) and VDI 2235 (B66), as reported by Gregory (B28).

Hubka (B32), Eder (B20) and others who have been working independently towards similar goals generally support this initiative.

In Britain there was growing interest in the human 'engineering design activity' during the 1970's and the modelling reflected this. An example is the 'design activity model' of Pugh and Smith (B54) [Appendix D] which was developed to help structure a postgraduate engineering design course and has since been adapted for use on an Open University distance learning course (B49). The model represents an 'iterative central core activity' (market : specification : concept : detail : manufacture : sell), within the design boundary of an evolving specification. "The whole of this activity is carried out under an umbrella of planning, organization and control..." (B52). This model is rather more flexible and adaptable than earlier ones and Pugh has used it, for example, to illustrate the way he differentiates between what he sees as 'static' and 'dynamic' concepts in design (B53). Ehrlenspiel's three-dimensional model (B22) [Appendix D] combines the type of framework used by Pugh and Smith with the detail of the Pahl and Beitz approach, and this has been used by Rutz (C28), for example, in structuring a study on problem-solving in engineering design.

The 1960's optimism over use of prescriptive systematic design methods and models faded to what Cross terms a 'descriptive mood' in the 1970's (B15):

> "It soon became realized, however, that design problems were not so amenable to systematization as had been hoped. Attention turned to trying to understand the apparent complexity of these particular kinds of problems."

Resulting debates helped to broaden traditional views [Jaques (B35)]. For example Jones, originally a strong advocate of systematic design methods, rejected it all in favour of a more fluid approach without formal models (B37). Matchett (B39) with his Fundamental Design Method (FDM), Rzevski (B57) with his Evolutionary Design Methodology (EDM) and Schregenberger (B58, B59) with his Programme for Methodical Conscious Problem-solvers (PMP) regard the engineering design process as a special case of general 'problem-solving' and have developed models accordingly. Archer (B6), Tovey (B63) and Cross (B14) have been concerned with modelling the thought processes of designers, which complements the work of Dixon and Simmons (B17), Whitefield (C36) and others whose models of designer activities are aimed at helping develop computer based methods. Increasingly a holistic 'systems' approach is taken, such as M'Pherson's System Design Methodology and 'spiral' model (B42). In Britain it seems that systems approaches, which came originally from engineering in the form of operations research, are finding their way into design not so much from engineering as through the approach developed by Checkland (B13) and others for more general use in management and organizational behaviour.

In 1979 Gregory proposed a hierarchical type of structure for engineering design activity models (C10), and this was developed by Bessant (C3) who suggested the use of nested levels (See Appendix D). Others, including Andreasen (B2, B29), Archer (B6), Eekels (B21) and Peters (B50), have used similar structures for their most recent models. These systems models all feature a series of hierarchical levels rather similar to those suggested by Bessant though what is meant by 'level' is not often clear. 'System' levels; 'perception' levels; 'organization' levels; and 'process' levels are all commonly referred to. Examples of this modelling approach were looked for in other disciplines. Fields linking 19 relevant disciplines were mapped and more than 100 people were visited to build up a network of useful ideas. Four complementary references based on a 'systems' approach were of particular value: Checkland (B13); Wilson (B71); Carter, Martin, Mayblin & Munday (B12); and Humphreys (B33, B34).

Checkland's 'Systems Methodology' was developed for modelling what he has termed 'Human Activity Systems', rather than 'Designed Systems', 'Natural Systems', or 'Social and Cultural Systems'. His concern is with the way people do things rather than the technical systems or products they make, the natural world around them or the communities in which they live. If designed or technical systems are considered as 'hard' systems, modelled in engineering terms as described by Calladine (B11), then in the spectrum from 'hard' to 'soft', human activity and management systems are at the 'soft' end, modelled in human activity terms as described by Checkland. To model the engineering design process, which involves a mixture of the hard and the soft, varying in proportions according to the type of design task, an approach is needed which adequately represents both 'hard' and 'soft' systems. Systems methodology thus offers useful techniques for modelling the aspects of the engineering design process which have tended to be left out of models based solely on hard engineering.

Use of systems methodology is described by Wilson, the concept of 'levels' and 'viewpoints' being the key: "...a system is, at the same time, a sub-system of some wider system and is itself a wider system to its subsystem. What we define to be 'a system' is a choice of resolution level or the choice of level of detail at which we wish to describe the activities." Unlike 'designed systems', human activity systems are not considered to exist. What exist are perceptions of human activity systems in the minds of observers. An analyst developing a human activity system model is not trying to describe what exists, but a view of what exists, and the aim is to try and model the same situation from several appropriate viewpoints. Humphreys uses resolution levels as 'levels of abstraction' when modelling decision problems, and considers that what is represented as 'form' at one level is manipulated as 'content' at the next level higher. He adds that:

"...a person must be fully conversant with the operations used at the first level, so that the pattern of principles underlying these operations ... can itself be used as an operator at the next level."

Carter et al. describe the systems approach using diagrams and pictures. The notion of 'weltanschauung' (W) or 'world-view' (individual viewpoint) is clarified. This is central to the modelling of human activity systems and according to Wilson is "...that view of the world which enables each observer to attribute meaning to what is observed." He uses the analogy of 'W' being a filter through which events are observed, the filter being continually moulded by experience, politics, society and the situation.

1.4 Summary and Review

There is a need for higher quality engineering design and more effective management of the engineering design process in industry. To achieve this it is first necessary to gain a better understanding of the engineering design process in practice, which calls for more accurate analyses of what actually happens as distinct from what is presumed to happen. This is supported by the main conclusion of the 1983 Lickley Report (A4):

"The fundamental requirement is a directed and practical programme of work, continuing over a long period, to establish design as the integrating theme of all engineering disciplines and to improve the general quality of engineering design."

More specific research needs are made clear in *Managing Design* (A5):

"Priorities for research into the management of design include international comparisons of design performance, case studies of design management practice... greater understanding of the tasks that designers perform and what is involved in design work..." "Some idea of the typical 'productivity' of designers could be useful ... research into designers' activities ... does not appear to have been carried out on anything like the scale of research into managers' activities."

Similar conclusions from the National Science Foundation study on research needs in the U.S.A. led to the 1985 NSF workshop (A9) on design theory and methodology, to help define: "...a multidisciplinary research program that can provide a better understanding of the theory and methodology underlying the design process as practiced by the most productive engineers and scientists in all disciplines." Nadler summarizes the issues (B45).

In review it appears that:

(i) Despite a long history of innovative engineering design in industry and the development of many prescriptive methods and models, the engineering design process is not yet considered well understood or adequately exploited in practice.

(ii) There is a mismatch between the design process as it is currently modelled in theory and what actually happens in practice.

(iii) There is strong support for research aimed at developing a basic understanding of the engineering design process and improving its effectiveness in practice.

(iv) Participant observation of design projects in industry is advocated as a way of gathering suitable empirical field data for analysis.

(v) Development of hybrid quantitative/qualitative approaches for the analysis of empirical data is recommended for design research.

(vi) Development is needed of contingency models, having multiple levels of resolution and capable of representing the human activities in engineering design as well as the resulting design output.

1.5 Research Objectives

The overall research objectives for this study were:

(i) To conduct a detailed study of an engineering design project in industry, gathering field data by means of participant observation.

(ii) To develop techniques for analysing the data with reference to an appropriate model, and to draw conclusions which could help towards better understanding of the engineering design process in practice.

(iii) To identify further work likely to lead to improved engineering design and more effective design management in industry.

These objectives raised a series of questions, such as:

(i) What defines the 'engineering design process' within a project?

(ii) Which design procedures and techniques are useful in practice?

(iii) To what extent are they actually used?

(iv) What is the nature of the mismatch between 'theory and practice'?

(v) How are 'effectiveness', 'efficiency' and 'success' defined?

(vi) How can 'effectiveness', 'efficiency' and 'success' be assessed?

(vii) What factors influence effectiveness, efficiency and success?

(viii) Which model of the engineering design process should be used?

(ix) What design project should be chosen, who should be involved and which design procedures should be used, if any?

(x) What data should be collected, in what form and for how long?

(xi) How should the data be analysed; what results might be expected?

(xii) What conclusions are likely and might generalizations be possible?

Preliminary answers to some of the questions could be found by reference to relevant literature, other questions were answered during the course of the field research, but many, and in particular the last two, could not be addressed until the data had been gathered, reduced and scanned. Those initially addressed by reference to the literature are treated in the remainder of this chapter. Chapter 2 covers quantitative aspects, while Chapter 3 covers qualitative aspects. Questions regarding the field study are covered in the Appendices: those on the design project in Appendix A; those on the data gathering in Appendix B; and those on data reduction in Appendix C. Questions needing more investigation, including new ones arising from the research, are discussed in Chapter 5 on future research.

1.6 Terminology

The question of terminology was found to be a serious problem, and not one which could be adequately addressed here. Many engineering design terms vary in meaning according to discipline, context and interpretation. For example 'design', 'engineering design' and 'engineering design process' are defined according to individual viewpoints. In the Feilden Report (A1) engineering design was defined as: "...use of scientific principles, technical information and imagination in the definition of a mechanical structure, machine or system to perform pre-specified functions with the maximum economy and efficiency." Other definitions have been suggested by numerous people including Archer (B5, B7), Holt (A45), Luckman (C19), Lickley (A4), Rzevski (B57), Thomas and Carroll (C32), Topalian (D19) and Wallace (B67). Oakley gathered together a crossection of contemporary views in the CNAA Report (A5). Although the Feilden definition remains popular [Leech and Turner (A38)], the tendency is for simpler and more commercially relevant ones to be used such as:

> "Engineering design is the process of converting an idea or market need into the detailed information from which a product or system can be produced." [Wallace (B69)].

This, in conjunction with Finkelstein and Finkelstein's description of the 'engineering design process' (B23) as a goal-orientated sequence of stages within each of which is an iterative series of steps, provides an adequate definition for this thesis.

In addition to interdisciplinary terminology problems there are those of translation from language to language and in meaning from one country to another [Eder (B18), Wallace (B68)]. Hubka made a valuable contribution with WDK-3 (E8), a multilingual glossary of terms for engineering design, and Eder provides a translated glossary (E9) in Hubka (B31). Humphreys' finding that language barriers are more difficult to overcome across resolution levels than across cultural or national differences (B34) suggests an area needing further investigation. Schregenberger (B59) has come to the conclusion that design engineers must adapt to the terminology accepted in the social sciences as it is unlikely that this terminology would ever be changed to suit design engineers.

To overcome the problems of terminology, which are not the main concern of this thesis, it was decided that simple terms having generally accepted meanings would be used wherever possible and that the number of terms used would be minimized. This was not easy, and for certain terms additional notes have been needed where they first appear. When 'design' is used it refers to 'engineering design' unless otherwise stated, and both terms are occasionally used to refer to the 'field' of enquiry or of practice. 'Design engineer', 'engineering designer' and 'designer' have been treated as synonomous but 'design engineer' is preferred. The glossaries referred to during this research are listed in Section E of the References.

1.7 Effectiveness, Efficiency and Success

> "Efficiency is about doing things right; Effectiveness is about doing the right thing." [Barnato (A29)].

Prescriptions for how to improve the 'effectiveness' and 'efficiency' of the engineering design process abound, but definition and assessment proves difficult. Muster and Mistree (B43) offer definitions which allow certain assessments to be made, but valid only for their very specific viewpoint. Little (A40) concluded from a review of organization theory:

> "It is generally accepted that 'effectiveness' implies a wider assessment of all aspects of performance than 'efficiency'. The criteria for such assessment, however, are subject to considerable debate."

Malouin and Landry (A41) suggest a definition for efficiency:

> "A system is efficient when it does well what it does. Efficiency is the result of a relationship between the input and the output of a system."

'Effectiveness' appears more difficult to define in a meaningful way. Johns (A37) in commenting on managerial effectiveness concludes:

> "In an organizational setting, and for most practical purposes, managers can only perceive themselves as effective if they are seen to be effective in the judgment of others ... effectiveness is not something which can be determined internally, by introspection alone. Effectiveness depends crucially on evaluation by others."

Bennett and Langford (A30) expand on this:

> "Any attempt to measure effectiveness must take account of the different kinds of organization and different levels in the hierarchy."

Nagar, Tenda and Singu (A43) studied 'group effectiveness', developing a multi-dimensional scaling method for its assessment. Hoy, Van Fleet and Yetley (A36) tested three organizational effectiveness models, concluding that the 'Pickle and Friedlander model' seemed to offer a comprehensive evaluation with measures apparently relating to the financial performance of the firm. Effectiveness is evaluated from seven viewpoints: the owner; the employees; the customers; the suppliers; the creditors; the community in general; and the government. All these approaches are complicated and require specialist knowledge. It seems accepted that effectiveness and efficiency are concerned with the quality and the rate of output from an activity and that they are dependent on viewpoint. However, the question of assessment remains open.

As the engineering design process is goal-orientated, degrees of 'success' (and 'failure') are important when assessing results. Oxford Dictionary definitions for 'success' include "favourable outcome, accomplishment of what was aimed at..." and, for 'failure', "lack of success; unsuccessful person, thing or attempt..." Assessment would seem to depend on when it was made and from whose viewpoint. Consider Professor Heyman's apocryphal story of the passerby who asked four men breaking stones on a cathedral building site what they were doing. One said "breaking stones", one said "building a wall", one said "building a cathedral" and one said "building to the Glory of God." The relative success of each man's activity clearly depends on elapsed time and the assessor's viewpoint in this case!

In relation to the engineering design process perhaps 'success' could be assessed at the end of each phase in the process or, for that matter, at any other convenient point in the life cycle of a product. More difficult than elapsed time is the question of 'viewpoint'. One common one is the uncompromising commercial approach typified by Fox (A32):

> "Success in business is generally measured in terms of net profit, which is a function of two factors: gross margin and volume. If both are right: success. If either or both are wrong: failure."

While this may be true from a manufacturer's viewpoint, Leech and Turner (A38) point out that from the design engineer's viewpoint "...success is not so easily defined because he is not often in the position of selling his designs directly to a customer." In very small companies the design effort is more likely to be the work of a single individual and assessment may therefore appear to be simpler, but as Oakley (A44) discusses, success is so highly dependent on the available resources in small companies, that pinning down the success or otherwise of the engineering design effort may still be very difficult. Gardiner and Rothwell (A14) add the fact that customers themselves can play a major role in determining the degree of success of a product, and Turner (A48) suggests that in the end it is the responsibility of management, who should ensure that proper design reviews [Baker (B9)] are conducted at each stage of the work. For Project Sappho, a study on industrial innovation (A47), the view was:

> "Since the project is concerned with innovation in industry the criterion of success is commercial. A 'failure' is an attempted innovation which fails to obtain a worthwhile market share and/or make a profit, even it if 'works' in a technical sense. Often a failure is relatively clear, e.g. a firm withdraws a product or closes a plant down, but success is not always so self-evident. A product may achieve a worldwide market but take a long time to show a profit. There are obviously varying shades of grey between the 'white' success and the 'black' failure..."

The main finding was that "...no single factor can by itself explain the success-failure difference." Legard (A39) also questions the validity of taking the profit-based viewpoint in assessing 'success'. Microcomputer industry patterns suggest that companies which rapidly become a commercial success with a popular product often fail to meet the demand created for a second-generation product. This is further complicated by the 'bulldozer' effect that large companies can exert on a market if they feel threatened.

Other questions arise. Kelly, in his historical study of Veloce Ltd (A21) supported the adage that "success begats success and the reverse is true." How true is this? The rapid swing from commercial failure to commercial success of Jaguar Cars (A19) resulted from changes in management style and attention to product quality, rather than from design improvements. How might the recognized success of the Jaguar design team's contribution over such a commercially turbulent period be assessed? Criteria for success of a process plant may be profit-based, but expensive tests on materials may be needed to ensure the plant's safe and economic operation. How should success as applied to the test equipment design engineer be assessed? It may be based on performance of the equipment within agreed estimated costs but could even be on technical performance in minimum time at *any* cost. A change in Government policy can also affect the success of projects for, like the TSR2 aircraft in Britain and coal gasification projects in the U.S.A., what was urgently required at one point in time may suddenly be made redundant at another. Radcliffe and Holt (A45) summarize the debate:

> "The success or otherwise of a design is conditioned by the people who will use it, make it and maintain it, by the technology and facilities they have available and by their economic expectations and constraints."

Others suggest factors to be considered from specific viewpoints:

Economic Viewpoint	- market competitiveness or slackness [Grant (A33)].
Commercial Viewpoint	- company growth; market share; return on capital; profit [Gregory (A34), Rothwell et al. (A46)].
User Viewpoint	- psychological, ergonomic and technical criteria [Hay (A35)].
Project Viewpoint	- cost, time and technical criteria [Might and Fischer (A42), Woodward (A49), Pitts (B51)].
Design Viewpoint	- perceptual and objective measures [Edstrom (A31)]. Concept used; attitude improvement; skill development; commitment; productivity [Nadler (B44)].

It would seem that success is not only dependent on viewpoint but also on time-scale, and that it may perhaps be assessed on relative scales using a combination of measures from different levels of resolution. However the question is by no means satisfactorily answered.

1.8 Conclusions

(i) There is a call for more effective engineering design management and practice in industry.

(ii) To help meet this call a better understanding of the engineering design process in industry is needed.

(iii) To improve understanding of the engineering design process more detailed studies of it are needed, set in its industrial context.

(iv) Empirical data of analytical value must be gathered; participant observation of real engineering design projects is advocated.

(v) Hybrid quantitative/qualitative approaches need developing for the analysis of empirical field data.

(vi) Adaptable models with multiple levels of resolution are needed for representing the contingent, dynamic nature of engineering design.

(vii) Terminology is a problem. A universally agreed terminology for design would be a great advantage.

(viii) Assessments of effectiveness, efficiency and success are important but difficult issues, dependent on viewpoints and timescales.

CHAPTER 2

QUANTITATIVE ANALYSIS OF AN ENGINEERING DESIGN PROJECT

2.1 Introduction

To meet the first research objective, that of participating in an engineering design project in industry and observing the design process, a non-trivial project involving a variety of people within a company was needed, and one which would allow the collection of field data from first ideas to detail drawings within a two-year period. Establishing such a project and the necessary field research routine presented few problems, but reduction and subsequent analysis of the case history data, the second objective, proved far more difficult than anticipated. Analytical procedures had to be developed as well as a model to represent the design process set in the project's industrial and commercial context.

The chosen project was in fact observed for 2.8 years, during which it passed from the initial proposal through all phases of the design process to near completion of detail design. From task clarification through to detail design the procedures recommended by Pahl and Beitz (B48) were followed, for two reasons. Firstly the company was keen to try a more structured approach to their in-house design work than they had used for previous similar projects, and secondly it offered a framework for initial categorization of the field data. A total of 37 people were involved and 1373 'interchanges' were recorded, covering 2368 hours of work effort in time intervals down to 0.1 hour. As detailed in Appendix B.4 an interchange was considered to be any uniquely identifiable work effort, meeting or communication, each being recorded in terms of date, time, type, topic, location and people. The field data comprised 1180 pages of diary notes, 76 hours of audio tape-recordings, 116 weekly reports and 6 design reports including diagrams, sketches and drawings. Data was reduced by colour-coding the notes according to participant, compiling a set of data sheets for each person and entering the 2488 records into a computer database for indexing, sorting and grouping. Summary database files were translated into spreadsheet files for final numerical and graphical analysis.

Most processes, even ones involving human activities (e.g. the production process), may be analysed in terms of variables which can be measured. A problem with the engineering design process is that so few of the many variables can be objectively measured, and in fact the only simple measure is work effort in hours. From this costs may be derived, with a breakdown of who has put effort into the project, how much and at what stage, but the numbers alone are little help in understanding what actually happened. If however, the simple measurement of work effort in hours is enhanced by the addition of 'context' then a potentially far more meaningful analysis is possible. By context is meant what the work was, who it was done with, when it was done, where it was done, what techniques were used and what other factors were involved at the time. For this particular project the approach taken was to record the time taken for each interchange and as much other contextual information that the 'participant observer' could collect about each one.

In this chapter quantitative time and cost results are presented, after a brief overview of the project and a description of the context model used. Times are measured in hours to one decimal place and costs are calculated using the hourly rate of each person including overheads. Most results are given in terms of percentages, for comparative purposes. The concern is with characterization of the phases of the engineering design process within the overall project, identification of steps or activities within each phase, and the identification of design-related techniques used. A simple way of characterizing and monitoring design projects by phase is proposed. Measured results are compared directly with some work effort percentages estimated by Pahl and Beitz, and a number of activities and design techniques are identified which are not taken into account by the Pahl and Beitz model of the design process. Breakdown of work effort by type, location, participant group and mood is also given, but the more qualitative aspects of these are discussed in Chapter 3, together with other influences observed to affect the engineering design process.

A full set of coded interchange data is given in Appendix A.1, the project case history is detailed in Appendix A.2, and summaries of the six design reports are given in Appendix A.3. Details of data collection methods used are given in Appendix B, and the data reduction procedures developed are described in Appendix C. All Figures for Chapter 2 have been grouped at the end of the chapter to simplify finding and comparing specific ones.

2.2 Project Summary

The project called for design of a high-pressure, high-temperature system for the evaluation of materials in a simulated slagging coal gasification environment. The design task was regarded by the company as both difficult and complex in that it required the automatic control of temperatures, gas flows, liquid flows and coal flows at high pressure for continuous periods of up to 1000 hours. The main difficulty, and the novel feature of the proposed system, lay in the handling of flowing coal on such a small scale under extreme pressure and temperature conditions. Although the need for this type of equipment had been identified within the company for some time, the requirements had not been formally established, and ideas as to the nature and possible usage of the equipment were vague. In engineering design terms the 'problem was ill-defined' (C25, p.206).

Design work was scheduled to spread over two budget years at the company's request, and initially it was planned that construction would follow on directly from detail design, subject to funding approval. Approval times were anticipated to be lengthy, and this was allowed for in the schedule. All participants would, as a matter of course, be working on a number of other projects during the same period and the project was not regarded as different from any other in this respect; it merely followed others in a sequence and developed further what had gone before. A task team approach was planned in as much as team participants, and their involvement, would be varied according to project needs. The only unusual aspects from the company's point of view were firstly that the Pahl and Beitz procedures would be introduced where appropriate and secondly that every activity related to the project would be recorded in detail for analysis. It was clear that the use of the Pahl and Beitz procedures, under the guidance of a contract design engineer, would affect the outcome of the project to a certain extent, but from a research point of view this was a necessary intervention to provide an adequate framework for the analysis. For the purposes of this thesis it has been assumed that the technical design work followed the procedures of Pahl and Beitz but that all the other project activities followed their normal pattern within the company.

The project began with a proposal, submitted through the University to the Company at the request of a research group within the Company and with the guidance of their management staff. The proposal was accepted, a contract was signed and the design work started in October 1982. During the first three months the design task was clarified by defining the problem more precisely and compiling a detailed list of 'demands' and 'wishes' (B48) which formed the core of the design specification or list of requirements. This 20-page document, tabulating 308 requirements and constraints, served to formalize the input of everyone involved and to record what had been agreed. Conceptual design, which was completed during the next 4 months, presented few problems. The final concept was developed further during the course of the following 17 months and this phase, termed 'embodiment design' in accordance with Pahl and Beitz, was taken to include document preparation for obtaining construction approval and also the design of the control system. Detail design of the seven sub-systems and steelwork overlapped considerably with the embodiment design phase and was carried out during the final 14-month period. The main sub-system was the reactor vessel assembly, shown in Figure 2-1.

The project is fully described in Appendix A.2 and sample pages from the six design reports are reproduced in Appendix A.3. These reports, issued as internal Company Reports and available on request, record in detail all design work carried out including calculations, correspondence, meetings and weekly reports. Observational data was collected from the time of the original proposal to the end of Month 34, by which time the detail design drawings were almost complete and it was clear that little more useful data could be obtained. A sample Interchange Data Sheet from the main computer file is shown in Figure 2-2.

2.3 A Context Model for Engineering Design

For the analysis of the project it was necessary to differentiate between the overall project effort and that part of it regarded as the engineering design process, and to be able to classify the inputs to the project at different levels. To help visualize this a model was needed to represent:

(i) The engineering design process in an industrial context;

(ii) Appropriate resolution levels within the overall context;

(iii) The human activities and outputs in engineering terms.

Pugh and Smith's activity model (B52) was a starting point, and the Pahl and Beitz model (B48) defined activities and outputs for each phase of the engineering design process. Resolution levels were taken from Gregory's contingency model (C10), modified according to Humphreys' levels (B33) and structured as suggested by Bessant (C3). The idea of incorporating a supply-demand loop came from Grant (A33) and from Ostrofsky's production-consumption cycle (B46). The systems approach of Checkland (B13), as used by Wilson (B71), helped in modelling human activity aspects. The result was a set of two diagrams, one representing the overall context within which engineering design takes place as shown in Figure 2-3, and the other representing the engineering design process set in this context as shown in Figure 2-4. Within the external *environment* are markets; within a particular *market* are competing companies; within the particular *company* is the management team controlling *projects*; and feeding into each project through individuals or groups are *resources* from the environment, the market, and the company. Customers (and the users) purchase products, generating revenue through exchange processes. From this the company pays costs, taxes and dividends etc, with the surplus providing an operating profit. External influences have an impact on the market, and so affect the activities and outputs at all lower levels.

Within such a context we are concerned with the *engineering input* to the project, as distinct from marketing, quality assurance or any of the other inputs. By highlighting the engineering input, with both the design and production processes displayed as sub-sets within the project, the phases of the *engineering design process* may be visualized in terms of *activities and outputs*, set in context with production, as part of a project within a company, within a market, within the external environment. The phases may be described as:

(i) Through task clarification activities the problem is defined. Output is a design specification.

(ii) Through conceptual design activities solutions are generated, selected and evaluated. Output is a concept.

(iii) Through embodiment design activities the concept is developed. Output is a final layout.

(iv) Through detail design activities every component is fixed in shape and form. Output is manufacturing information.

Iterations in the process are represented in Figure 2-4 by the feedback loops, and the transformation from 'abstract ideas' to 'concrete products' is shown by changes in line-style around the loop as the information flow changes to document flow then finally to material flow. The model exhibits five levels of resolution which have been termed:

- *Macroeconomic Level* - Environment external to the Market;
- *Microeconomic Level* - Market within which the Company is operating;
- *Corporate Level* - Company within which the Project takes place;
- *Project Level* - Project with Engineering Design input;
- *Personal Level* - Individual inputs to Engineering Design Process.

As this Context Model was developed it was reviewed by specialists to test for accuracy and terminology [Suckling (B60)] and 14 different versions were produced before it was considered satisfactory. Final checks were:

(i) Assessment against requirements;

(ii) Compatibility with existing models;

(iii) Accuracy in representing real world situations [Calladine (B11)].

A weakness found was the lack of dynamic representation; a complementary approach is needed for this. A strength lay in the keyword representation of sub-sets to 'window' in on; a sort of spatially orientated checklist. On the basis of elementary checks the model proved adequate for grouping the different types of input to the project.

Although the model could be used in the general form as described above, it was possible to simplify it for this particular project as the company holds a monopoly in its main product area. In a monopolistic situation the 'company' may be regarded as equivalent to the 'market' [Grant (A33)]. This is represented on the model by 'windowing-out' the 'Company' box to become coincident with the 'Market' box while leaving everything else the same, as shown in Figure 2-5. The economic 'loop' for the project then lies wholly within the overall company. 'Revenue' represents potential 'cost savings' attributable to the results of the tests carried out in the 'gasifier test rig' (e.g. enabling use of lower cost materials for a full scale plant). 'Finance' represents a budgetary allocation for the project within a particular section of the company, and other resources are drawn from elsewhere in the company or from what has been termed the external environment. External influences have a direct impact on the company. 'Users' are research scientists working under the same management as that for the project itself, and the 'Customer' could be regarded as management at one level higher than that for the project. In the observed structure of the organization 'Engineering' and 'Administration and Services' were combined, and there was no separate 'Purchasing' group. 'Marketing' of the project took place within the overall company in that the project had to appear as a viable proposition to other groups competing for the same funds. 'Sales and Service' equates to system commissioning. 'Personnel', 'Quality Assurance' and 'Accounts' all existed as in-house service groups.

2.4 Overall Project Effort

For an analysis of the overall project, as distinct from the engineering design process, the work effort of all project participants was included. The Context Model was used to help categorize the work effort of each of the 37 project participants by resolution level and to help differentiate between project effort and engineering design process effort. Graphs of overall project hours and overall cost are shown by month in Figures 2-6 and 2-7. Some features are:

- Between Month 3, when the proposal was prepared, and Month 7, when the scheduled design effort started, almost no effort was put in.
- Between Month 8 and Month 24 the hours and cost per month were at a relatively steady level but then increased markedly.
- In month 16 there was no input to the project.
- In month 27 there was over twice the effort than in any other month.
- By month 34 the work effort was dropping off to a low level.

Further features emerge when the overall project effort is broken down by design process phase according to the Context Model, with actual hours and costs converted to percentage hours and costs as shown in Figure 2-8:

- The Task Clarification and Conceptual Design phases each contributed about 10% of the total effort, the Embodiment Design phase 35% and the Detail Design phase 40%.
- The Proposal phase effort was lowest at 3% but was not negligible.

- The Conceptual Design phase contributed a lower proportion of the overall project effort than any other phase except the Proposal.
- The relationship between percent of time and percent of cost was approximately 1:1. During Detail Design the relative cost of each hour was slightly lower, balanced by very slightly higher relative costs per hour during the other phases, as might be expected.

For production and construction projects the work effort is often graphed as 'resource allocation' in terms of 'man-days', but this approach was not strictly applicable for this design project as so much of the work effort was in the form of short interchanges between different people. However the variation in numbers of people involved each month, as shown in Figure 2-9, gives some idea of the commitment of resources. From the 3 to 4 people involved in Months 1 to 7 the numbers increased to an average of about 10 between Months 8 and 26 and then to about 18 for the rest of the project.

To consider the overall project in more detail the interaction between the project phases was studied. Figure 2-10 shows the project effort in each phase by month, and therefore indicates the overlap between phases. At a first glance the graph appears to have a lot of 'noise', which would be increased if time was plotted in days or weeks, and decreased if time was plotted in 2-monthly or 6-monthly intervals. It became apparent, however, that the 'spiky' nature of the graph plotted by month is significant for this particular project as each major 'peak' and 'dip' relates to specific events in the project history as discussed in Chapter 3. Furthermore it appeared that had such events not occurred, or had been foreseen and then compensated for, the profile of phase-by-phase effort would have been more like that shown in Figure 2-11. In summary:

(i) If the project had gone according to plan (ideal case) the project phases would have been characterized by five 'humps' or bell-shaped curves on the graph, each overlapping others by a certain amount.

(ii) In practice the project did not go according to plan, and specific events caused specific 'peaks' and 'dips' in effort.

(iii) Those 'dips' caused by non-ideal events reduced the proportion of work done within the envelope of the 'ideal curves'. For example during Conceptual Design one team member's vacation resulted in the major dip in Month 13 (Figure 2-10), at a time when the ideal case (Figure 2-11) would call for effort greater than that in Month 12.

(iv) For each dip occurring within the envelope of an ideal curve, there is a corresponding peak of effort to compensate later in time and outside the ideal curve for that phase. For example, to compensate for the dip in effort during Month 13 a peak of additional effort occurred in Month 17. This peak might have been expected in Month 16, but the chance illness of a key team member delayed the work.

(v) Each such compensating peak delayed the finish time for that phase in the real case, diverting effort from the phase which followed and extending the overall project time.

The possibility of characterizing the 'ideal curves' in mathematical terms seemed attractive for comparing actual effort against the ideal case, but data from more projects would be required for the development of a valid mathematical model. Approaches tentatively considered were:

(i) Assume a normal distribution for the effort in each phase;

(ii) Characterize each phase by its median point, height at the median and band-width at its 'half-height';

(iii) Characterize the curve for each phase in general statistical terms (2nd, 3rd and 4th moments about the mean).

The first one is a special case of the third and although its simplicity makes it an attractive approach the 'ideal curves' shown in Figure 2-11 do not meet the necessary conditions such as zero skewness. The second one is also simple but, although it might adequately characterize the curves for the first three phases of the project, it would be unsatisfactory for the less symmetrical embodiment and detail design curves. Of the three, characterizing the curve for each phase in general statistical terms would seem the best possibility, as comparisons of curve characteristics such as skewness, kurtosis (peak sharpness) and overlap could then be made between projects. Whether or not a mathematical approach proves possible, Figure 2-10 is a useful summary of the overall project effort, and can help to characterize the project. It shows that the Proposal phase was separate from the others, with a three month period before the Task Clarification phase began. One other zero period occurred, at the point where the Conceptual Design had almost finished and the Embodiment Design phase was starting. This was also the only other point where there was little phase overlap. Each project phase other than the Proposal phase ended with a peak of effort apparently outside the 'ideal' curve and this seemed to form a pattern throughout the project. Had the right things been done at the right time (i.e. effectively) and done in the best way when they were done (i.e. efficiently) then the work effort may well have been completed within the envelope of the ideal phase diagram, and the project would have been completed sooner.

This suggests that the higher the peak to width ratio of each phase curve and the larger the overlap between phases the more effective and efficient the project work effort would be, but it may not necessarily be so. For example, if embodiment design had overlapped with conceptual design there would have been the risk that the 'wrong' concept was being developed. On the other hand, once the layout of the simpler sub-systems had been agreed on through embodiment design there would have been an advantage in going straight on to detail design for those, which would have been indicated by greater overlap between the embodiment and detail design phase curves. It is not possible to generalize from these results but certainly the flatter the curves, and the less the overlap, the longer the project time-span.

Figure 2-10 also shows another feature. It appears from the graph that the Task Clarification phase was completed in two distinct stages separated by a period of 18 months. In fact what happened was that due to the effect of external influences two changes were made in the design specification: the maximum operating pressure was increased from 1500 psi to 2500 psi and the maximum operating temperature from 1100 C° to 1300 C°. Unlike the late effort required to compensate for work not completed at the ideal point in time, this represents extra work outside the ideal envelopes altogether. What the graphs cannot show is the extra work effort created in other phases by the change in specification during Month 27 but, even ignoring this 'knock-on' effect, it is clear that the additional task clarification effort added work hours and cost to the project. Design of the control system, which was completed almost as a 'project-within-a-project' during embodiment design, also called for additional hours of task clarification.

At this point a number of questions might be asked such as:

(i) How did project costs relate to project effort measured in hours?

(ii) Did hourly charges reflect the relative 'value' of project effort?

(iii) What about wasted effort, mistakes or mismatched expertise?

(iv) What about people not always working to capacity?

(v) Were there 'good' hours and 'bad' hours in terms of results?

The only costs incurred during the project other than direct labour costs were incidentals such as travelling expenses, telephone charges and postal charges. For the Company Staff these were included in the normal overhead added to the salary cost for in-house work, and for Contract Staff they were incorporated in the hourly charge rate used (including trans-Atlantic flights for one engineer). This allowed the simplifying assumption to be made that project costs were proportional to project hourly charges. In addition, although there was a 3:1 ratio between the highest and lowest hourly charge rate, the recorded hours for the highest and lowest rates were so few by comparison with the total that they had little affect on the overall relationship between hours and cost (see Figure 2-8). Thus, once the overall project cost had been calculated from the hours and cost-per-hour for each individual, a back-calculated average hourly charge rate gave a good overall approximation, and the project cost in pounds sterling could be considered directly proportional to project effort in hours. It also meant that although the 'value' to the project of hours worked varied in a subjective sense, for the sake of quantitative argument it could be reasonably assumed that all hours were of equal value. This is not to say that the issues raised by the above questions are unimportant. They most certainly are important, and are discussed further in Chapter 3. However for the quantitative analysis some simplification was needed, and it came through the use of the following two assumptions:

(i) Project cost directly proportional to project effort in hours.

(ii) All hours contributed equally to the project effort.

By plotting cumulative effort by time as shown in Figure 2-12, using these assumptions, it is possible to gain some idea of the 'percent completion' at various points in the project. The first 25% of project effort took 50% of the project timespan and the first 50% of the project effort took 75% of the project timespan. Thus 50% of the total project effort was completed in the final 25% of the project timespan. It is interesting to note that the 50% point in the project timespan was the point at which the Conceptual Design phase was ending and the Embodiment Design phase was beginning. This illustrates that, even for a project which did not have severe time constraints, most of the effort seemed to be put in at the end, and also that the Company resources involved increased with time. The graph has the 'S-Curve' characteristics typical of graphs showing percent completion of construction and production projects, as described by Hajek (I11). Based on Assumption (ii) the curve of 'actual' cumulative effort in Figure 2-12 may be considered to show 'percent completion' for this project. Based on Assumption (i) a cumulative cost graph would follow the same curve, closely matching the typical cumulative cost 'S-Curve' which Turner and Williams (H44), and Darnell and Dale (I9), suggest may be used for project cost control in engineering. From the Ideal Phase Diagram shown in Figure 2-11 the 'ideal' graph of cumulative effort shown in Figure 2-12 was produced, and comparison of the 'actual' curve with the 'ideal' curve provides a measure of where the project deviated from what was expected and by how much.

As the outputs from the engineering design process are less tangible than those from the production process or the results of construction projects, percent completion is more difficult to estimate for design work, but it is still regarded as a necessary measure of performance by management. By generating an 'ideal phase diagram' for a particular engineering design project, based on performance data from previous projects, a realistically modelled 'ideal' graph of cumulative effort may be produced. Comparison of actual work effort against the ideal could then be used for monitoring and control of engineering design work based on achievable goals, and the design team would have a better chance of producing reliable estimates of 'percent completion' and 'cost-to-completion'. This in turn could give management earlier warning of deviations and more time to take appropriate compensatory action.

This discussion may be summarized in the form of four hypotheses:

Hypothesis 1

Ideal engineering design projects may be classified and characterized by a series of mathematically defined and overlapping curves, each representing the work effort in a particular project phase along a time axis, and in combination termed an 'Ideal Phase Diagram'.

Hypothesis 2

An 'ideal' graph of cumulative effort, based on an ideal phase diagram for a project, provides a model against which to measure actual performance.

Hypothesis 3

Design work not completed within the envelope of the ideal phase diagram for a particular project will have to be completed outside the envelope at a later time, causing diversion of effort and significant cost increases.

Hypothesis 4

Changes to the design specification outside the ideal curve for the Task Clarification phase cause increases in total project effort, and the later they come the greater the effect.

2.5 Project Effort by Individual and Group

As the project effort of each participant was recorded down to 0.1 hour it was possible to investigate the nature of the overall effort from any one of many viewpoints, and in great detail. For example the work effort by each of the eight participant groups, as summarized in Figure 2-13, may be broken down by individual participant and tabulated by month, as shown in Figure 2-14. In this particular table, hours rounded to the nearest hour are totalled by participant (rows) and by month (columns), the totals then being converted to percentages of the overall 2369 hours of effort. From these the cumulative hours and cumulative percentage were derived, giving rise to the graphs of overall project effort discussed in the previous section. The 37 participants are grouped by job and affiliation as listed by code in the left-hand columns and detailed in Appendix C.2. The format of this table is general in that it was used to create equivalent master tables of other types of data such as as participant mood, type of effort and work location.

As illustrated in Figure 2-13, and detailed in the master table of hours, 1507 hours (64%) of the overall project effort came from contract staff, 69 hours (3%) came from outside supply companies, 56 hours (2%) came from university staff and the remaining 741 hours

(31%) came from five groups of permanent staff within the Company. The input from four of these eight groups is detailed in Figures 2-15 to 2-18. To highlight the pattern of involvement for each group, the graphs are in terms of actual hours rather than percentages of totals and the vertical axis scales vary. By laying each of these graphs over the phase diagram (Figure 2-10), it was possible to see the following:

(i) Directors had little involvement until midway through embodiment design when the developed concept was presented, and thereafter had slightly more, but irregular, involvement. The most input was 7.8 hours in Month 22 and the total recorded input was 21 hours (1%).

(ii) Managers had a continual input throughout the project, the most being in task clarification and embodiment design. There is some evidence to suggest that their input increased at those times when the work effort fell outside the envelope of the ideal phase curves for the project. Their total recorded input was 154 hours (7%).

(iii) The input of the research staff was also continual, and followed the general level of activity on the project. In particular there was over twice the normal level of input from research staff during the design of the control system in Month 27, and this is discussed further in Chapter 3. Their total input was 365 hours (15%).

(iv) As the input of the contract design staff far outweighed that of any other group, it is not surprising that the overall pattern of project effort was in fact set by this group, and again this is discussed further in Chapter 3. In Month 27 two contract design engineers between them put in 290 hours of effort, which amounted to 12% of the total project effort and was the most concentrated period of project effort. Their total input was 1507 hours (63%).

2.6 The Engineering Design Process

2.6.1 Activities

The Pahl and Beitz model of the engineering design process shown in Figure 2-19 may be taken as representing one of the more defined and detailed general procedures currently available to the design engineer and project manager. As previously mentioned, the use of these procedures during this project provided a structure for initially categorizing the field data, and the data proved detailed enough to allow a quantitative investigation of two particular aspects. These were the identification of phases and 'steps' (or activities) in the engineering design process and the use of design 'methods and aids' (referred to in this thesis as 'design-related techniques'). Specifically it included comparing the measured results for this project with the recommended use of techniques and estimated use of time provided by Pahl and Beitz (B48, pp. 409-413) and reproduced in Figures 2-20, 2-21 and

2-22. The list of participants shown in Figure 2-14 was restructured according to the Context Model levels of resolution (Figure 2-5) and only those project hours directly attributable to the engineering design process were counted for this part of the analysis. The input of management and others not involved in design work was excluded, leaving 27 participants with 2178 hours (92%) of the total project effort.

The hours of each person were categorized firstly by *phase* of the design process and then by '*step*' within each phase, according to the Pahl and Beitz model as shown in Figure 2-23. Much of the work effort could not be categorized in this way and was coded 'X' in the first instance. When all the engineering design input had been classified the 'X'-coded input was reviewed, and six additional activities were identified, not specific to particular phases (and therefore not 'steps' in the Pahl and Beitz sense) but observed to occur in all phases. These activities were:

General Activities

XP - Planning Work (personal day-by-day planning of activities)

XR - Reviewing/Reporting (verbal or written project reports/reviews)

XC - Cost Estimating (design costs, labour costs, hardware costs etc)

XI - Information Retrieval (information processing of all kinds)

XS - Social Contact (social interaction outside other categories)

XH - Helping Others (informal help given on other projects)

The hours were also categorized by usage of design-related techniques as listed by Pahl and Beitz in Figures 2-20 and 2-21. Again much of the work effort did not fit any of these categories and was 'Y'-coded in the first instance. When all hours had been classified the 'Y'-coded hours were reviewed, and 13 additional techniques were identified. Those hours where no identified technique had been observed remained 'Not Classified'. The additional techniques were as follows, grouped into three sets:

Working Techniques

YL - Making Lists (personal reminder lists)

YC - Cost Estimating (all types of costing)

YS - Calculating (simple and complex calculations)

YG - Scheduling (use of bar charts etc.)

YF - Filing (making/using personal files of information)

Communicating Techniques

YQ - Questioning People (informal/formal, verbal/written)

YP - Presenting Viewpoints (informal/formal, verbal/written)

YN - Negotiating Agreements (informal/formal, verbal/written)

YR - Reviewing and Reporting (informal/formal, verbal/written)

Motivating Techniques

YI - Becoming Involved (with the design, the person or the situation)

YE - Injecting Enthusiasm (conscious effort to raise level of enthusiasm)

YH - Adding Humour (to break tension or bind group together etc.)

YT - Team Building (conscious effort to optimize group effort)

Five master tables were compiled, which together detail all the techniques observed during each activity within each phase of the engineering design process for this project. Proposal preparation involved input from design engineers so it was included as a separate phase of the engineering design process, in addition to those of Task Clarification, Conceptual Design, Embodiment Design and Detail Design. Total hours, and percentage of total hours per phase, were tabulated for each activity and each technique. The five sets of results are shown in Figures 2-24 to 2-28. Two more tables were derived from these, for comparison with the Pahl and Beitz ones shown in Figures 2-20 and 2-21. To produce an equivalent to Figure 2-20 the tables for the Proposal, Task Clarification and Conceptual Design phases were combined, and the totals recalculated. To produce an equivalent to Figure 2-21, techniques No.5 to No.14 from the Embodiment Design table (Figure 2-27) were combined into a single line item termed 'concept phase methods'. The resulting two tables are shown as Figure 2-29 and 2-30 respectively. Finally, as shown in Figure 2-31, a bar graph was produced for comparison with the Pahl and Beitz estimate on percentage breakdown of 'man-hours spent on the conceptual phase'.

The main features of these results may be summarized as follows:

(i) 47% of the engineering design effort could be categorized according to the Pahl and Beitz 'steps' of the engineering design process.

(ii) By adding 6 more 'activity' categories, and using these in each phase of the engineering design process, the remaining 53% of the observed engineering design effort could be accounted for.

(iii) 22% of the observed engineering design effort could be categorized according to the 'methods and aids' recommended by Pahl and Beitz.

(iv) By adding 13 more techniques for 'working', 'communicating' and 'motivating', a further 74% of the total engineering design effort could be accounted for, the remaining 4% being left unclassified.

(v) In general the observed activities followed the sequence of 'steps' represented in the Pahl and Beitz model, except that 'abstraction of the problem' occurred during task clarification rather than in conceptual design. The only missing 'step' (i.e. one with no hours attributed to it) was 'firming up into concept variants'. This one became redundant when it was decided to combine the best features of the four final concepts into a single preferred concept.

(vi) The activity which accounted for the most engineering design effort was found to be 'reviewing and reporting' at 22% of the total.

(vii) The most used design-related technique was 'communicating by means of reviews and reports', observed as taking 15% of the total time.

The summarized data in Figures 2-24 to 2-31 could be used for a far more detailed study on the activities within each phase and the techniques used than is possible within the scope of this thesis, and if equivalent data from other projects became available useful comparative studies could be carried out. All that can be done here is to compare the work effort measured on this project against the estimates which Pahl and Beitz have compiled based on their experience in Germany. Figure 2-31 shows their estimated percentage breakdown of 'man-hours' for task clarification and conceptual design together with the equivalent results for this project. There appears to be little correlation between them and there are good reasons for this. The estimates of Pahl and Beitz are based on their experience with a number of different projects, perhaps many. Compared with this are the measured results from a particular project, with its own particular characteristics. One represents an average across a spectrum of projects while the other represents a single project at one end of the spectrum. This project was a 'one-off', so a high proportion of effort on clarifying the task is to be expected, and it involved the design of test equipment operating under such extreme conditions that the scope for producing many different concepts was restricted. The low proportion of time spent on actual conceptual design, by comparison with clarifying the task, would therefore seem in keeping with the nature of the project. It appears that the bar graph of engineering design effort by activity gives a 'profile', characteristic of this phase of the project. If this were extended to cover the activities for all phases, the resulting overall project profile could be used to help classify this project for comparative studies.

At the time of writing, a new edition of *Konstruktionslehre* (B47) has been published in Germany. It includes a new chapter on cost estimating, and the tables shown in Figures 2-20 and 2-21 have been revised to reflect this. Cost estimating as an 'activity' accounted for 119 hours (5%) of the Gasifier Test Rig engineering design effort. Estimating costs, as an observed 'technique', was used during 62 hours (3% of the design time). This compares, for example, with 122 hours (6%) spent on clarifying the task and 57 hours (3%) using embodiment design detail guidelines. The data thus provides evidence in support of the emphasis now given to cost estimating in the new edition of *Konstruktionslehre*.

2.6.2 Outputs

So far the concern has been with the *activities* which occurred within each phase of the engineering design process. In this section the *outputs* from each phase are considered. Nadler sums up the problem with outputs (B45):

> "Productivity is usually measured by comparing the amount of effort put into the work with the quality and quantity of work produced. Manufacturing output is much easier to measure than office output. Also, because a designer's productivity is measured qualitatively as well as quantitatively, the value of his work is related not only to the number of designs produced, but also to their effectiveness."

Proposal preparation resulted in a proposal document, task clarification in a design specification, conceptual design in a concept, embodiment design in scaled layouts and detail design in manufacturing drawings with other production documents (Figure 2-5). The question was: how to assess these outputs? Once the Gasifier Test Rig had been built and commissioned its design could be analysed on the basis of actual performance, but in the absence of operational data this was not possible. This is typically the position of a project manager when deciding to commit a project to manufacture. What was possible, since the procedures recommended by Pahl and Beitz (B48) had been followed, was to compare the procedures in theory with what actually happened in practice as discussed below.

Proposal Phase

Specific guidelines for the preparation of project proposals are suggested by Hajek (E7) and others specializing in project management, but although procedures for 'product planning' are offered by Pahl and Beitz, proposal preparation is not considered a 'phase' of the engineering design process in its own right. For the Gasifier Test Rig, three percent of the overall engineering design effort went in helping to prepare the original project proposal (Section 2.6.1). The 15-page document included preliminary ideas from the project team, a description of the proposed design approach, a schedule and a cost estimate. It was completed four months before the funded design effort started, and it had to be considered either as part of the Task Clarification phase, which was hardly the case as no project existed at the time, or as a phase of the engineering design process in its own right which complicated the issues. As shown in the simplified Context Model in Figure 2-5, a compromise was reached by including it as a separate phase of the engineering design process for this project. It was seen as a link between the 'project brief' and the 'design task', with its own activities, including the steps of 'product planning' and 'selection of task' shown in Figure 2-23.

The 15-page proposal was accepted in time for the design work to start on the proposed date, and a contract was agreed without problems. Only two points regarding support staff and the cost breakdown required negotiation and the rig design was carried out within the estimated cost. The output of this phase was assessed as satisfactory in quality and quantity, and it took 64 hours of the engineering design effort (3%).

Task Clarification Phase

The recommended procedure used for clarifying the design task (B48, p.49) involved defining the task (i.e. a statement of the problem to be solved), then using a checklist in questioning all project participants to generate a list of 'demands' (essential requirements) and 'wishes' (preferences). The detailed design specification compiled from this would theoretically provide criteria for selecting and evaluating design concepts, and the requirements to be met during embodiment and detail design.

The finally agreed design specification for the Gasifier Test Rig was a 20-page document (sample page in Appendix A.3) listing 308 requirements and constraints, of which 217 were 'demands' and 91 were 'wishes'. There were 13 contributors, representing 5 of the 8 participant groups shown in Figure 2-14, and 34 of the requirements came from 400 ideas generated by a 45-minute brainstorming session involving 15 people. A breakdown of the specification by demands and wishes is shown in Figure 2-32. No attempt was made to rank each item in order of importance, as this would be a matter of opinion, but they have been grouped into four categories:

Function - concerned with the performance of the rig;

Production - concerned with manufacture of the rig;

Operation - concerned with running and maintaining the rig;

Information - information of use in designing the rig.

Two main points emerged:

(i) A confidential internal report indicated that researchers needing a test rig would generally sketch out the requirements in the form of a concept, and submit this either to the senior design engineer in the Company or to an outside supplier. Design work would begin, and there would often be misunderstandings and problems, leading to disagreements and wasted effort. One reason for this was the lack of involvement of groups such as safety specialists at the task clarification stage. Many important requirements would be omitted from the initial list, and continual changes would be made during the rest of the project. The table in Figure 2-33 shows that for the Gasifier Test Rig over 40% of the design requirements came from sources other than research staff. In particular 19% came from the services staff responsible for manufacture. It was evident that the procedure used for this particular design specification almost doubled the list of requirements which might have been expected had normal Company practice prevailed, and this avoided later problems.

(ii) Each requirement in the specification was labelled with the name of the contributor, and the document was circulated to all project participants for review. A total of 92 corrections, clarifications and additions were made, involving 72 demands and 20 wishes. Once the specification had been agreed on by all parties only two items were changed during the rest of the project, and these were caused by specific external influences as will be discussed in Chapter 3.

In functional terms the specification was assessed as being adequate in quality and quantity, and it provided a solid base for all further work. The procedure used was regarded as most effective by the project team and was later adopted by several participants for use on other projects. Task Clarification took 258 hours (12% of the engineering design effort).

Conceptual Design

Design theory (B48, p.112) indicates that the output from the Conceptual Design phase should be the concept which most fully satisfies the requirements of the design specification. Only those candidate concepts which satisfy every 'demand' in the specification should pass from the selection 'step' to the final evaluation 'step'. The most appropriate concept is then determined from an evaluation of how well each candidate meets the wishes or preferences.

For the Gasifier Test Rig this meant that any candidate concept would have to satisfy 217 demands to be selected and those selected would have to be evaluated against 91 wishes. This presented the problem of how to deal with such a full list of requirements, and in practice the selection and evaluation procedure was based only on those requirements judged to be the most important. The 'objectives tree' procedure described by Pahl and Beitz (B48, p.121) for weighting criteria according to relative importance could have been used, but it was found unnecessary to go to this level of detail in order to come to a decision regarding the final concept. As is detailed in Appendix A.2, eight concepts were generated, and a great many possible solutions were generated for various 'sub-functions' (B48, p.67) by using discursive techniques. Four selection charts (B48, p.113) were used in the selection process, and subsequent evaluation led to the final reactor concept shown in Figure 2-34. Associated with this were concepts for its six ancillary sub-systems. Some important features were:

- Modular construction to allow various internal reactor configurations;
- Double-wall vessel; all-bolted assembly for easy maintenance;
- Vessel trunnion-mounted to allow vertical rotation for lower access;
- Specimens and instrumentation mounted on a sub-assembled cartridge;
- Adaptable for different types of test using same vessel and controls;
- Automatic control system for 1000-hour continuous operation;
- Three-level automatic alarm and shut-down procedure.

Many safety requirements and building constraints came from participants other than researchers, and these were taken into account in the final concept features. An example is the requirement that: 'Rupture discs should discharge to a proper vent-line system'. This sounds a small item but it involved a long run of high-pressure piping which would have been omitted from the cost estimate for construction, had the requirement not been included in the design specification.

The output from this phase was a concept, judged by the project team to be capable of meeting the requirements of the design specification, and a preliminary cost estimate for construction of £85,555 with reserves of £16,950 (to reflect the confidence level). Of the procedures recommended by Pahl and Beitz which were used during this phase, the selection charts were found to be the most helpful. In general the overall procedure for arriving at the final concept was considered rather cumbersome for this project. As no procedures were offered for estimating costs (see page 38) a Company procedure was adapted to suit the project (see Appendix A.2). Conceptual Design took 211 hours (10% of the engineering design effort).

Embodiment Design

In theory Embodiment Design is seen as "...that part of the design process in which, starting from the concept of a technical product, the design is developed, in accordance with technical and economic criteria and in the light of further information, to the point where subsequent detail design can lead directly to production." (B48, p.166). Many different approaches have evolved for the development of concepts, and the one chosen depends on the nature of the project. For the Gasifier Test Rig the approach used was progressive detailing of layouts, rather than prototyping, modelling, experimenting, computing or other approach. Design theory (B48, p.171) offers 'rules', 'principles', 'guidelines' and checklists to help with this (rather than a generalized procedure), and a specific checklist is provided for evaluating the embodiment design output (B48, p.310).

In practice it was found difficult to classify work hours specifically as 'conceptual design', 'embodiment design' or 'detail design'. It had to be done in some definite way for the analysis, so all those hours between the meeting when the design specification was finalized and the one when the concept was finalized were classified as 'conceptual design'. Subsequent hours were divided into 'embodiment design' or 'detail design' depending on whether they contributed to the development of the reactor concept and overall layout (embodiment design) or dealt with individual components, detail part drawings or detail calculations (detail design). This proved adequate except for those hours spent on cost justification documentation and those spent on design of the control system. The cost justification documents referred to the *developed* concept, with refinements such as the recirculation of gases and partial separation of tars and gases within the reactor, so these hours were categorized as embodiment design. For the control system design each interchange was considered individually. There were task clarification hours for the contract controls engineer, as well as embodiment and detail design hours, but the conceptual design had been completed previously.

Whereas conceptual design was mainly concerned with the reactor assembly, embodiment design was concerned with the development and integration of all seven sub-systems. For the analysis it was assumed that at any point in time all sub-systems were at the same stage of development except for the control system. Actual fluctuations were small enough to be neglected when considered on the month-by-month basis used here. The details of the developments to the reactor concept during this phase are described in Appendix A.2, and Figure 2-1 shows the developed concept. Examples of its features are:

- Sub-assembly cartridge for the specimens and instrumentation modified to incorporate partial separation of tars and gases;
- Heating element cartridge modified to accept four independently controlled elements instead of two;
- Double O-ring seals with leak detection and provision for emergency nitrogen pressurization between them;
- Annular-groove weld preparation in pressure vessel cap to permit the welding of replacement 'inner reactor chamber' tubes to this cap with no need for certified inspection.

These features, and the many others like them, may be considered in terms of the embodiment design rules, principles and guidelines recommended by Pahl and Beitz, and may be assessed according to the evaluation checklist. Of the 38 reactor components (Figure 2-1) given a full design treatment, the 'inner reactor chamber' welded fabrication provides an illustrative example involving almost all the rules, principles and guidelines and this is shown in in Figure 2-35. The 'rules' were considered more as 'overall guidelines' for this type of evaluation, and the 'principles' and 'guidelines' more as 'detail guidelines'. This simplified the categorization of hours for the tables in Figures 2-24 to 2-31. For sub-systems other than the reactor assembly a high proportion of bought-out components were used, so there is less evidence of the importance of the detail guidelines, but the the 'overall guidelines' of clarity, simplicity and safety applied to all sub-systems, and the evaluation checklist could still be used. For instance the rupture disc mentioned in the last section is an example of a 'protective system', as described by Pahl and Beitz (B48, p.189).

For this project the output of the Embodiment Design phase included: the developed reactor concept; the equipment selection and incidental design for the seven sub-systems; the preliminary and detailed overall layouts; a more detailed cost estimate with cost justification documentation; and the control system design complete with the Process and Instrumentation (P&I) Diagram. In addition to the 'rules', 'principles' and 'guidelines' for layout design, other types of guideline were used, such as those given in manufacturers' catalogues for selection of bought-out components. Final layouts produced were well-received by the 'customer' and 'users', and through them the project gained more support at this stage. The quality of output from this phase was considered satisfactory, but productivity was low. This is discussed in Chapter 3. Embodiment Design took 770 hours (35% of the engineering design effort).

Detail Design

Detail design theory draws together techniques used in the 'form' design of individual components, and guidelines for completing and checking the final production documents (B48, p.362). Form design is concerned with the interactions between shape, materials and manufacturing process for components, and the integration of components into assemblies. The output from the Detail Design phase has traditionally been in the form of detail drawings but is now often in the form of digitally stored manufacturing information. For the Gasifier Test Rig project there were no facilities for 'computer-aided drafting' available at the time, and all drawings were manually produced.

There was clearly overlap between the embodiment design and detail design phases, and it was sometimes difficult to classify a specific interchange as one or the other. However there was a precisely defined point at which detail design started. This was a meeting with the design office manager to agree on a schedule, starting from that date, for the completion of all necessary manufacturing drawings. It marked a definite change of emphasis on the project. Had everything gone as planned the drawings would have been completed within the time limit set for research data collection and the data would have been complete for this phase. However, despite the careful planning, no qualified detail designer was available until well into the agreed period. This delayed the work for 5 months, and the situation was not resolved until too late for all the drawings to be completed before the field research ended. Approximately 12 remained to be finished before the detail design work could be considered complete and an estimate of the time required to finish these was 30-40 hours. This amounts to just over 1% of the overall engineering design effort, and it was considered a small enough proportion to be omitted without materially affecting the research findings.

The majority of the detail drawings necessary for manufacture and assembly of the Gasifier Test Rig system were completed, together with the 138-page GTR-6 design report containing detailed calculations, descriptive notes, correspondence, and detailed sketches. The 'inner reactor chamber' welded assembly described previously also provides a typical example of a shape-materials-manufacture interaction problem tackled during detail design, as shown in Figure 2-36. It included: selection of materials (discussed in I12, I17, I19); use of the pressure vessel 'codes' BS 5500 and ASME VIII (see Appendix A.3, Report 5); dimensional and geometrical tolerancing; welding sequences during assembly; selection of standard O-rings using the manufacturer's guidelines; and questions of thermal expansion, creep and heat transfer. The output from the detail design phase, up to the cut-off point for data collection included:

- 42 pages of pressure vessel calculations;
- 8 pages of scrubber calculations;
- 19 pages of steelwork calculations;
- 18 pages of other calculations;
- 65 detail drawings;
- 14 files of supplier information with index.

Although the work which was completed was assessed as satisfactory, the productivity during this phase was poor, and the reasons behind this are discussed in Chapter 3. Detail Design took 875 hours (40% of the overall engineering design effort), excluding the estimated hours for completion of the drawings.

2.7 Participant Interchange Characteristics

2.7.1 Type

Each of the 2488 interchanges was coded according to the number of people present and the following categories of type:

Type of Effort	*Description*	*Code*
Letter	- note or formal letter (being read or written)	LI or LO
Telephone	- telephone communication (incoming or outgoing)	TI or TO
Meeting	- any face-to-face discussion, meeting or chat	M + People
Work	- personal or collaborative on specific tasks	W + People

The proportions of work effort by type are shown in Figure 2-37. Of the project effort, 36% came from participants working alone on specific tasks, 16% came from meetings between two participants, 13% came from work in pairs on specific tasks, and 8% on meetings involving three participants. Of the remaining 27%, 9% was split between letters and telephone calls, 5% came from meetings involving four participants, 4% from working trios and the final 9% involved 5 participants or more, with a maximum of 20.

What may be concluded from this is that half the project effort was from people working alone or in pairs, that meetings or other contact between two people played an important part and that a lot of time was spent in remote communication by letter and telephone. Rather than answer any questions, this opens up an area worth investigating in more depth than is possible in this thesis. For example what is the breakdown of type of effort by month and by phase of the design process, and do particular types of effort correlate with particular activities or use of techniques within each phase? It also suggests that communication between people, as distinct from work effort on specific tasks, is an important part of the engineering design effort in its own right, and needs investigation as such. For example, on this project some 43% of the total effort was spent in direct communication of one sort or another. In the activity and technique tables (Figures 2-24 to 2-30) this was accounted for by the inclusion of the 4 categories of communicating 'technique'.

2.7.2 Location

Each participant's work effort within each interchange was also coded by type of location according to the grouped listing below:

Type of Location	*Description*	*Code*
	Offices in Company	
Own Office	- personal office in Company premises	O
Another's Office	- someone else's office	A
Shared Office	- office with cross talk from non-participants	N
Design Office	- office dedicated to design and drafting	D
Laboratory	- scientific research laboratory	L
	Public Areas in Company	
Conference Room	- conference room or other meeting room	R
Cafeteria	- cafeteria, or dining area in the company	C
Library	- library in the company or elsewhere	B
Lobby	- corridor, lobby or other open public area	P
	Remote Locations	
Outside	- areas external to normal office buildings	E
Travel	- in transit by any form of transportation	T
Home	- personal or other living accommodation	H

Of the overall project effort 36% was carried out by participants working in their 'own office', that is at a desk in an enclosed space allocated specifically to them, and 15% was by people working temporarily in someone else's office. An example of this would be a design engineer meeting with a manager in the manager's office to review project progress. Another 17% was carried out in an office dedicated to design and drafting and 10% in a conference room. Many other locations were involved to a lesser degree, ranging from 7% work at home to 0.5% in libraries as shown in Figure 2-38.

The observation from this is that although most of the project effort took place in offices, one third of it took place in laboratories, conference rooms, cafeterias, libraries, corridors, at home, outside and while in transit. In other words the project effort was not confined to specific locations but often took place wherever particular participants happened to be at the time. This will be discussed in more detail in Chapter 3. The split of effort amongst the five different classification of offices is also of importance. Less than one fifth of the project effort took place in the 'design office' while almost the same amount took place in other people's offices and over twice this took place in participant's own offices. So for this engineering design project less than one fifth of the work effort took place in what was normally regarded by the Company as 'the place where design work is done'.

There is scope for further analysis with this data. For example it would be possible to separate out the engineering design effort from the project effort according to the Context Model, and then map the use of different locations during each phase and activity of the design process. The same could be done for design-related techniques, for type of effort, for each participant and for groups. All of these could add more insight regarding engineering design effort and where it is carried out in practice.

2.7.3 Mood

A great deal of data was recorded which indicated the state of mind or the 'mood' that participants appeared to be in as they worked on the project. It was realized that this was useful data but in the diffuse form of diary notes it didn't mean much, and within the engineering design field there was no guidance on how it could be handled. However, as it was known from the literature (H15, H35, H44, I1), and from personal experience, that the influence of enthusiasm, involvement and tenacity is important in design, it was felt that a preliminary attempt should be made to develop a way of handling this sort of data.

The first step was to indicate the observed 'mood' of each participant in every interchange by means of a single word where possible, entering it in the 'Mood' column of the database as shown in Figure 2-2. By masking all columns except person, topic, mood and remarks, a 'plus', a 'minus' or a 'zero' was assigned in the 'M' column for each of the 2488 records, based on whether the observed mood was judged positive, neutral or negative with regard to the well-being and progress of the project. It proved possible to mentally set the 'mood' word in context by glancing at the other fields displayed for that record, and to recall the interchange in enough detail to assess whether the mood had been good, bad or neutral from the project point of view. Having done this the results were plotted, to see what could be observed from this information. Just as the number of take-offs and landings is often more important than hours flown in aircraft design, it appeared that the number of positive, negative and neutral counts by record was of importance here, rather than the 'mood' weighted by the number of hours. The table shown in Figure 2-39 was compiled by assigning +1 for each '+' in the 'M' column of the database, zero for each '0' and -1 for each '-', summing the scores per month for each participant, and dividing by the sum of the participant's records for that month. This gave an average or 'mean mood', varying between totally positive (+1) and totally negative (-1) for each participant during each month.

From this table various graphs were produced, and three examples are shown in Figures 2-40 to 2-42. Figure 2-40 indicates that the 'mean mood' for the project was almost always positive, starting at a value of about 0.6 and exhibiting a gradual decline with time. The equivalent graph for the Managers, shown in Figure 2-41, indicates a pronounced drop-off with time, while the graph for Contract Staff in Figure 2-42 shows no such general decline. These results can be explained by reference to influences which affected the project, as discussed in Chapter 3. A better approach might be to show vertical bars indicating total positives and total negatives instead of just points on the graphs, as this would give an indication of spread within each month and generate a bandwidth pattern. However, this is beyond the scope of this current research.

2.8 Conclusions

(i) Empirical field data capable of being analysed has been gathered from all phases of an engineering design project in industry by means of participant observation.

(ii) A Context Model has been developed for the project, to help in differentiating between overall project effort and the 92% part of it attributable to the engineering design process.

(iii) Analysis of the project effort by month revealed the nature of the project phases and the extent of overlap between them, which gave rise to four hypotheses based on measurement of actual effort against an 'Ideal Phase Diagram' and ideal cumulative totals.

(iv) A table of monthly project effort for each participant was used to produce a series of graphs showing relative input and cumulative totals for different groups during the five phases of the project.

(v) The 'steps' of the engineering design process, as modelled by Pahl and Beitz, accounted for 47% of the observed engineering design effort. Six additional categories of activity were identified which accounted for the remaining 53%.

(vi) The Pahl and Beitz listing of 'methods and aids' accounted for 22% of the observed engineering design effort. Thirteen additional categories of design-related techniques were identified which accounted for a further 74%. Four percent remained unclassified.

(vii) The activity which accounted for the highest proportion of the total design effort (22%) was found to be reviewing and reporting, and the most used design-related technique (15%) was communicating by means of reviews and reports.

(viii) Theoretical and observed outputs were compared for each phase of the engineering design process, and actual outputs were evaluated in terms of quality and quantity. Those from the Proposal, Task Clarification and Conceptual phases were assessed as adequate in both quality and quantity. Those for the Embodiment Design and Detail Design phases were of adequate quality but productivity was low. In general the outputs were found to match those in theory, except for the addition of cost justification documentation and the control system design in the Embodiment Design phase.

(ix) Over 50% of the observed project effort was carried out by people working alone or in pairs on specified tasks, 30% was spent in meetings involving 2, 3 or 4 people and 9% was split between the writing or reading of letters, and on telephone calls.

(x) The work effort was carried out in a variety of locations ranging from specifically allocated personal space to more public areas within company premises, and remote locations such as in aircraft or at home. Over 50% took place in a personal office of one or other participant. Only 17% took place in the 'design office'.

(xi) A preliminary way of reducing and quantifying subjective data collected on the 'mood' of participants during the course of their project work has been developed. The variation in 'mean mood' of different participant groups by month was plotted, as well as the overall 'mean mood' by month. The results reflect the subjective assessments of team members, as will be seen in Chapter 3.

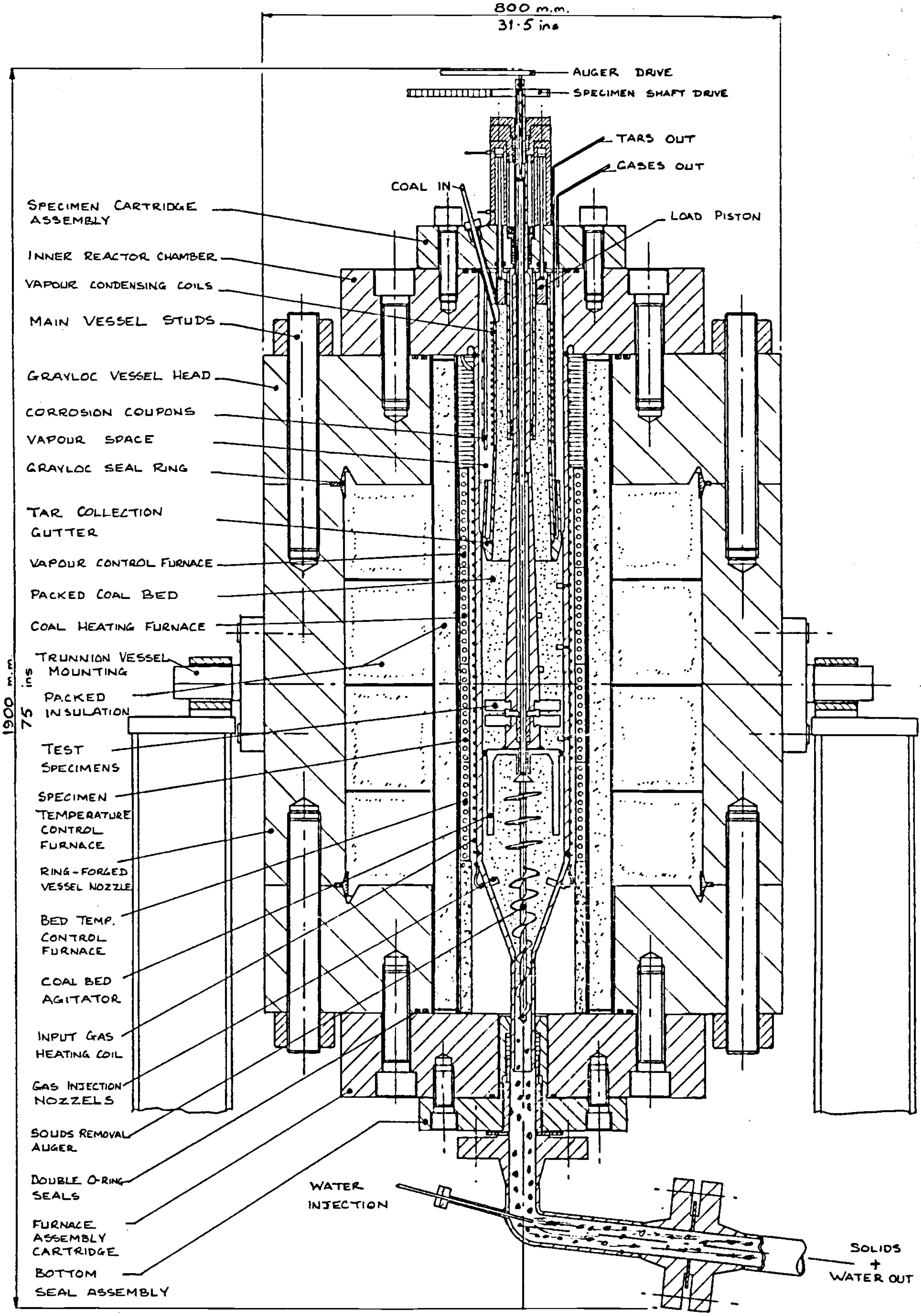


Figure 2-1 Developed Reactor Concept

GTR PROJECT INTERCHANGES

INT/NO	PERSON	DATE	TYPE/L		TOPIC	HRS	£/H	P/ACT	TQ	M	MOOD	REMARKS
211	ASL_A	04/18/83	M 2	O	PREPARATION OF A-FORM	0.2	14	C XC	YP	+	HELPFUL	HOW TO PREPARE FORMS
211	CDE	04/18/83	M 2	A	PREPARATION OF A-FORMS	0.2	17	C XC	YQ	0	QUESTIONING	NEED FOR GOOD APPROACH
212	S1_A	04/18/83	W 2	O	COAL CHARACTERISTICS	0.5	13	C XI	YQ	+	FRIENDLY/HELPFUL	SAMPLES OF COKE ETC.
212	CDE	04/18/83	W 2	A	COAL CHARACTERISTICS	0.5	17	C XI	YQ	0	QUESTIONING	NEED MORE INFO
213	CDE	04/20/83	T 2 C	O	CONTROLS DESIGN	0.5	17	E XP	YT	+	CHEERFUL	CCE AVAILABLE? (CALL TO USA)
213	CCE	04/20/83	T 2 I	O	CONTROL SYSTEM DESIGN	0.5	16	E XP	YT	0		CDE IDEA/ BRING CCE TO UK
214	CDE	04/20/83	T 2 C	O	ARRANGE MEETING	0.4	17	C XI	YE	+	ENTHUSIASTIC	VISIT LOCAL REP
214	SE_VE	04/20/83	T 2 I	O	ARRANGE MEETING	0.4	15	C XI	YE	+	FRIENDLY	MEETING WITH LOCAL REP
215	CDE	04/20/83	W 2	A	COST ESTIMATE FOR VESSEL	3.0	17	C XC	YC	+	PLEASED	COSTED ALL PARTS
215	SE_VE	04/20/83	W 2	O	COST ESTIMATE FOR VESSEL	3.0	15	C XC	YC	+	GOOD WORKING ATMOS	IN EVENING AT REP'S HOUSE
216	CDE	04/20/83	W 1	O	VESSEL DRAWING	2.0	17	E PL	SK	+	BUSY	FOR LEAVING WITH REP
217	CDE	04/21/83	W 1	O	VESSEL WTS & COSTS	3.0	17	C XC	YC	0	TECHNICAL	HELP NEEDED FROM SL_A
218	CDE	04/21/83	T 2 C	O	BUDGET QUOTE NEEDED	0.1	17	C XC	YC	+	FRIENDLY	QUOTE WILL BE IN ON 22 APR
218	SE_FE	04/21/83	T 2 I	O	BUDGET QUOTE NEEDED	0.1	15	C XC	YC	+	INTERESTED	WILL CALL BACK TOMORROW
219	CDE	04/22/83	T 2 C	O	BUDGET PRICE GIVEN	0.1	17	C XC	YC	+	PLEASED	APPROX 9000
219	SE_FE	04/22/83	T 2 C	O	BUDGET PRICE GIVEN	0.1	15	C XC	YC	+	HELPFUL	VERY SPEEDY QUOTE
219	SE_FL	04/22/83	T 2 I	O	PRICE FOR CHAIN HOIST	0.1	15	C XC	YC	+	HELPFUL	875 BUDGET PRICE
220	CDE	04/22/83	T 2 C	O	PRICE FOR CHAIN HOIST	0.1	17	C XC	YC	+	PLEASED	875
221	CDE	04/22/83	M 2	N	COST ESTIMATE/A-FORM	0.8	17	C XC	YC	+	CHEERFUL	PRIORITY SCHEDULE
221	RM_U	04/22/83	M 2	O	COST ESTIMATES/A-FORM	0.8	17	C XC	YC	+	ENCOURAGING	PRIORITIES FOR CDE
222	CDE	04/22/83	W 1	O	CONTROLS & EMBODIMENT DESIGN	3.0	17	E XP	YT	+	ENTHUSIASTIC	PLANNING & CCE FROM USA
223	CDE	04/22/83	W 2	A	COST ESTIMATE	2.5	17	C XC	YC	+	APPRECIATIVE	APPROX 8000./SAW FACILITIES
223	DE_U	04/22/83	W 2	O	COST ESTIMATE (INT. REACTOR)	2.5	12	C XC	YC	+	FRIENDLY/HELPFUL	MACHINE PARTS COSTED
224	CDE	04/22/83	W 1	O	9 COST ESTIMATE SHEETS	6.0	17	C XC	YC	+	ENTHUSIASTIC	102,500 TOTAL
225	DE_U	04/23/83	W 1	O	COSTS OF INCONEL	0.5	12	C XC	YC	+	FRIENDLY/HELPFUL	INCOLOY 600 & 800H
226	SL_A	04/25/83	M 3	A	GREETINGS	0.1	17	C XC	0	+	CHEERFUL	SL_A CALLED AWAY
226	ASL_A	04/25/83	M 3	O	PROJECT COST JUSTIFICATION	0.1	14	C XC	0	0	NEUTRAL/PESSIMIST	SL_A CALLED AWAY
226	CDE	04/25/83	M 3	A	GREETINGS/COST JUSTIFICATION	0.1	17	C XC	0	+	CHEERFUL	SL_A TO OTHER MEETING
227	ASL_A	04/25/83	M 2	O	COMPUTER PACKAGES	0.9	14	C XS	0	+	CHEERFUL	INTERLUDE
227	CDE	04/25/83	M 2	A	COMPUTER PACKAGES	0.9	17	C XS	0	+	CHEERFUL	INTERLUDE
228	SL_A	04/25/83	W 3	A	COSTS/CALCULATIONS/CONTROLS	1.5	17	C XR	YP	0	NEUTRAL	COST EST.BREAKDOWN & CCE
228	ASL_A	04/25/83	W 3	O	A-FORM PREPARATION	1.5	14	C XR	YP	+	HELPFUL	DISCUSSED COSTS
228	CDE	04/25/83	W 3	A	A-FORM PREPARATION	1.5	17	C XR	YP	+	PLEASED	HELPFUL ON APPROACH
229	AM_A	04/25/83	M 2	O	A-FORM & COSTS	1.3	19	C XC	YC	+	OPTIMISTIC	RIG CONSTRUCTION COST ESTIM.
229	CDE	04/25/83	M 2	O	A-FORM & COSTS	1.3	17	C XC	YC	+	CHEERFUL	DISCUSSED COST EST SHEETS
230	CDE	04/26/83	L 1 I	O	CONTROL & EMBODIMENT DESIGN	0.3	17	E XI	YE	+	PLEASED	HELPFUL INFO FROM USA
231	CDE	04/26/83	W 1	O	WEEKLY REPORTS	4.0	17	C XR	YR	+	BUSY	CATCHING UP
232	CDE	04/26/83	T 2 C	O	THANKS FOR HELP	0.1	17	C XS	YI	+	APPRECIATIVE	
232	DE_U	04/26/83	T 2 I	O	THANKS FOR HELP (FROM CDE)	0.1	12	C XS	YE	+	PLEASED TO HELP	CALL FROM CDE
233	CDE	04/26/83	T 2 C	O	VAT ON A-FORMS	0.3	17	C XC	YC	0	QUESTIONING	VAT TAKEN OFF LATER
233	LO_U	04/26/83	T 2 I	O	VAT ON A-FORM	0.3	16	C XC	YC	+	HELPFUL	NORMALLY VAT INCLUDED
234	CDE	04/27/83	W 1	O	COST JUSTIFICATION	8.0	17	C XC	YN	0	NEUTRAL	DRAFT
235	CDE	04/29/83	T 2 C	O	COAL FEEDER PRICE	0.2	17	C XC	YC	0	NEUTRAL	MORE DETAILS OBTAINED
235	SE_FE	04/29/83	T 2 I	O	MORE DETAILS ON PRICE	0.2	15	C XC	YC	+	HELPFUL	INFORMATION GOOD
236	AM_A	04/29/83	T 2 I	O	MEETING ARRANGEMENTS	0.1	19	C XP	0	0	NEUTRAL	AM_A & M_A
236	CDE	04/29/83	T 2 C	O	MEETING ARRANGEMENT	0.1	17	C XP	0	0	NEUTRAL	16 MAY MTG M_A & AM_A
237	CDE	04/29/83	M 2	O	USE OF PAHL & BEITZ	0.5	17	C XP	YQ	0	QUESTIONING	
237	RM_U	04/29/83	M 2	O	USE OF PAHL & BEITZ	0.5	17	C XP	0	+	HELPFUL	USE ONLY WHERE IT HELPS
238	CDE	05/02/83	W 1	O	A-FORM & DRAFT	4.0	17	C XR	YN	0	NEUTRAL	PREP OF FORM & COST JUSTIF.
239	CDE	05/03/83	W 1	T	PLAN FOR DAY	0.9	17	C XP	YL	0	NEUTRAL	ON TRAIN
240	SL_A	05/03/83	W 2	O	HEATING/GAS REACTIONS	1.0	17	C XP	YS	0	NEUTRAL	SELLING HIS HOUSE
240	CDE	05/03/83	W 2	A	HEATING/GAS REACTIONS	1.0	17	C XP	YS	0	NEUTRAL	S1_P TO HELP

Figure 2-2 Sample Interchange Data Sheet

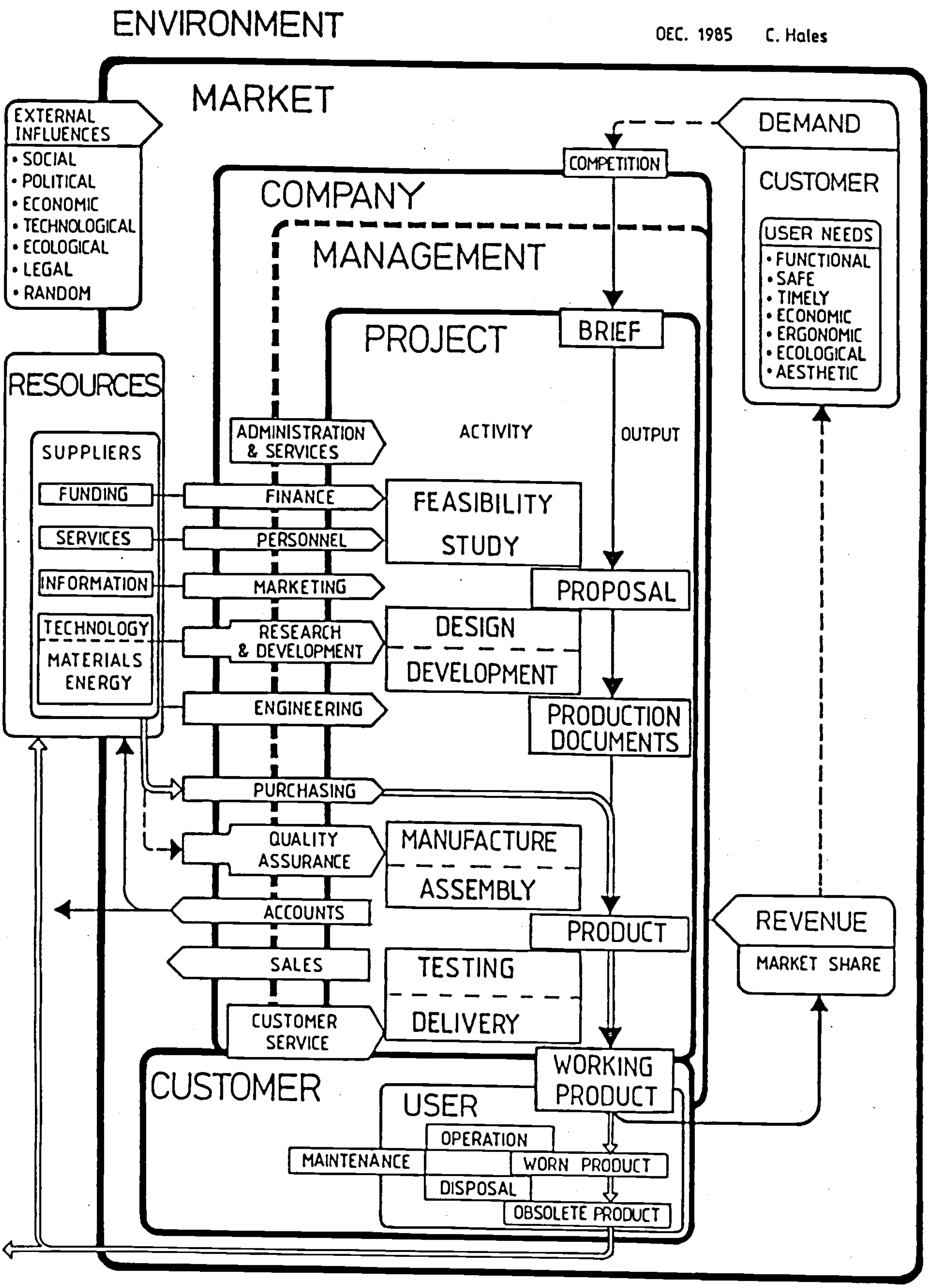


Figure 2-3 Context of Engineering Design

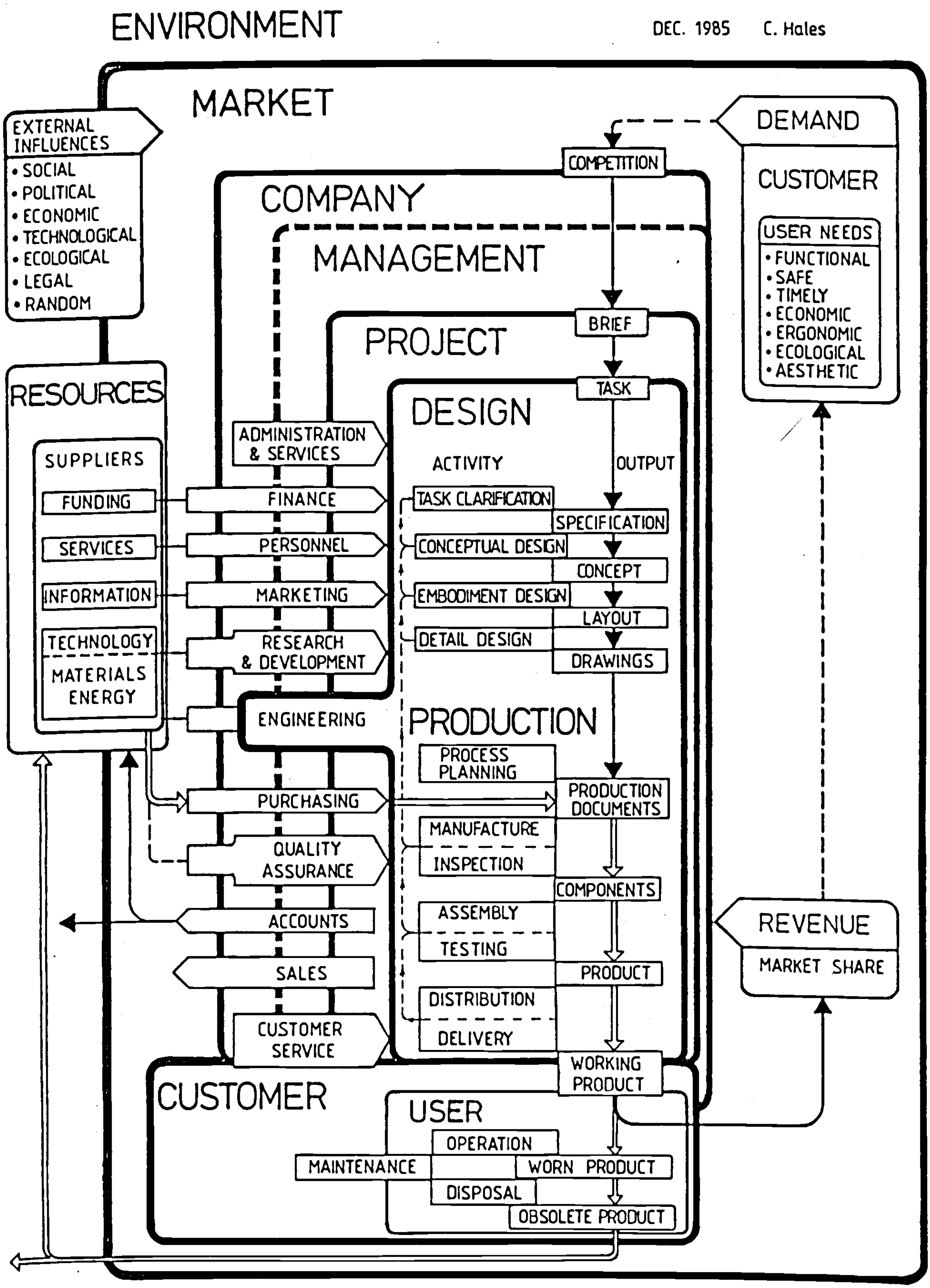


Figure 2-4 Engineering Design Process Set In Context

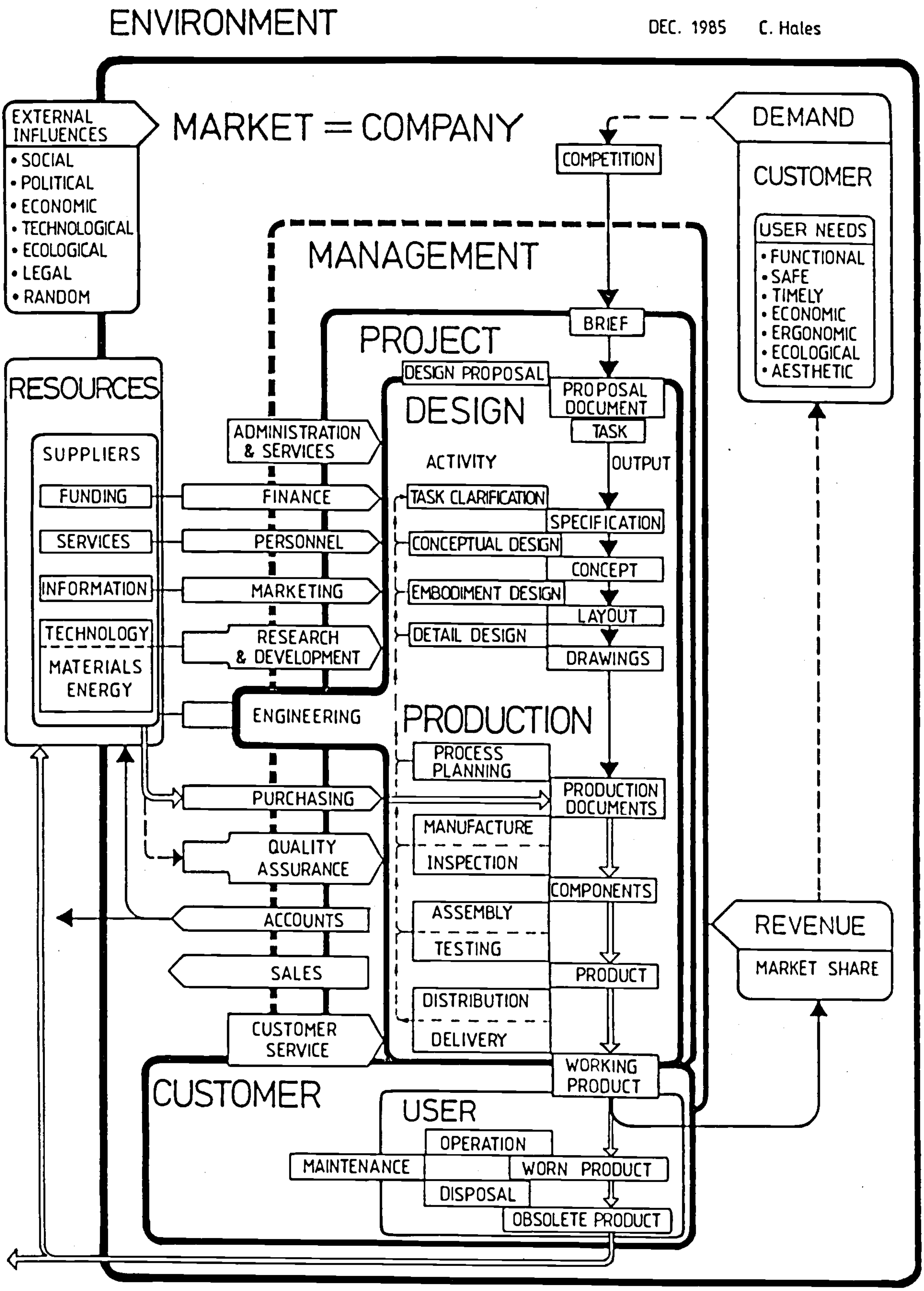


Figure 2-5 Engineering Design Process Set In Context of Gasifier Test Rig Project

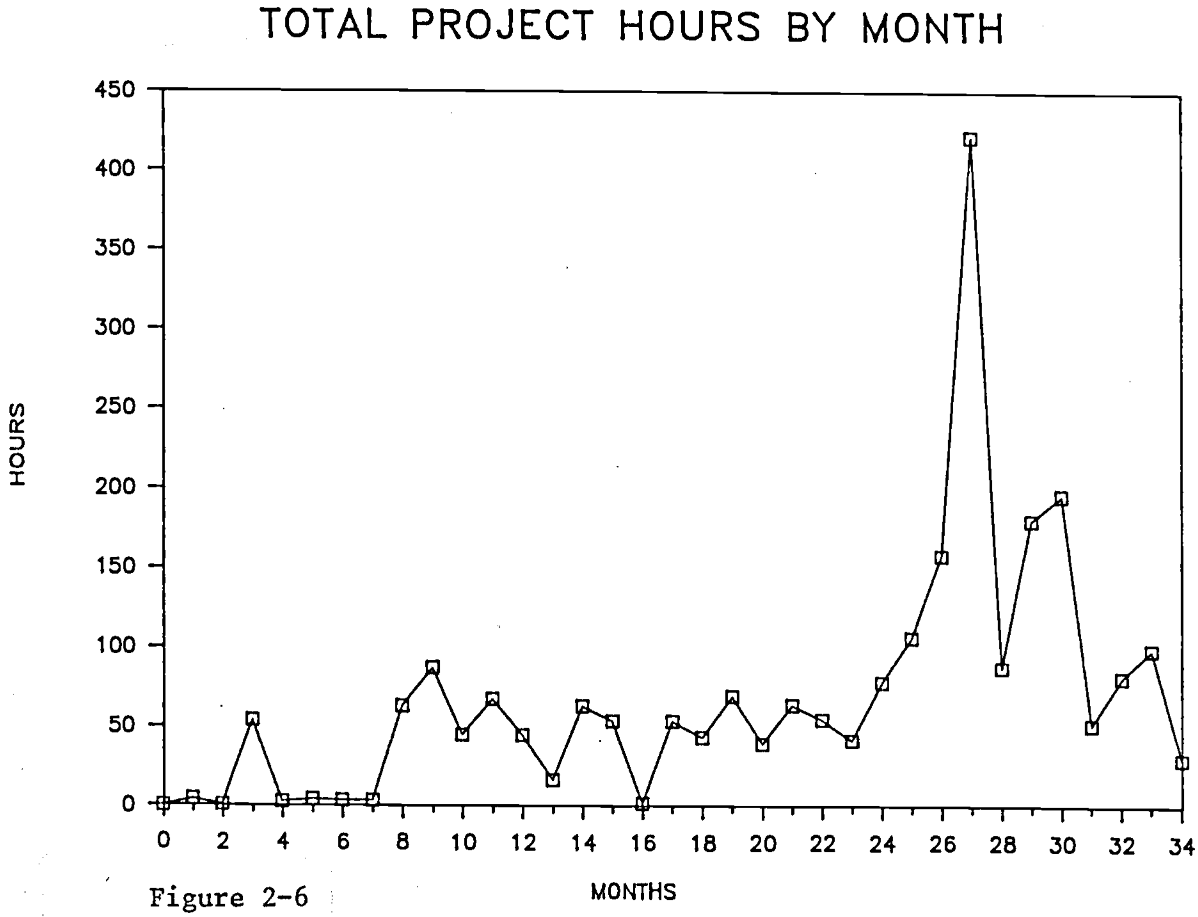
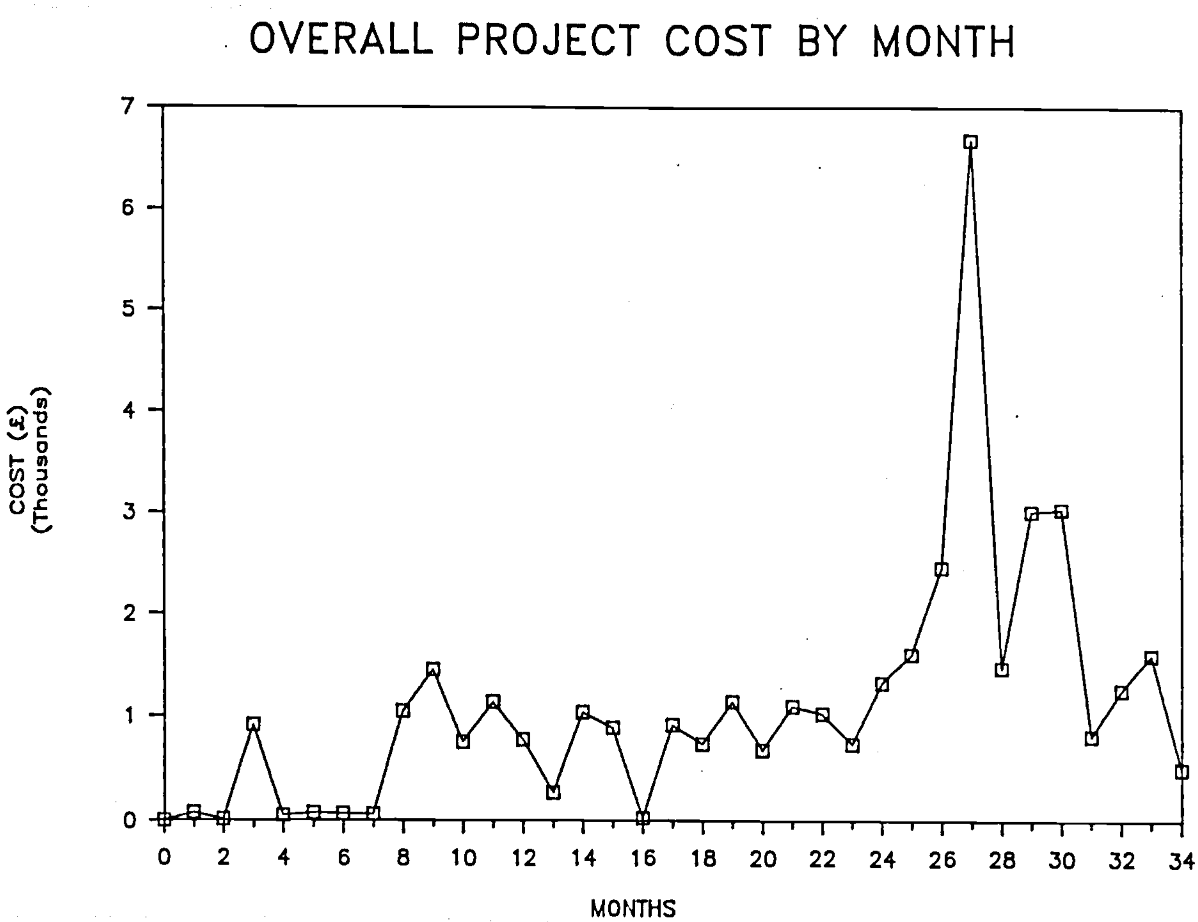


Figure 2-6

Figure 2-7



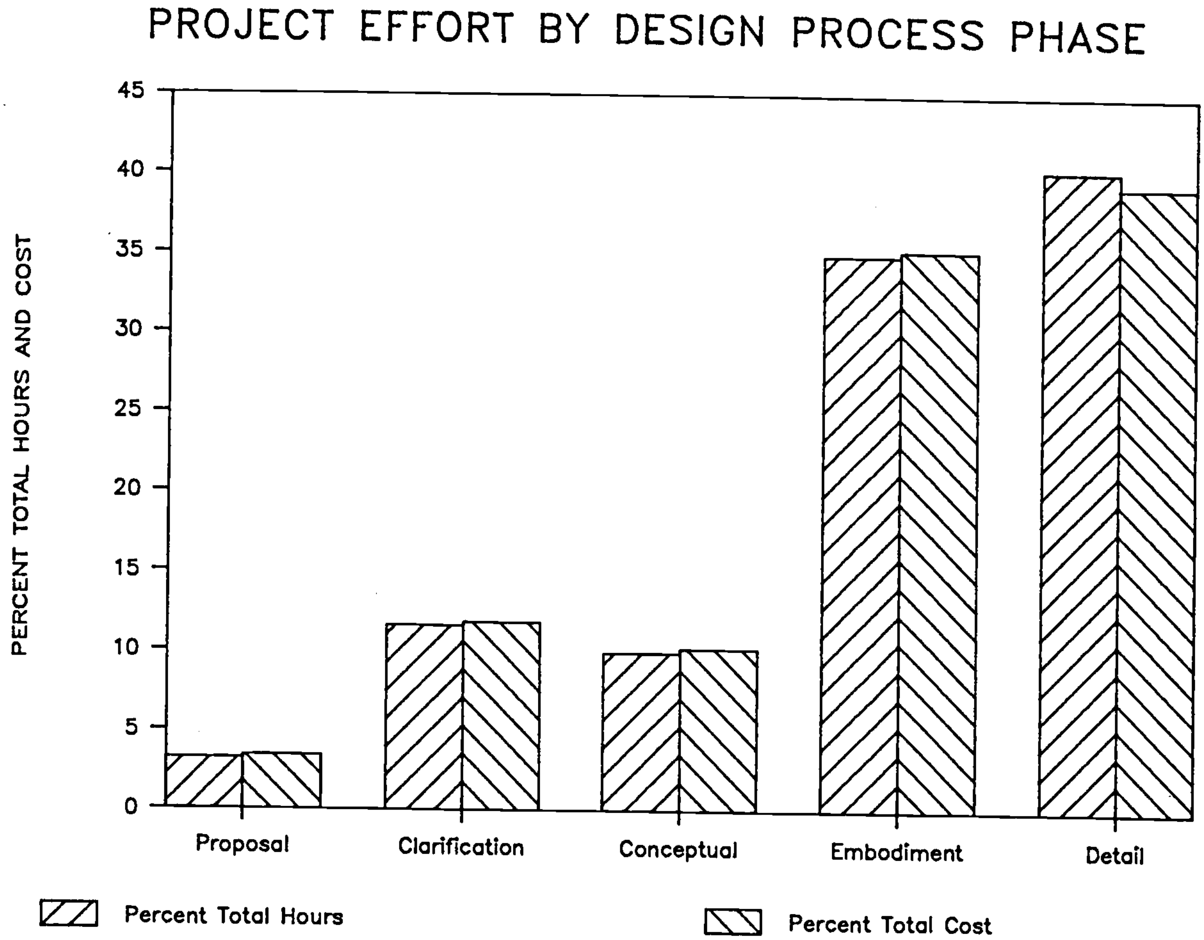
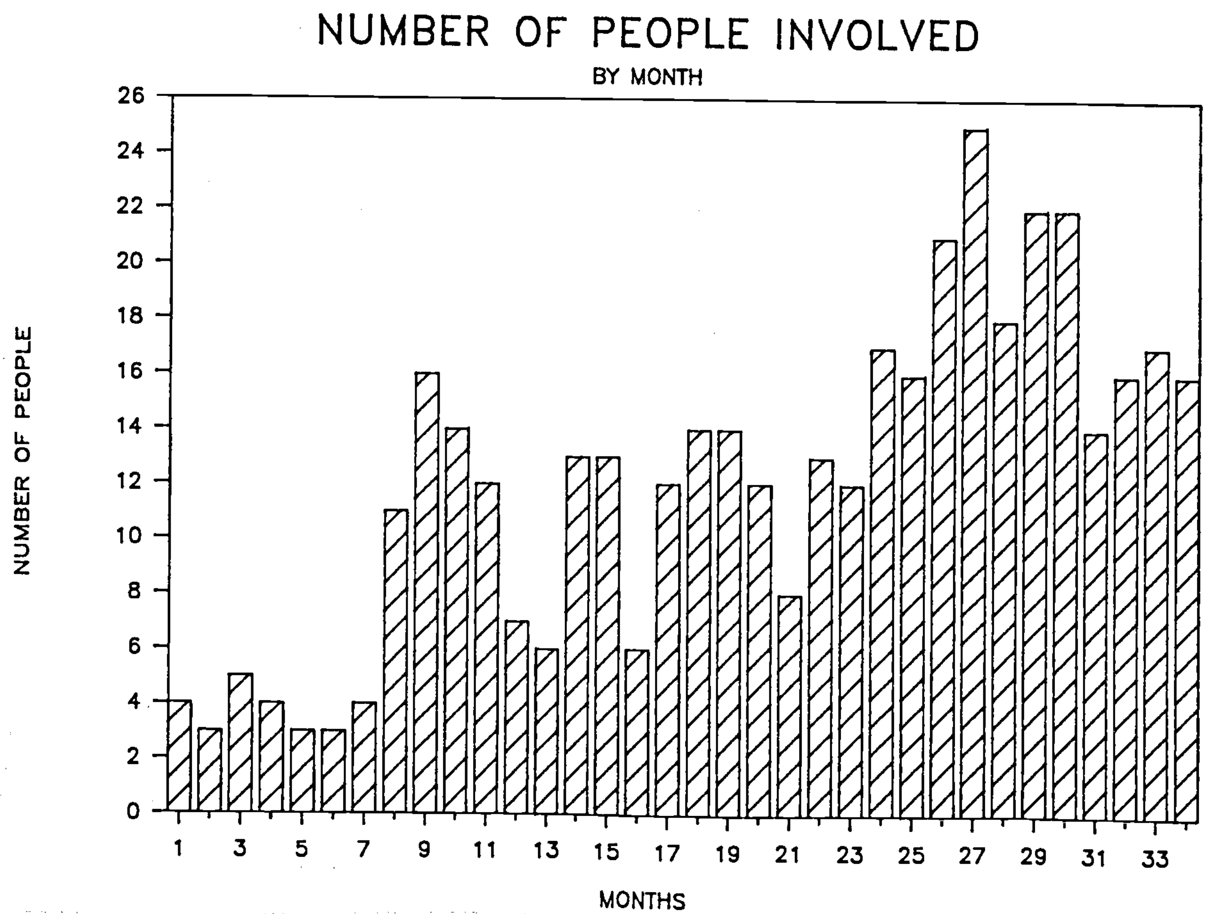


Figure 2-8

Figure 2-9



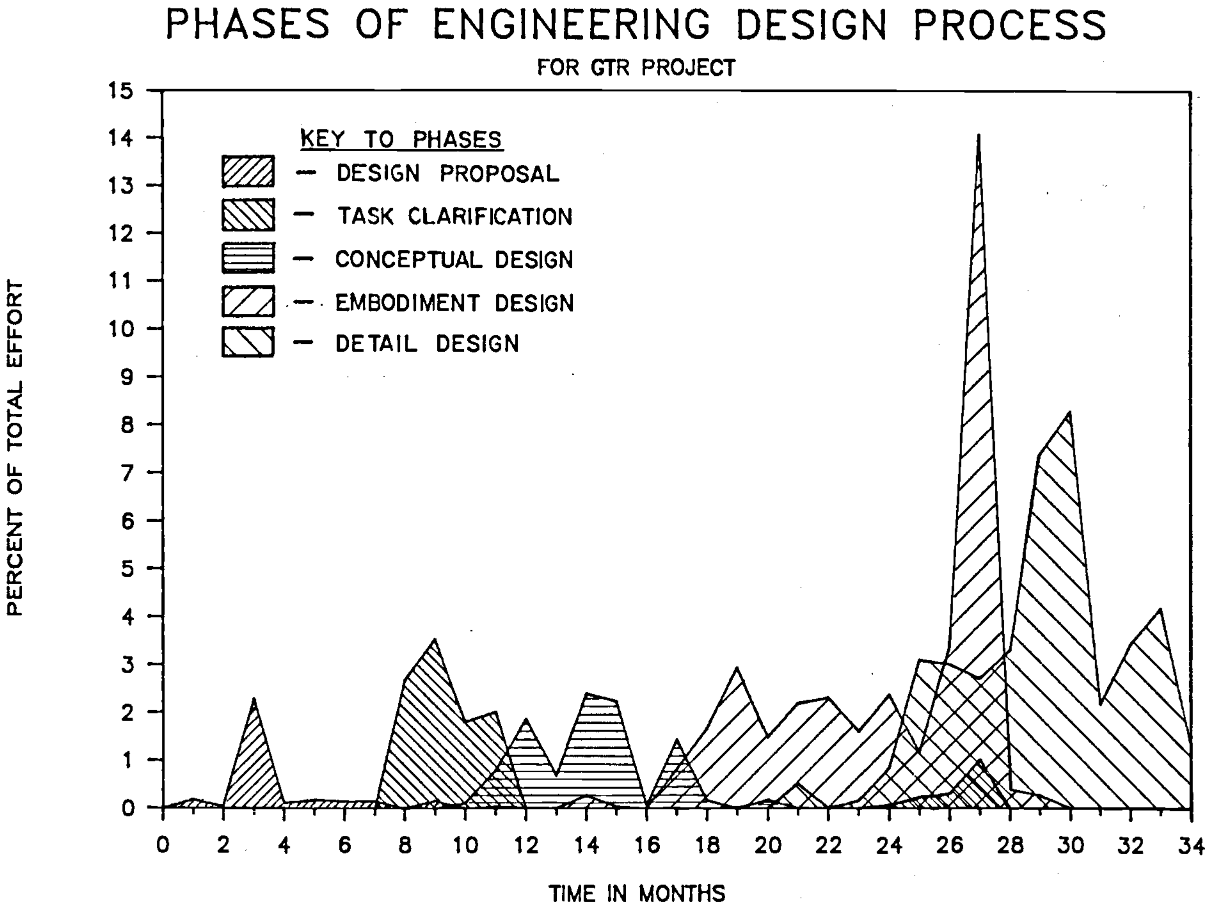
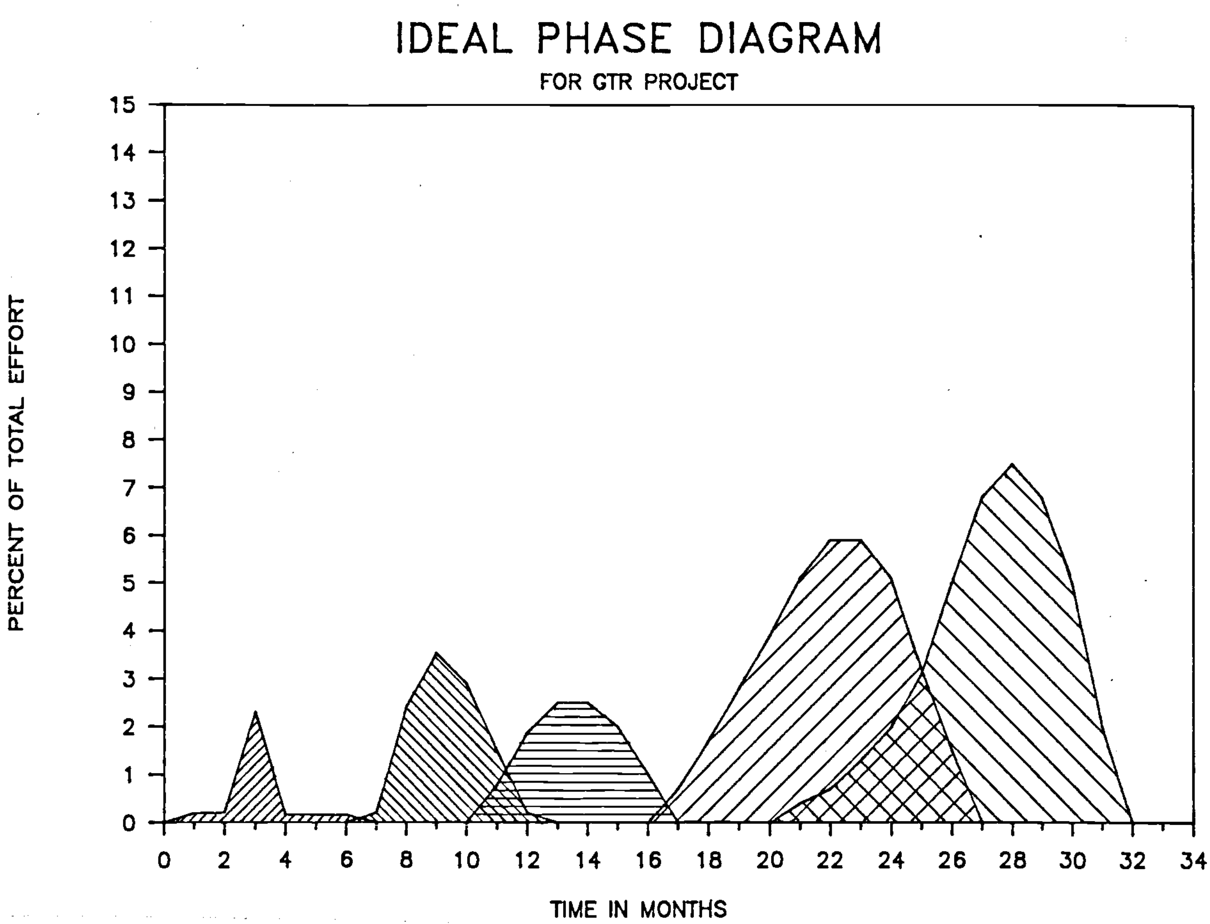


Figure 2-10

Figure 2-11



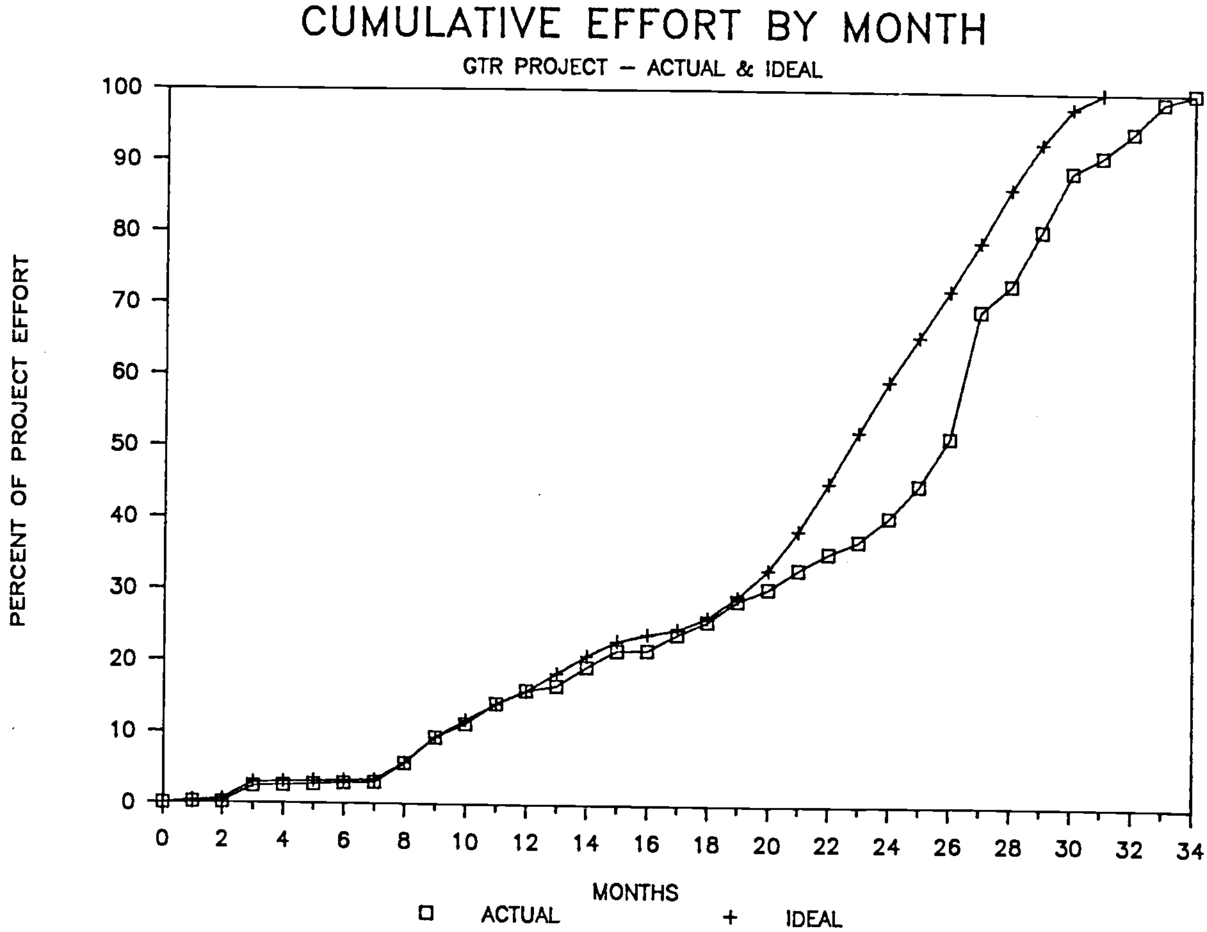
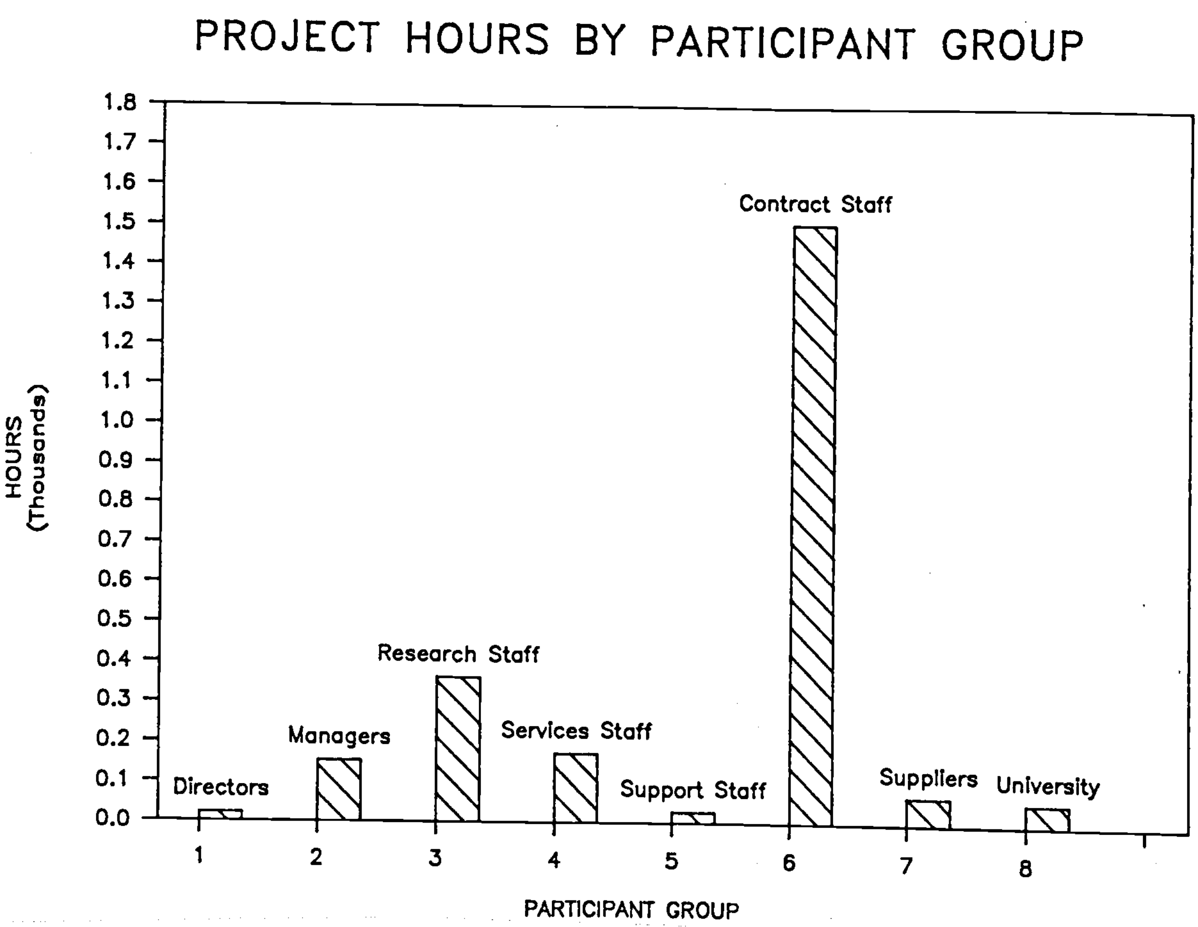


Figure 2-12

Figure 2-13



PROJECT GROUP	MONTH	YEAR 1												YEAR 2												YEAR 3										HOURS BY GROUP	% OF TOTAL HOURS
	PERSON	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34		
DIRECTORS	D_G																	0	1		0		3	2			0									6	0.2
	D_R											0	0		0				1	0			3	0												4	0.2
	AD1_R										1																			2	1			0		3	0.1
	AD2_R																						3	1			0	3	1		0			1		8	0.4
MANAGERS	M_A	1	0		1				2	0	1	1				2	0	2	1		0	2	4	2	4	1	0	0	2	3	1	0	1	0	2	32	1.3
	M_S								2	0		1									0				2	1		1	2	0	0	0		0	1	9	0.4
	AM_A	1	0	2	1	1	2	0	2	9	0	2	6	1	1	3	0	4	4	0	3	3	5	1	2		5	8	9	4	3	1	0	3	2	88	3.7
	AM_S									2	0	1				0				3	1				4	2	1	5	3	1	0	0	1	0	1	25	1.1
RESEARCH STAFF	SL_A	1		5	0			0	10	12	4	5	14	5	4	1	0	4	9	4	8	24	8	9	9	7	6	10	5	8	6	5	4	3	0	189	8.0
	SL_P																					3		1	3	1	1	1					0	5	2	17	0.7
	ASL_A									2	0				3	4	0	0	0	0	0		0		2	1		0	0	0	0	0	0	1	0	15	0.6
	R1_A								4	3	0	1		2		2				3	0	0			1	2	2	20	8	1	7	1	5	2	1	64	2.7
	R2_A								2	3	0	1						0	0	0			2		0	2	5	21	2	3	1	1	4	0	1	50	2.1
	S1_A			2					2		4	3			1	0		0	1			1			2						0					15	0.6
	S2_A															1												4	0		0					5	0.2
	S1_P									1						1		1						1	6	1					0					10	0.4
SERVICES STAFF	BPO_S								3	1	2					1							2	0		1	0	0		5	2	0		0	1	18	0.8
	SO_S								2	0						0																			0	2	0.1
	DE_S									3	1	2				2			2	5	1				2	12	7	17	2	6		11	9	8	1	89	3.7
	DR_S																								0	14	18	5	0	2	5	1	1	3	2	51	2.1
	G1_S																									4	0	3	0	0	0	0	3	3		13	0.6
REMOTE SUPPORT STAFF	C_G																		0				3	0												3	0.1
	QAO_H																			1								6								7	0.3
	SO_H																											3								3	0.1
	DE1_M																	0	8			0						1	4		0					14	0.6
	DE2_M																										1									1	0.0
CONTRACT STAFF	CDE	1	0	34	1	2	1	2	35	41	30	49	16	7	46	38	1	40	17	43	26	30	18	26	42	49	77	124	46	134	58	19	32	59	15	1159	48.9
	CCE														1				1				1			6	20	164		1						195	8.2
	CDD																			2	1									6	106	12	16	10	1	153	6.5
SPECIALIST SUPPLIERS	SE_FE													0	0											3	10		0	0						15	0.6
	SE1_VA																										0	11	2	1			3			17	0.7
	SE2_VA																											11		1			3			15	0.6
	SE_VE													1	3		0	0	0											0						5	0.2
	SE_FL									4	0		0		0					5	0						0	2	0	2	2		1		0	17	0.7
UNIVERSITY SUPPORT	RM_U			11		1	1	2	1	4	2	3	7		1					1			5	0	0		0	1		0	0					40	1.7
	LO_U									1			1		0			2		1					1		4	1								10	0.4
	DE_U														3																3					6	0.3
MONTHLY TOTALS		4	1	54	3	4	3	3	63	87	45	67	45	16	63	54	1	53	43	69	39	64	55	41	78	106	158	422	87	181	196	52	81	99	30	2369	100
% OF TOTAL HOURS		0.2	0.0	2.3	0.1	0.2	0.1	0.1	2.7	3.7	1.9	2.8	1.9	0.7	2.7	2.3	0.1	2.3	1.8	2.9	1.7	2.7	2.3	1.7	3.3	4.5	6.7	17.8	3.7	7.6	8.3	2.2	3.4	4.2	1.3	100	
CUMULATIVE HOURS		4	5	59	61	65	69	72	135	222	267	335	379	396	458	512	513	567	610	679	718	782	837	878	956	1063	1221	1643	1730	1911	2107	2158	2240	2339	2369		
CUMULATIVE %		0.2	0.2	2.5	2.6	2.8	2.9	3.0	5.7	9.4	11.3	14.1	16.0	16.7	19.4	21.6	21.7	23.9	25.8	28.7	30.3	33.0	35.3	37.1	40.4	44.9	51.5	69.4	73.0	80.7	89.0	91.1	94.6	98.7	100		

All Hours and Totals Rounded to Nearest Integer

Figure 2-14 Work Effort of Each Participant by Month

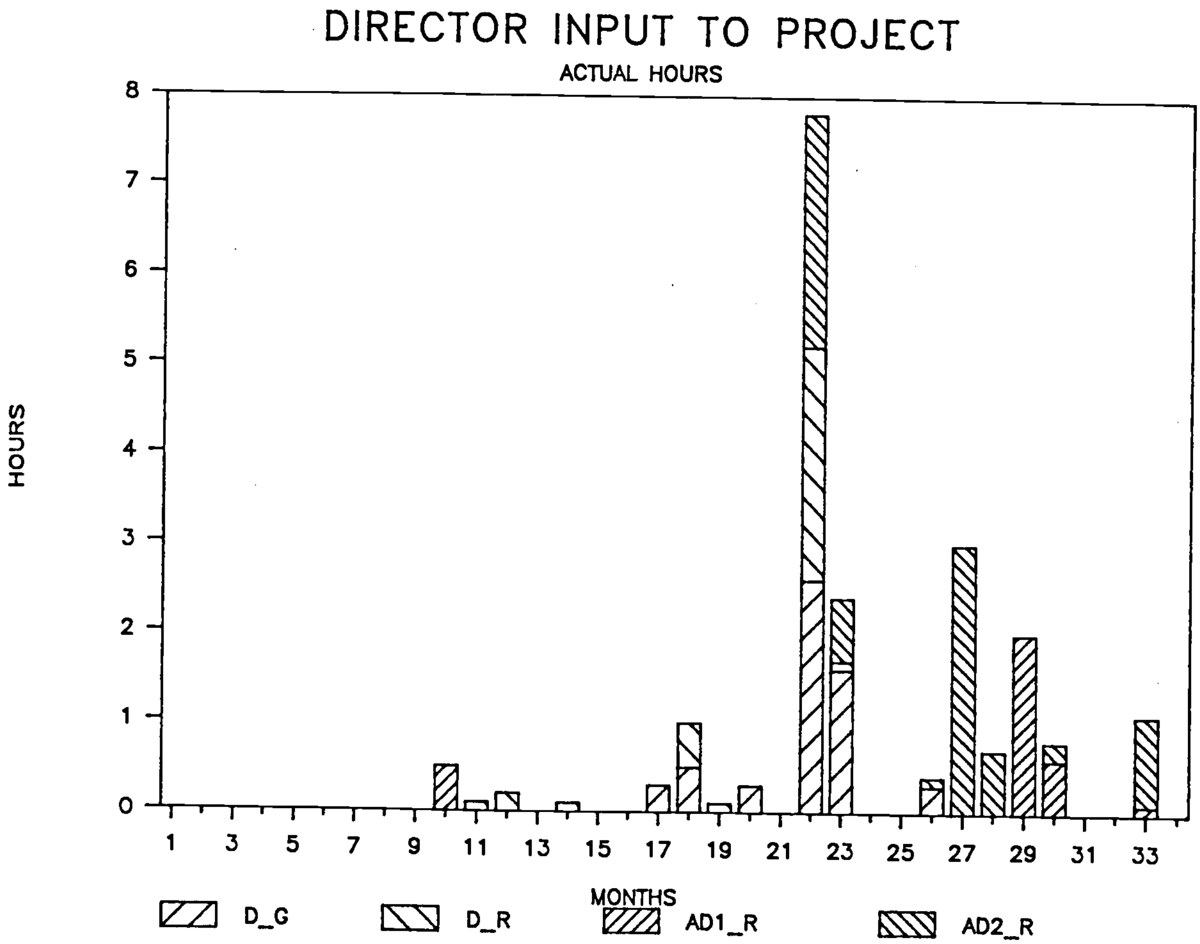
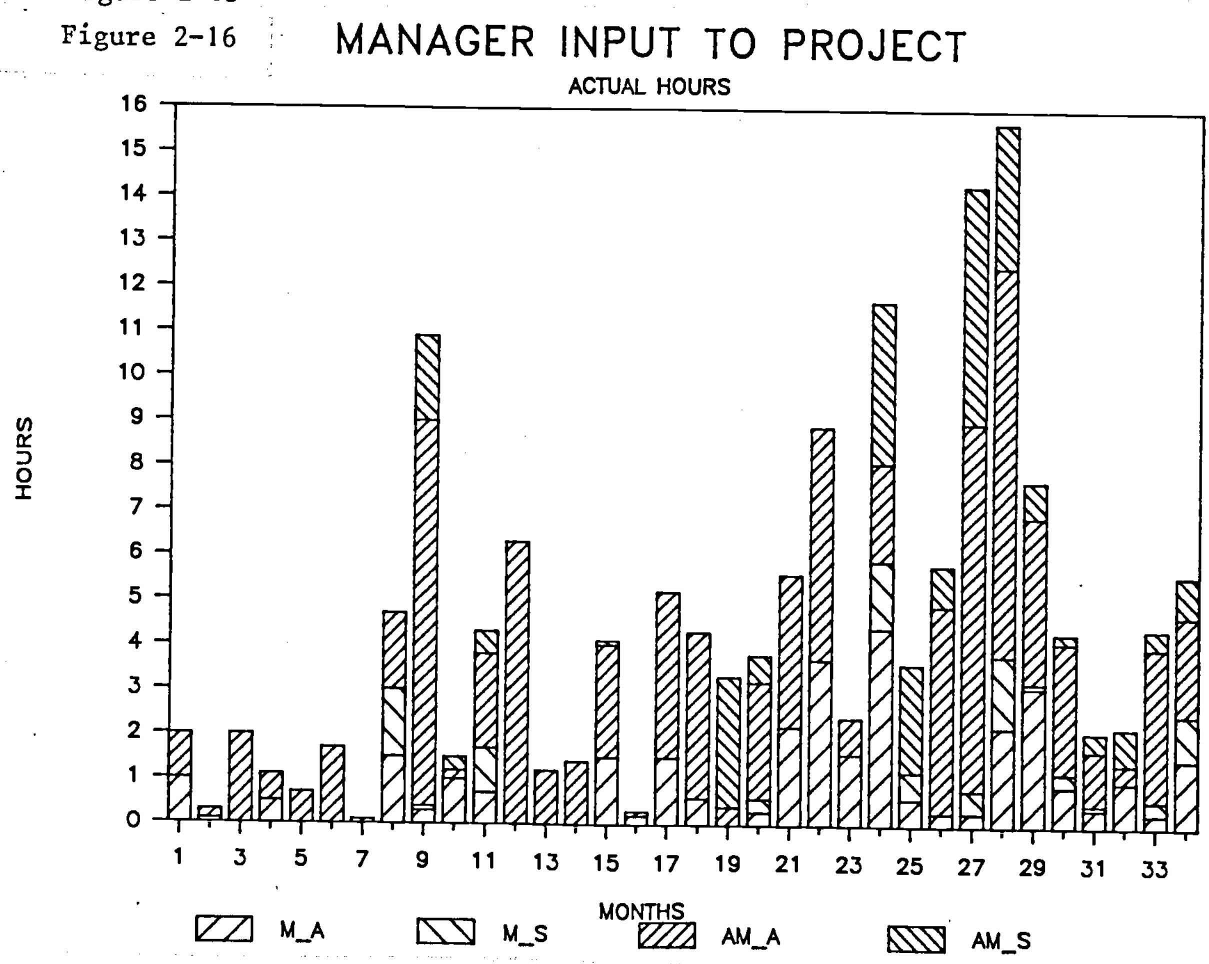


Figure 2-15

Figure 2-16



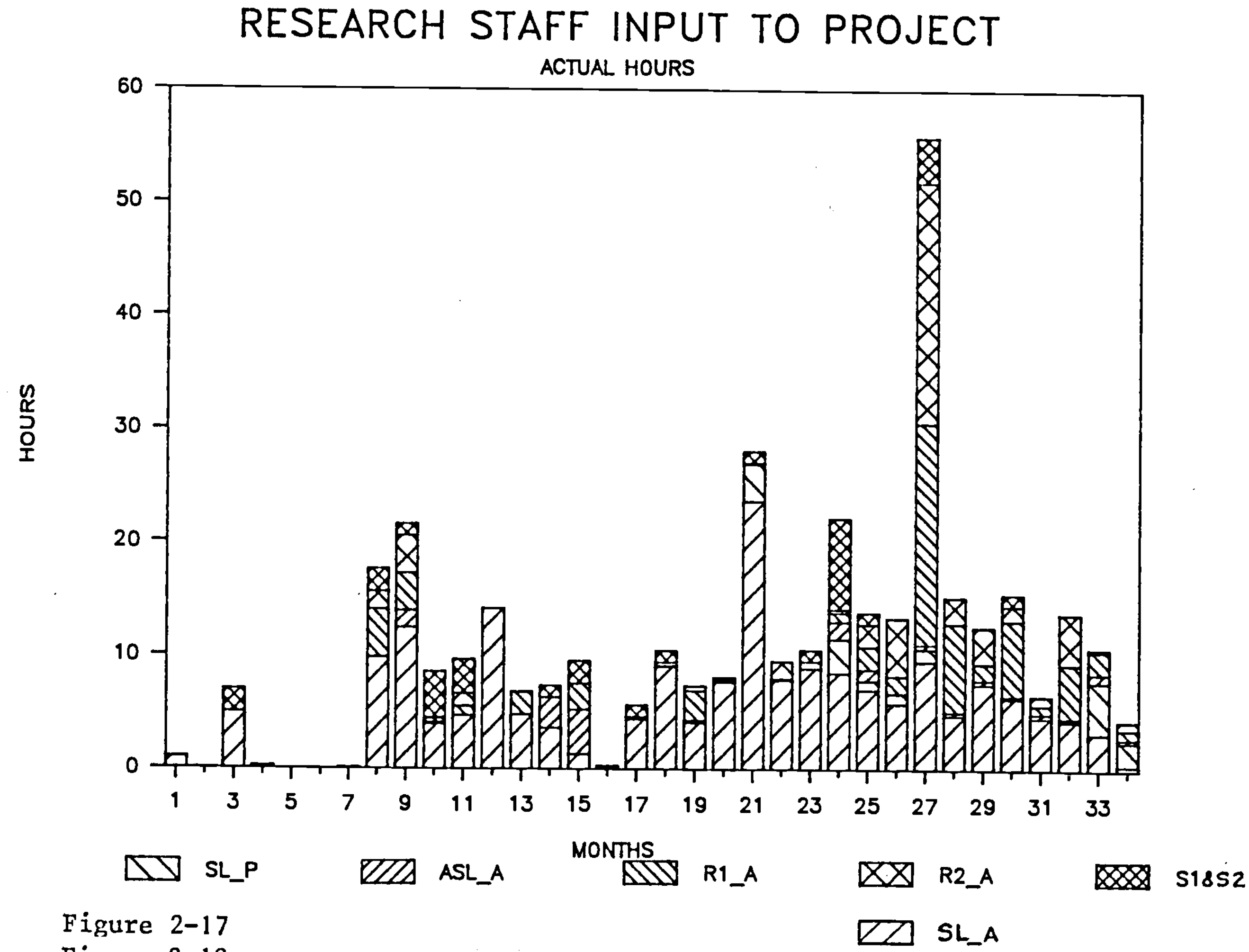
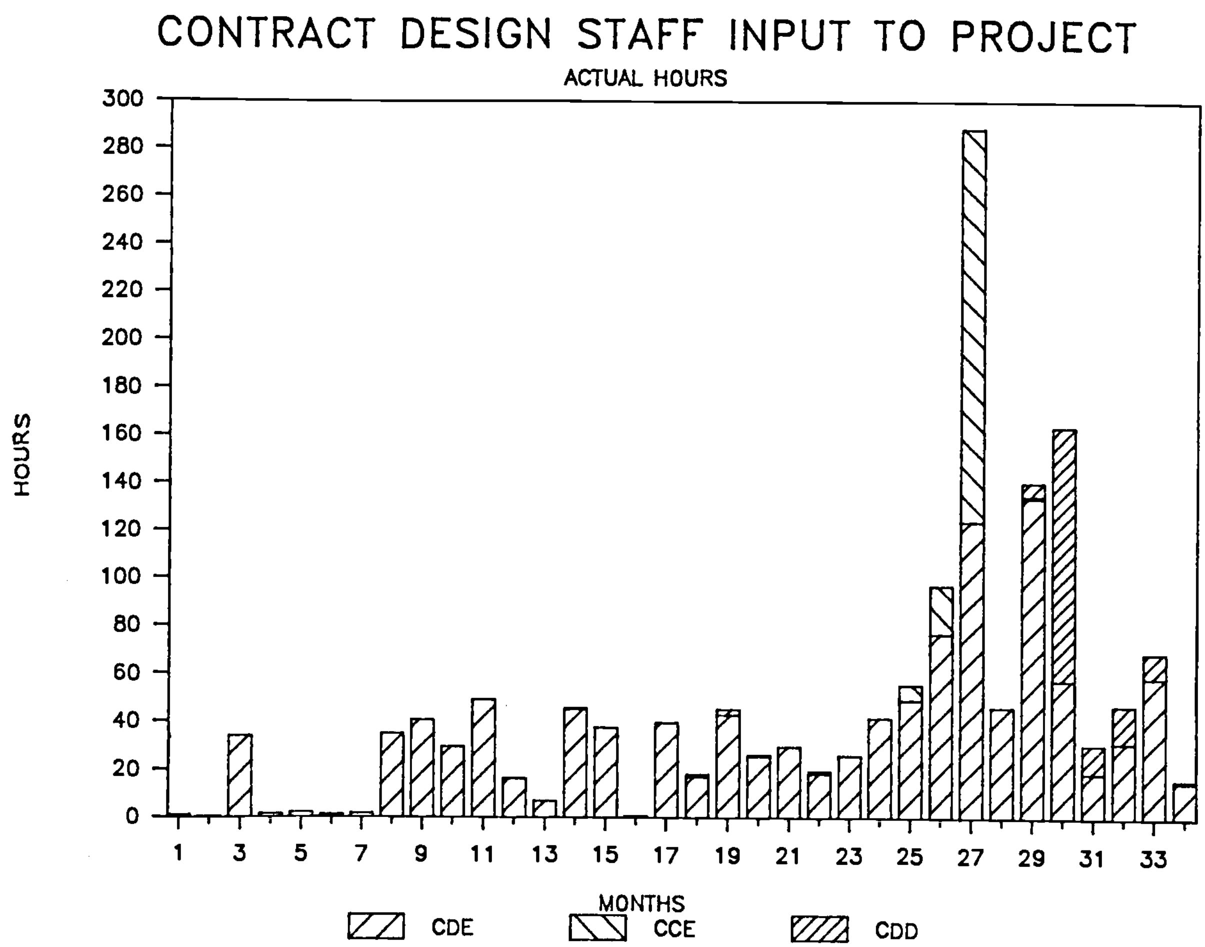


Figure 2-17
Figure 2-18



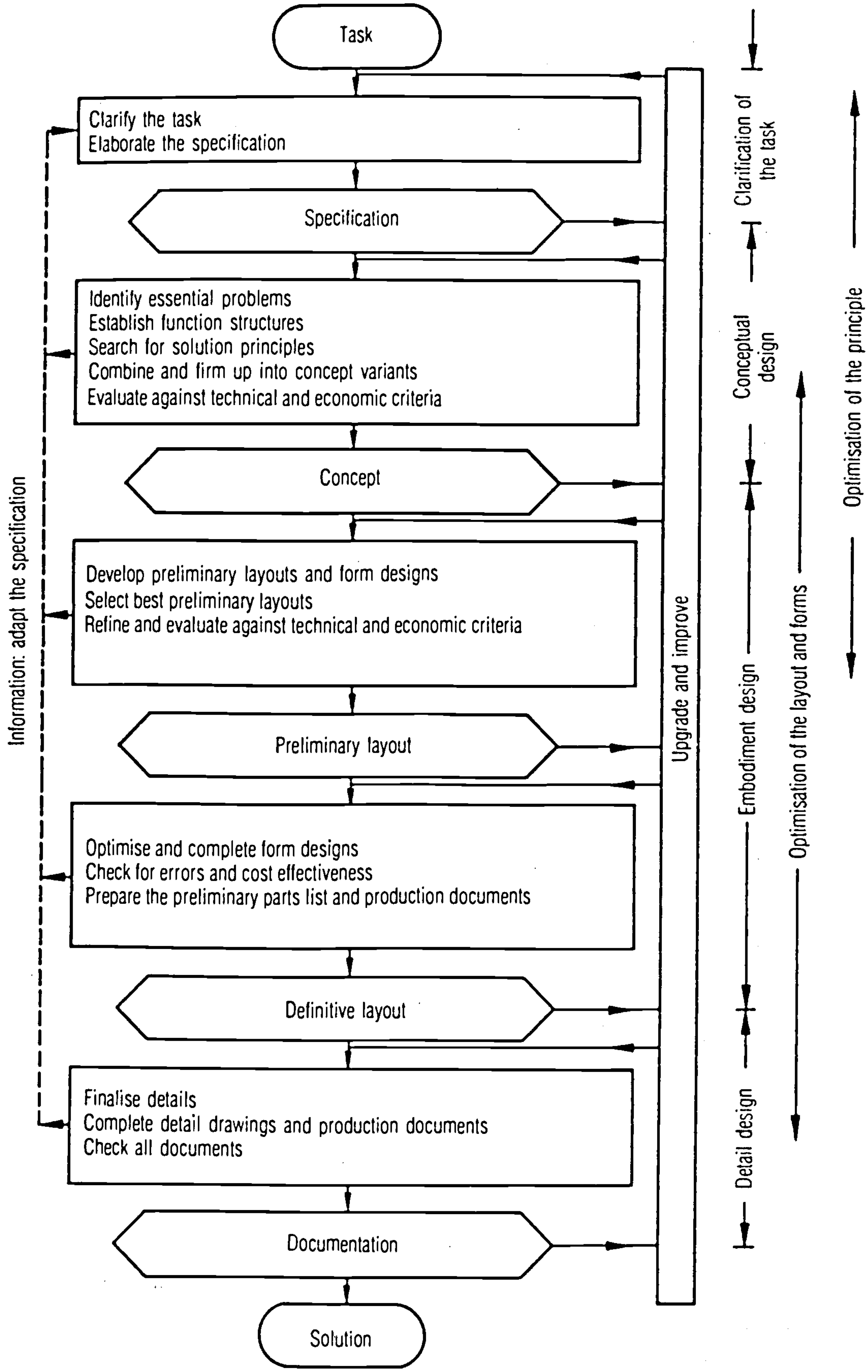


Figure 2-19 Steps of the design process
from: G.Pahl & W.Beitz, Engineering Design. (Ref.B48, p.41)

Methods and aids / Steps

● main
○ supporting

CODE	Methods and aids	NO.	Product planning Selecting the task	Clarifying the task Elaborating the specification	Abstracting to identify essential problems	Establishing function structures	Searching for solution principles	Combining solution principles	Selecting suitable combinations	Firming up into concept variants	Evaluating concept variants
MA	Trend studies Market analysis	01	●	○							
SP	Specification	02		●	○						
AP	Abstraction	03			●	○					
DS/FS	Black box representation Function structure	04			○	●					
LS	Literature search	05	○	○			●			○	
NS	Analysis: natural systems	06				○	●				
KS	Analysis: known solutions	07		○		●	●	●		○	
AS	Analysis: mathematical - physical relationships	08				●	●				
ES	Tests, measurements	09					●	●		●	
BS/TS	Brainstorming Synectics	10	○				●				
SS	Systematic study of physical processes	11					●				
CS	Classification schemes	12					●	●			
DC	Design catalogues	13					●	●			
SK/II	Sketches Intuitive improvements	14					○	●		●	
SL	Selection procedures	15				○	○	●	●	○	
EM	Evaluation methods	16									●
VA	Value analysis	17							○		○

Figure 2-20 Correlation of 'methods and aids' with the steps of the Conceptual Design phase, showing codes used for Gasifier Test Rig Project. Table taken from G.Pahl & W.Beitz, Engineering Design. (Ref. B48, p.410).

CODE	Methods and aids (● main, ○ supporting) \ Steps	NO.	Identifying embodiment-determining requirements	Specifying spatial constraints	Identifying main function carriers	Developing preliminary layouts of main function carriers	Selecting suitable preliminary layouts	Developing preliminary layouts for the remaining main function carriers	Searching for solutions to auxiliary function carriers	Developing detailed layouts of main function carriers	Developing detailed layouts of auxiliary function carriers	Checking and refining overall layouts	Evaluating	Preparing definitive layout	Checking for errors and disturbing factors	Preparing preliminary parts list and production documents
SP	Specification	02	●	●								○	○		○	
FS	Function structure	04			●											
SC	Solution concept	18	●	●	●	○		○								
—	Solution methods during conceptual phase	19							●							
CK	Checklist	20				●	○	●		●	●	●			○	○
OG	Basic rules: simplicity, clarity, safety	21				●	○	●	○	●	●	○	○	○	○	○
DG	Principles Force transmission Division of tasks Self-help Stability and planned instability	22			●	●		●	○	○						
	Guidelines Durability (Stress) Deformation Stability Resonance Expansion Creep Relaxation Corrosion Wear Ergonomics Standards Production Assembly Quality control Transport Operation Maintenance					○		○		●	●	○		●		●
SL	Selection procedures	15					●		●							
FT/RR	Fault-tree analysis Risk reduction	23										○			●	
EM	Evaluation methods	16							○				●			

Figure 2-21 Correlation of 'methods and aids' with the steps of the Embodiment Design phase, showing codes used for Gasifier Test Rig Project. Table taken from G.Pahl & W.Beitz, Engineering Design. (Ref. B48, p.411).

Steps		
Clarifying the task		10 %
Abstracting to identify essential problems		1 %
Establishing function structures		4 %
Searching for solutions	Intuitive e.g. brainstorming	4 %
	discursive	15 %
Combining solution principles and selecting qualitatively		3 %
Firming up into concept variants	Preliminary calculations	25 %
	Preliminary layouts	35 %
Evaluating concept variants		3 %
		100 %

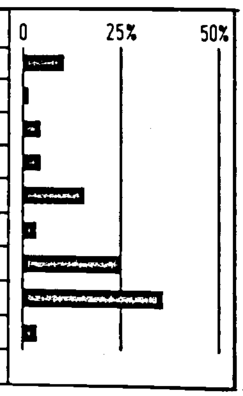
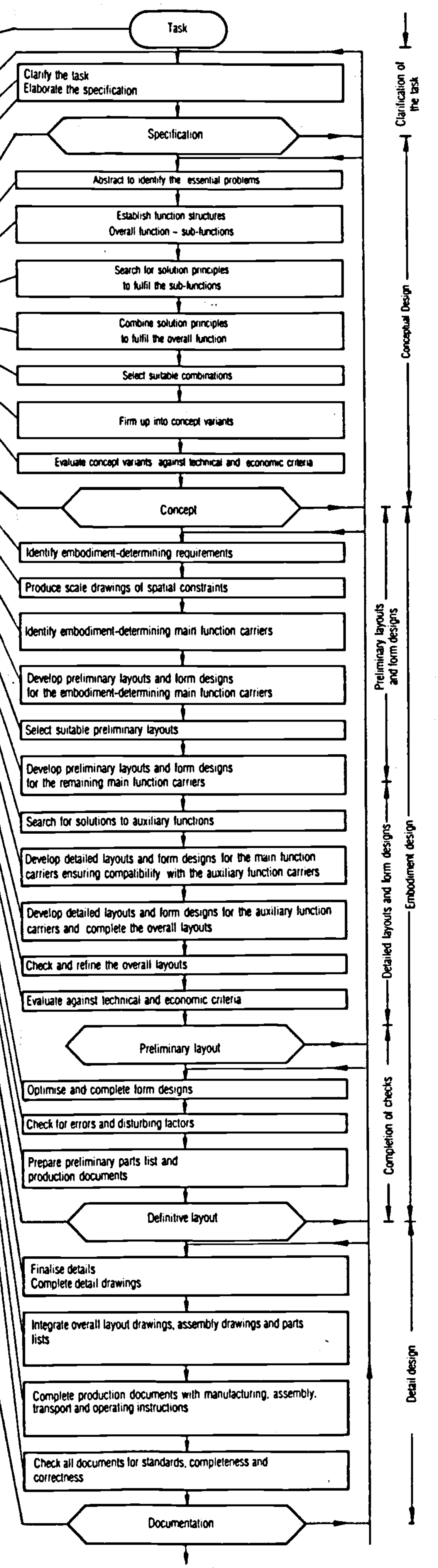


Figure 2-22 Estimate of percentage breakdown of design effort in hours spent on Conceptual Design phase from G.Pahl & W.Beitz, Engineering Design. (Ref. B48, p.413).

PHASE	CODE		OBSERVED STEPS
Design Proposal	P	PP	Product Planning
		ST	Selecting Task
		X	Remainder
Task Clarification	T	CP	Clarifying Problem
		SP	Specification Prep.
		X	Remainder
Conceptual Design	C	AP	Abstract Problem
		FS	Function Structures
		SS	Search for Solutions
		CP	Combining Principles
		SC	Selecting Combinations
		CV	Concept Variants
		EV	Evaluation of Variants
		X	Remainder
Embodiment Design	E	RC	Review Concept
		SC	Spatial Constraints
		FC	Identify Function Carriers
		PL	Preliminary Layouts
		SL	Select Layouts
		ML	Main Layouts
		SS	Search for Solutions
		DL	Detailed Layouts
		AL	Auxiliary Layouts
		CL	Check Layouts
		EL	Evaluate Layouts
		OD	Optimise Form Designs
		RD	Review Design
		PD	Prepare Documents
		X	Remainder
Detail Design	D	FD	Finish Drawings
		ID	Integrate Drawings
		PD	Prep. Final Documents
		CD	Check Documentation
		X	Remainder

DESIGN PROCESS MODEL



ADDITIONAL ACTIVITIES OBSERVED	
XP	Work Planning
XI	Information Retrieval
XC	Cost Estimating
XR	Reporting/Reviewing
XH	Helping Others
XS	Social Contact

Figure 2-23 Codes Used for Design Process 'Steps' & 'Activities' During Gasifier Test Rig Project (Model from G.Pahl & W.Beitz: Engineering Design. Ref. B48)

ACTIVITIES & TECHNIQUES - PROPOSAL PHASE

PROPOSAL PHASE — ACTIVITIES / TECHNIQUES		P & B: PROD PLAN 1.01	P & B: DEFN TASK 1.02	GENERAL: WORK PLAN 1.15	GENERAL: INFO RETR 1.16	GENERAL: COST ESTM 1.17	GENERAL: REPORT REVIEW 1.18	GENERAL: MISC HELP 1.19	GENERAL: SOCIAL CHAT 1.20	TOTAL HOURS	% OF HOURS FOR PHASE
P&B: CONCEPTUAL DESIGN											
Market Analysis/Study	1									0	0
Requirements List/Spec	2									0	0
Abstraction of Problem	3									0	0
Function Structure	4									0	0
Literature Search	5									0	0
Analysis:Natural Systs	6									0	0
Analysis:Known Systems	7									0	0
Analysis:Maths/Physics	8									0	0
Tests/Experiments	9									0	0
Brainstorm/Synectics	10									0	0
Study Physical Process	11									0	0
Classification Schemes	12									0	0
Design Catalogues	13									0	0
Sketches/Intuitive Mod	14									0	0
Selection Procedures	15									0	0
Evaluation Techniques	16									0	0
Value Analysis	17									0	0
P&B: EMBODIMENT DESIGN											
Solution Concept	18									0	0
Concept Phase Methods	19	See	--	No.5	--	to	No. 14	--	above.	---	---
Checklists	20									0	0
Overall Guidelines	21									0	0
Detail Guidelines	22									0	0
Fault-tree Analysis	23									0	0
P&B: DETAIL DESIGN											
Detail Drawings	24									0	0
Check All Drawings	25									0	0
WORKING											
Making Lists	26									0	0
Estimating Costs	27					1				1	1
Calculating	28									0	0
Scheduling:Gantt Chart	29	0								0	0
Using Filing System	30									0	0
COMMUNICATING											
Questioning People	31	0	4		6					10	16
Presenting Viewpoints	32						29			29	45
Negotiating Agreements	33	3	0	0		1	1			6	9
Reviewing / Reporting	34	2								2	2
MOTIVATING											
Becoming Involved	35									0	0
Injecting Enthusiasm	36	8					9			17	26
Adding Humour	37									0	0
Team Building	38			0						0	0
NOT CLASSIFIED	40									0	0
TOTAL HOURS FOR ACTIVITY		13	4	0	6	2	39	0	0	64	100
% OF TOTAL HOURS FOR PHASE		20	6	1	9	3	61	0	0	100	

All Hours and Totals Rounded to Nearest Integer

Figure 2-24

ACTIVITIES & TECHNIQUES - TASK CLARIFICATION PHASE

CLARIFICATION PHASE		P & B		GENERAL							
TECHNIQUES \ ACTIVITIES		CLAR PROB 2.01	PREP SPEC 2.02	WORK PLAN 2.15	INFO RETR 2.16	COST ESTM 2.17	REPORT REVIEW 2.18	MISC HELP 2.19	SOCIAL CHAT 2.20	TOTAL HOURS	% OF HOURS FOR PHASE
P&B: CONCEPTUAL DESIGN											
Market Analysis/Study	1									0	0
Requirements List/Spec	2	10	40	1						51	20
Abstraction of Problem	3	7								7	3
Function Structure	4									0	0
Literature Search	5									0	0
Analysis:Natural Systs	6									0	0
Analysis:Known Systems	7									0	0
Analysis:Maths/Physics	8									0	0
Tests/Experiments	9									0	0
Brainstorm/Synectics	10	16								16	6
Study Physical Process	11									0	0
Classification Schemes	12									0	0
Design Catalogues	13									0	0
Sketches/Intuitive Mod	14									0	0
Selection Procedures	15									0	0
Evaluation Techniques	16									0	0
Value Analysis	17									0	0
P&B:EMBODIMENT DESIGN											
Solution Concept	18									0	0
Concept Phase Methods	19	See	--	No.5	--	to -	No.14	--	above.	---	---
Checklists	20	9								9	3
Overall Guidelines	21									0	0
Detail Guidelines	22									0	0
Fault-tree Analysis	23									0	0
P&B: DETAIL DESIGN											
Detail Drawings	24									0	0
Check All Drawings	25									0	0
WORKING											
Making Lists	26	15	3	6	1					24	9
Estimating Costs	27	5	0	1		5				11	4
Calculating	28	6								6	2
Scheduling:Gantt Chart	29		2	1						3	1
Using Filing System	30									0	0
COMMUNICATING											
Questioning People	31	23			1		1			24	9
Presenting Viewpoints	32						0			0	0
Negotiating Agreements	33	2		1	7	0	0			11	4
Reviewing / Reporting	34	7	0	2			38		1	48	19
MOTIVATING											
Becoming Involved	35	9		1					1	11	4
Injecting Enthusiasm	36	4	2	6	1		1		3	17	7
Adding Humour	37									0	0
Team Building	38	3		7			0			10	4
NOT CLASSIFIED	40	8	0	1	2		0.1		0	11	4
TOTAL HOURS FOR ACTIVITY		122	48	26	11	6	41	0	5	258	100
% OF TOTAL HOURS FOR PHASE		47	18	10	4	2	16	0	2	100	

All Hours and Totals Rounded to Nearest Integer

Figure 2-25

ACTIVITIES & TECHNIQUES - CONCEPTUAL DESIGN PHASE

CONCEPTUAL PHASE	PAHL & BEITZ							GENERAL						TOTAL HOURS	% OF HOURS FOR PHASE
ACTIVITIES / TECHNIQUES	ABST PROB 3.01	FUNC STRU 3.02	FIND SOLN 3.03	COMB PRIN 3.04	SLCT COMB 3.05	CONC VARS 3.06	EVAL VARS 3.07	WORK PLAN 3.15	INFO RETR 3.16	COST ESTM 3.17	REPORT REVIEW 3.18	MISC HELP 3.19	SOCIAL CHAT 3.20		
P&B: CONCEPTUAL DESIGN															
Market Analysis/Study 1														0	0
Requirements List/Spec 2											0			0	0
Abstraction of Problem 3														0	0
Function Structure 4		2												2	1
Literature Search 5														0	0
Analysis:Natural Systs 6														0	0
Analysis:Known Systems 7														0	0
Analysis:Maths/Physics 8														0	0
Tests/Experiments 9			2											2	1
Brainstorm/Synectics 10														0	0
Study Physical Process 11														0	0
Classification Schemes 12		6												6	3
Design Catalogues 13														0	0
Sketches/Intuitive Mod 14			22											22	10
Selection Procedures 15				10	4									14	6
Evaluation Techniques 16														0	0
Value Analysis 17														0	0
P&B: EMBODIMENT DESIGN															
Solution Concept 18														0	0
Concept Phase Methods 19	--	--	See	--	No.5	--	to	--	14	--	above.	--	----	---	---
Checklists 20														0	0
Overall Guidelines 21														0	0
Detail Guidelines 22														0	0
Fault-tree Analysis 23														0	0
P&B: DETAIL DESIGN															
Detail Drawings 24														0	0
Check All Drawings 25														0	0
WORKING															
Making Lists 26								4						4	2
Estimating Costs 27										33				33	15
Calculating 28							2	2		2				6	3
Scheduling:Gantt Chart 29														0	0
Using Filing System 30														0	0
COMMUNICATING															
Questioning People 31			1					1	10	0				12	6
Presenting Viewpoints 32										2	14		0	16	7
Negotiating Agreements 33								0		16	6			23	11
Reviewing / Reporting 34									1	1	51			53	25
MOTIVATING															
Becoming Involved 35								0		0			7	8	4
Injecting Enthusiasm 36									4		1		0	5	2
Adding Humour 37														0	0
Team Building 38										2				2	1
NOT CLASSIFIED 40								1		0			4	5	2
TOTAL HOURS FOR ACTIVITY	0	8	25	10	4	0	2	8	15	56	72	0	12	211	100
% OF TOTAL HOURS FOR PHASE	0	4	12	5	2	0	1	4	7	27	34	0	6	100	

All Hours and Totals Rounded to Nearest Integer

Figure 2-26

ACTIVITIES & TECHNIQUES - EMBODIMENT DESIGN PHASE

EMBODIMENT PHASE	PAHL AND BEITZ														GENERAL						TOTAL HOURS	% OF HOURS FOR PHASE
ACTIVITIES / TECHNIQUES	CONC REVW 4.01	DESN CONS 4.02	FUNC CARR 4.03	PREL LAYT 4.04	LAYT SELN 4.05	MAIN LAYT 4.06	FIND SOLN 4.07	DETL LAYT 4.08	AUXY LAYT 4.09	CHEK LAYT 4.10	EVAL LAYT 4.11	OPTI FORM 4.12	DESN REVW 4.13	DOCU MENT 4.14	WORK PLAN 4.15	INFO RETR 4.16	COST ESTM 4.17	REPORT REVIEW 4.18	MISC HELP 4.19	SOCIAL CHAT 4.20		
P&B: CONCEPTUAL DESIGN																						
Market Analysis/Study 1																					0	0
Requirements List/Spec 2	3								5			3									10	1
Abstraction of Problem 3																					0	0
Function Structure 4	11			14					7												32	4
Literature Search 5																					0	0
Analysis:Natural Systs 6																					0	0
Analysis:Known Systems 7																					0	0
Analysis:Maths/Physics 8																					0	0
Tests/Experiments 9							0				2										2	0
Brainstorm/Synectics 10																					0	0
Study Physical Process 11																					0	0
Classification Schemes 12																					0	0
Design Catalogues 13																					0	0
Sketches/Intuitive Mod 14				2	4	3	2	5	4			1									21	3
Selection Procedures 15																					0	0
Evaluation Techniques 16																					0	0
Value Analysis 17																					0	0
P&B: EMBODIMENT DESIGN																						
Solution Concept 18	6		1	1		5				3			9								25	3
Concept Phase Methods 19	--	--	--	--	--	--	--	--	See	--	No.5	--	to	--	No.	14-	--	above.	--	----	---	---
Checklists 20															0	1					1	0
Overall Guidelines 21		2						2		1	3						0				7	1
Detail Guidelines 22				5					3			3				0					11	1
Fault-tree Analysis 23										6				12							18	2
P&B: DETAIL DESIGN																						
Detail Drawings 24				15				2	23	0				8						1	50	6
Check All Drawings 25																					0	0
WORKING																						
Making Lists 26									41			0			8			2			52	7
Estimating Costs 27													3				8				11	1
Calculating 28	3	10		23					5			4						1			44	6
Scheduling:Gantt Chart 29									1						7						8	1
Using Filing System 30																6					6	1
COMMUNICATING																						
Questioning People 31	7	2	7	15					14	0	2				2	31	0	3	0		82	11
Presenting Viewpoints 32	1														3			58			62	8
Negotiating Agreements 33	2	6					3		11	1	7	1	5		6	1	1	1			44	6
Reviewing / Reporting 34	8	0							1	0			5	13	4	3	0	72			106	14
MOTIVATING																						
Becoming Involved 35									3						3	13			0	20	39	5
Injecting Enthusiasm 36	21	2		4				0	7						7	13		12		5	71	9
Adding Humour 37															0	1				7	8	1
Team Building 38								0	0						6					1	8	1
NOT CLASSIFIED 40	3	0		5	2		2		9		1		1		6	16		7		3	54	7
TOTAL HOURS FOR ACTIVITY	63	21	8	83	6	8	7	10	134	12	14	12	22	33	52	84	10	156	0	36	770	100
% OF TOTAL HOURS FOR PHASE	8	3	1	11	1	1	1	1	17	1	2	2	3	4	7	11	1	20	0	5	100	

All Hours and Totals Rounded to Nearest Integer

Figure 2-27

ACTIVITIES & TECHNIQUES - DETAIL DESIGN PHASE

DETAIL DESIGN PHASE — ACTIVITIES / TECHNIQUES		PAHL & BEITZ				GENERAL						TOTAL HOURS	% OF HOURS FOR PHASE
		FINI DWGS 5.01	LINK DWGS 5.02	FINI DOCS 5.03	CHEK DOCS 5.04	WORK PLAN 5.15	INFO RETR 5.16	COST ESTM 5.17	REPORT REVIEW 5.18	MISC HELP 5.19	SOCIAL CHAT 5.20		
P&B: CONCEPTUAL DESIGN													
Market Analysis/Study	1											0	0
Requirements List/Spec	2					1		2				3	0
Abstraction of Problem	3											0	0
Function Structure	4											0	0
Literature Search	5											0	0
Analysis:Natural Systs	6											0	0
Analysis:Known Systems	7		2									2	0
Analysis:Maths/Physics	8											0	0
Tests/Experiments	9						1					1	0
Brainstorm/Synectics	10											0	0
Study Physical Process	11											0	0
Classification Schemes	12											0	0
Design Catalogues	13											0	0
Sketches/Intuitive Mod	14	0	0									0	0
Selection Procedures	15											0	0
Evaluation Techniques	16											0	0
Value Analysis	17											0	0
P&B: EMBODIMENT DESIGN													
Solution Concept	18											0	0
Concept Phase Methods	19	--	--	--	See	No.1	to	17	above.	--	----	---	---
Checklists	20						1					1	0
Overall Guidelines	21		6									6	1
Detail Guidelines	22	38	15				2		2		1	57	7
Fault-tree Analysis	23											0	0
P&B: DETAIL DESIGN													
Detail Drawings	24	91	5	3	6		2					106	12
Check All Drawings	25				15							15	2
WORKING													
Making Lists	26	1		0	6	41						48	5
Estimating Costs	27							6				6	1
Calculating	28	89	4	7	5		1					105	12
Scheduling:Gantt Chart	29					5						5	1
Using Filing System	30		8				1					9	1
COMMUNICATING													
Questioning People	31	1	0	0	6	2	8	0	2	4	1	27	3
Presenting Viewpoints	32			1		11	14		24		1	50	6
Negotiating Agreements	33	0	17			36	1	33	7		0	95	11
Reviewing / Reporting	34		6	8	1	2	2	1	98	2	1	122	14
MOTIVATING													
Becoming Involved	35	0	2	1		4	11	1	14	29	41	101	12
Injecting Enthusiasm	36	7		1		6	2	1	16	4	9	45	5
Adding Humour	37	1			1	0			2	2	23	28	3
Team Building	38					10			3		4	17	2
NOT CLASSIFIED	40	5				6	1	1	1	4	8	25	3
TOTAL HOURS FOR ACTIVITY		232	65	20	41	124	47	45	168	45	89	875	100
% OF TOTAL HOURS FOR PHASE		27	7	2	5	14	5	5	19	5	10	100	

All Hours and Totals Rounded To Nearest Integer

Figure 2-28

ACTIVITIES & TECHNIQUES - TASK CLARIFICATION & CONCEPTUAL DESIGN PHASES

CONCEPTUAL PHASE	P & B		PAHL & BEITZ							GENERAL							% OF
TECHNIQUES \ ACTIVITIES	PROD PLAN 1.01	PREP SPEC 2.02	ABST PROB 3.01	FUNC STRU 3.02	FIND SOLN 3.03	COMB PRIN 3.04	SLCT COMB 3.05	CONC VARS 3.06	EVAL VARS 3.07	WORK PLAN 3.15	INFO RETR 3.16	COST ESTM 3.17	REPORT REVIEW 3.18	MISC HELP 3.19	SOCIAL CHAT 3.20	TOTAL HOURS	HOURS FOR PHASE
P&B: CONCEPTUAL DESIGN																	
Market Analysis/Study 1																0	0
Requirements List/Spec 2		50								1			0			51	9
Abstraction of Problem 3		7														7	1
Function Structure 4				2												2	0
Literature Search 5																0	0
Analysis:Natural Systs 6																0	0
Analysis:Known Systems 7																0	0
Analysis:Maths/Physics 8																0	0
Tests/Experiments 9					2											2	0
Brainstorm/Synectics 10		16														16	3
Study Physical Process 11																0	0
Classification Schemes 12				6												6	1
Design Catalogues 13																0	0
Sketches/Intuitive Mod 14					22											22	4
Selection Procedures 15						10	4									14	3
Evaluation Techniques 16																0	0
Value Analysis 17																0	0
ADDITIONAL TECHNIQUES																	
P&B: EMBODIMENT DESIGN																	
Checklists 20		9														9	2
WORKING																	
Making Lists 26		18								9	1					28	5
Estimating Costs 27		5								1		39				44	8
Calculating 28		6							2	2		2				12	2
Scheduling:Gantt Chart 29	0	2								1						3	1
Using Filing System 30																0	0
COMMUNICATING																	
Questioning People 31	4	23			1					1	17	0	1			47	9
Presenting Viewpoints 32												2	43		0	45	8
Negotiating Agreements 33	3	2								1	7	18	8			39	7
Reviewing / Reporting 34	2	7								2	1	1	89		1	102	19
MOTIVATING																	
Becoming Involved 35		9								1		0			8	19	4
Injecting Enthusiasm 36	8	6								6	5		11		3	39	7
Adding Humour 37																0	0
Team Building 38		3								7		2	0			12	2
NOT CLASSIFIED 40		8								2	2	0			5	16	3
TOTAL HOURS FOR ACTIVITY	17	170	0	8	25	10	4	0	2	34	32	63	152	0	17	533	100
% OF TOTAL HOURS FOR PHASE	3	32	0	2	5	2	1	0	0	6	6	12	29	0	3	100	

All Hours and Totals Rounded to Nearest Integer

Figure 2-29. For comparison with Figure 2-20 (Pahl & Beitz table)

ACTIVITIES & TECHNIQUES - EMBODIMENT DESIGN PHASE

EMBODIMENT PHASE	PAHL AND BEITZ														GENERAL							% OF HOURS FOR PHASE
ACTIVITIES / P&B TECHNIQUES	CONC REVW 4.01	DESN CONS 4.02	FUNC CARR 4.03	PREL LAYT 4.04	LAYT SELN 4.05	MAIN LAYT 4.06	FIND SOLN 4.07	DETL LAYT 4.08	AUXY LAYT 4.09	CHEK LAYT 4.10	EVAL LAYT 4.11	OPTI FORM 4.12	DESN REVW 4.13	DOCU MENT 4.14	WORK PLAN 4.15	INFO RETR 4.16	COST ESTM 4.17	REPORT REVIEW 4.18	MISC HELP 4.19	SOCIAL CHAT 4.20	TOTAL HOURS	
Requirements List/Spec 2	3								5			3									10	1
Function Structure 4	11			14					7												32	4
Solution Concept 18	6		1	1		5				3			9								25	3
Concept Phase Methods 19	0	0	0	2	4	3	2	5	4	0	2	1	0	0	0	0	0	0	0	0	23	3
Checklists 20															0	1					1	0
Overall Guidelines 21		2						2		1	3						0				7	1
Detail Guidelines 22				5					3			3				0					11	1
Selection Procedures 15																					0	0
Fault-tree Analysis 23										6				12							18	2
Evaluation Techniques 16																					0	0
ADDITIONAL TECHNIQUES																						
P&B: DETAIL DESIGN																						
Detail Drawings 24				15				2	23	0				8						1	50	6
Check All Drawings 25																					0	0
WORKING																						
Making Lists 26									41			0			8			2			52	7
Estimating Costs 27													3				8				11	1
Calculating 28	3	10		23					5			4						1			44	6
Scheduling:Gantt Chart 29									1						7						8	1
Using Filing System 30																6					6	1
COMMUNICATING																						
Questioning People 31	7	2	7	15					14	0	2				2	31	0	3	0		82	11
Presenting Viewpoints 32	1														3			58			62	8
Negotiating Agreements 33	2	6					3		11	1	7	1	5		6	1	1	1			44	6
Reviewing / Reporting 34	8	0							1	0			5	13	4	3	0	72			106	14
MOTIVATING																						
Becoming Involved 35									3						3	13			0	20	39	5
Injecting Enthusiasm 36	21	2		4				0	7						7	13		12		5	71	9
Adding Humour 37															0	1				7	8	1
Team Building 38								0	0						6					1	8	1
NOT CLASSIFIED 40	3	0		5	2		2		9		1		1		6	16		7		3	54	7
TOTAL HOURS FOR ACTIVITY	63	21	8	83	6	8	7	10	134	12	14	12	22	33	52	84	10	156	0	36	770	100
% OF TOTAL HOURS FOR PHASE	8	3	1	11	1	1	1	1	17	1	2	2	3	4	7	11	1	20	0	5	100	

All Hours and Totals Rounded to Nearest Integer

Figure 2-30. For comparison with Figure 2-21 (Pahl & Beitz table)

DESIGN EFFORT COMPARISON

Task Clarification & Conceptual Design Steps		Pahl & Beitz Estimate Time (0 – 25% – 50%)	Gasifier Test Rig Time (0 – 25% – 50% – 75%)
Clarifying the task		10 %	76 %
Abstracting to identify essential problems		1 %	3 %
Establishing function structures		4 %	3 %
Searching for solutions	Intuitive e.g. brainstorming	4 %	8 %
	Discursive	15 %	2 %
Combining solution principles and selecting qualitatively		3 %	4 %
Firming up into concept variants	Preliminary calculations	25 %	2%
	Preliminary layouts	35 %	1 %
Evaluating concept variants		3 %	1 %
		100 %	100 %

THE DESIGN EFFORT AS PART OF DESIGN TEAM EFFORT

Task Clarification & Conceptual Design — Design Process Steps		Gasifier Test Rig Time (0 – 25% – 50%)
Clarifying the task		34%
Abstracting to identify essential problems		1 %
Establishing function structures		1 %
Searching for solutions	Intuitive e.g. brainstorming	4 %
	Discursive	1 %
Combining solution principles and selecting qualitatively		2 %
Firming up into concept variants	Preliminary calculations	1 %
	Preliminary layouts	0 %
Evaluating concept variants		1 %
Sub-Total		45%
General Activities		
Personal Work Planning		6%
Information Retrieval		6%
Cost Estimating		12 %
Reporting & Reviewing		28%
Helping With Other Projects		0 %
Social Contact		3 %
Sub-Total		55 %
		100 %

Figure 2-31 Comparison of Pahl & Beitz Estimate on Percentage Breakdown of Design Effort Spent During the Conceptual Design Phase with Results from Gasifier Test Rig Project

GROUP OR SOURCE	PARTICIPANT OR SOURCE	FUNCTION OF RIG			PRODUCTION OF RIG			OPERATION OF RIG			INFORMATION FOR DESIGN			TOTALS BY SOURCE			
		D	W	C	D	W	C	D	W	C	D	W	C	Demand	Wish	Change	All
RESEARCH AND CONTRACT STAFF	SL_A	28	7	15	8	10	11	5	4	7	3	3	2	44	24	35	103
	R1_A	6	4		1				1	1				7	5	1	13
	R2_A	4	1		2			6	4	1			1	12	5	2	19
	S1_A	2	1	1		1		1	1	2				3	3	3	9
	CDE	5	2	1	11	4				3	8	4		24	10	4	38
MANAGERS	M_A		1			1									2		2
	M_S			1			2						1			4	4
	AM_A			5			1			4			3			13	13
	AM_S									3		2	1		2	4	6
SERVICES STAFF	BPO_S/SO_S	1	1	1	14		2	1		4	16		8	32	1	15	48
	DE_S			1			2			4	1		2	1		9	10
OTHER SOURCES	AD1_R			1												1	1
	BRAINSTORM	4	13		3	6	1	3			4			14	19	1	34
	CO. STD.										8			8			8
SUB-TOTALS	14 SOURCES	50	30	26	39	22	19	16	10	29	40	9	18	145	71	92	308
TOTALS BY TYPE		106			80			55			67			308			

Figure 2-32 Breakdown of Requirements Listed in Gasifier Test Rig Design Specification by Source of Contributions and Type of Requirement

D = Demand
W = Wish
C = Change

SOURCE	FUNCTION OF RIG	PRODUCTION OF RIG	OPERATION OF RIG	INFORMATION FOR DESIGN	TOTALS BY SOURCE
RESEARCH STAFF	77	48	36	21	182
MANAGEMENT STAFF	7	4	7	7	25
SERVICES STAFF	4	18	9	27	58
OTHER SOURCES	18	10	3	12	43
TOTALS	106	80	55	67	308

Figure 2-33 Overall Breakdown of Design Specification by Source and Type of Requirement Listed

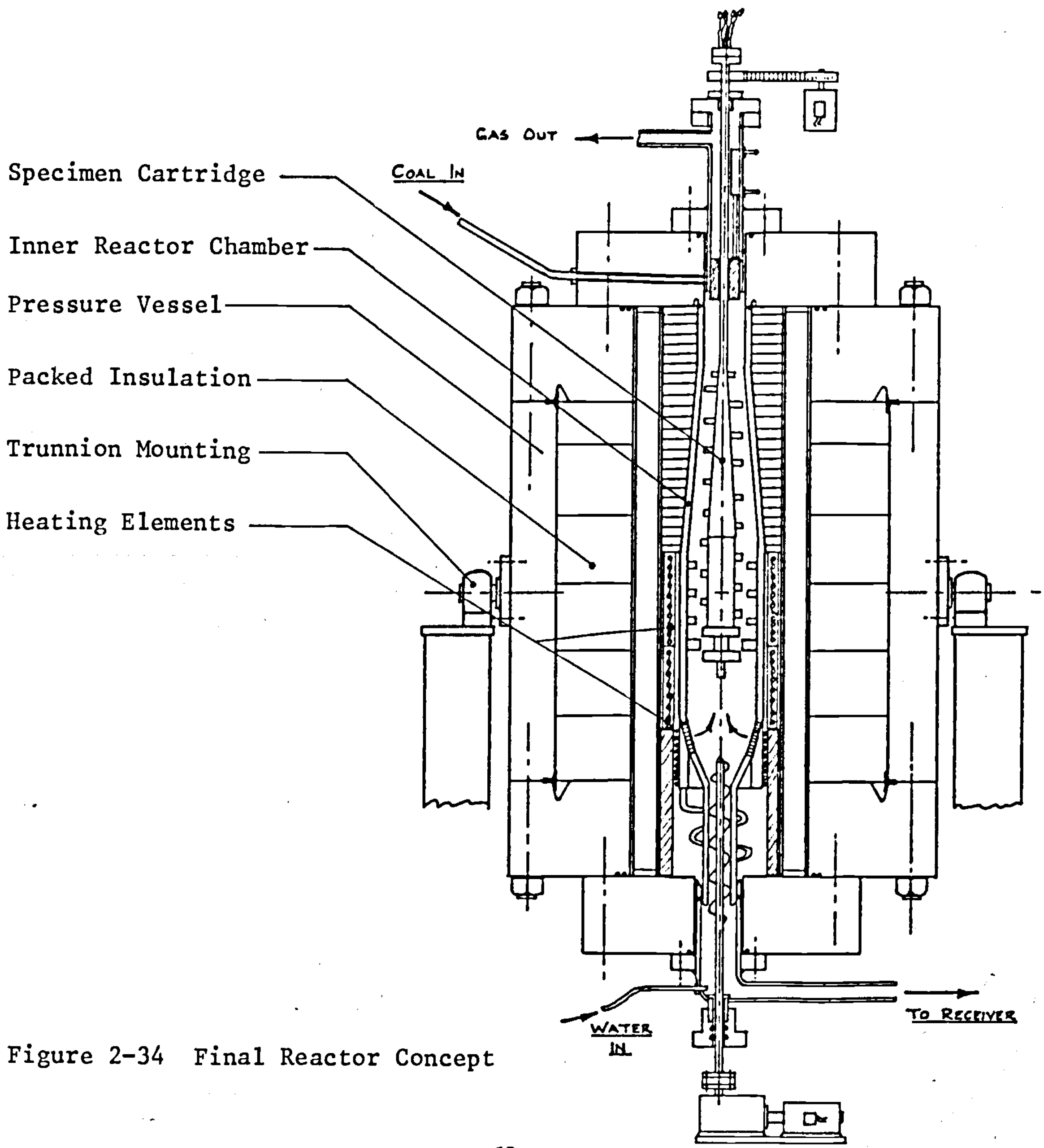


Figure 2-34 Final Reactor Concept

INNER REACTOR CHAMBER

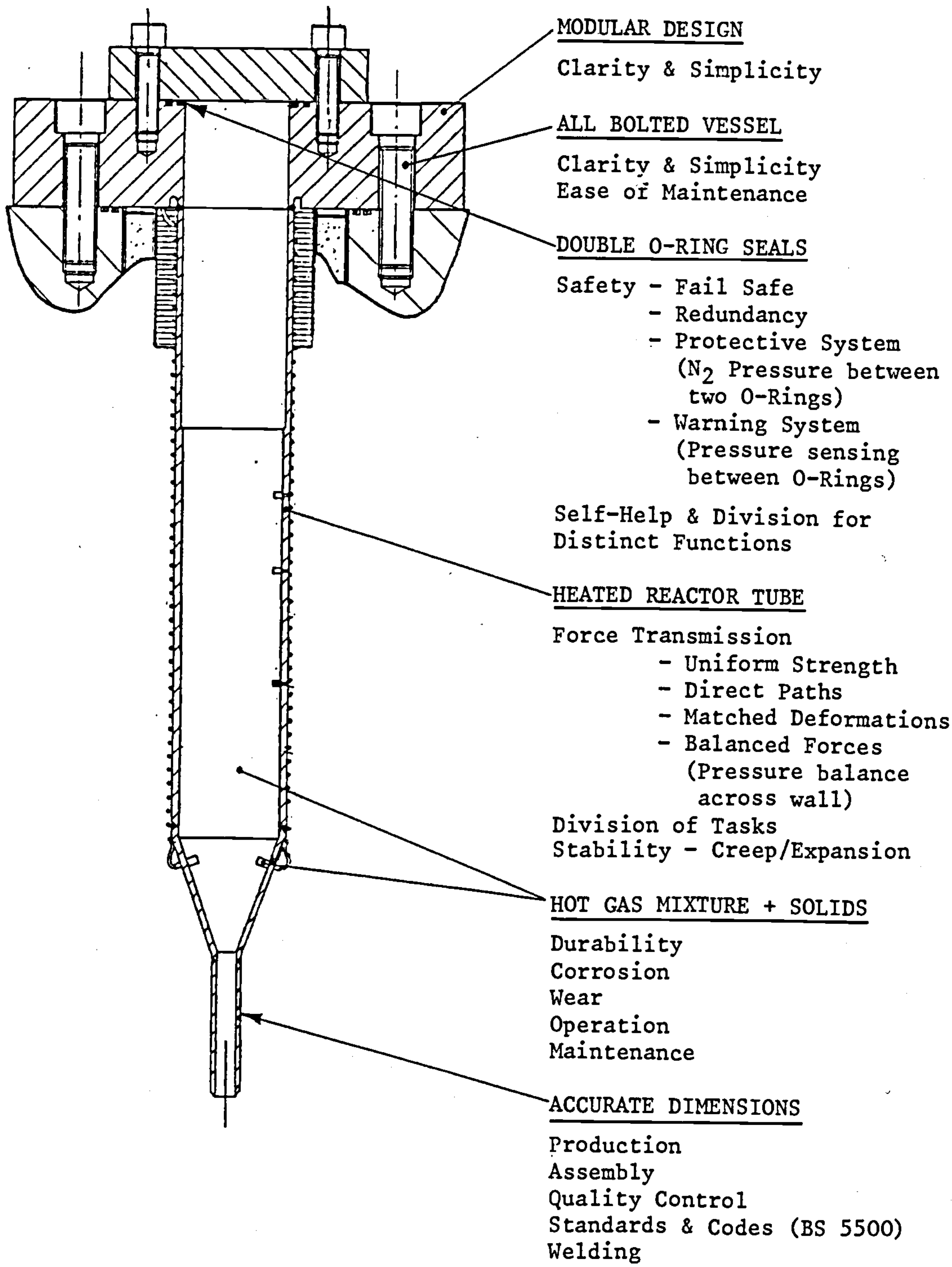


Figure 2-35 Example to show where some of the Embodiment Design 'Rules', 'Principles' & 'Guidelines' were involved

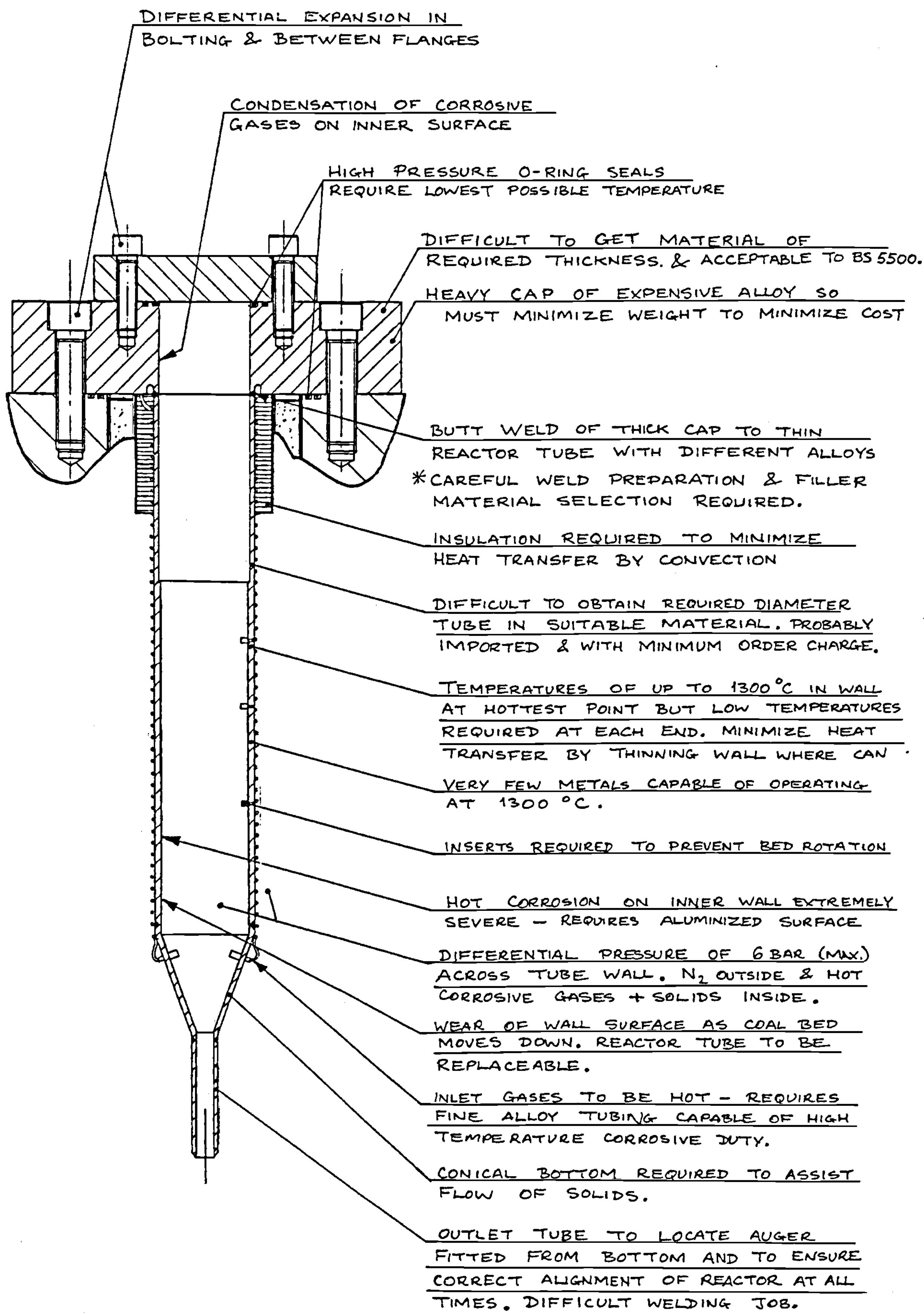


Figure 2-36 Problem of Materials Selection for Inner Reactor Chamber

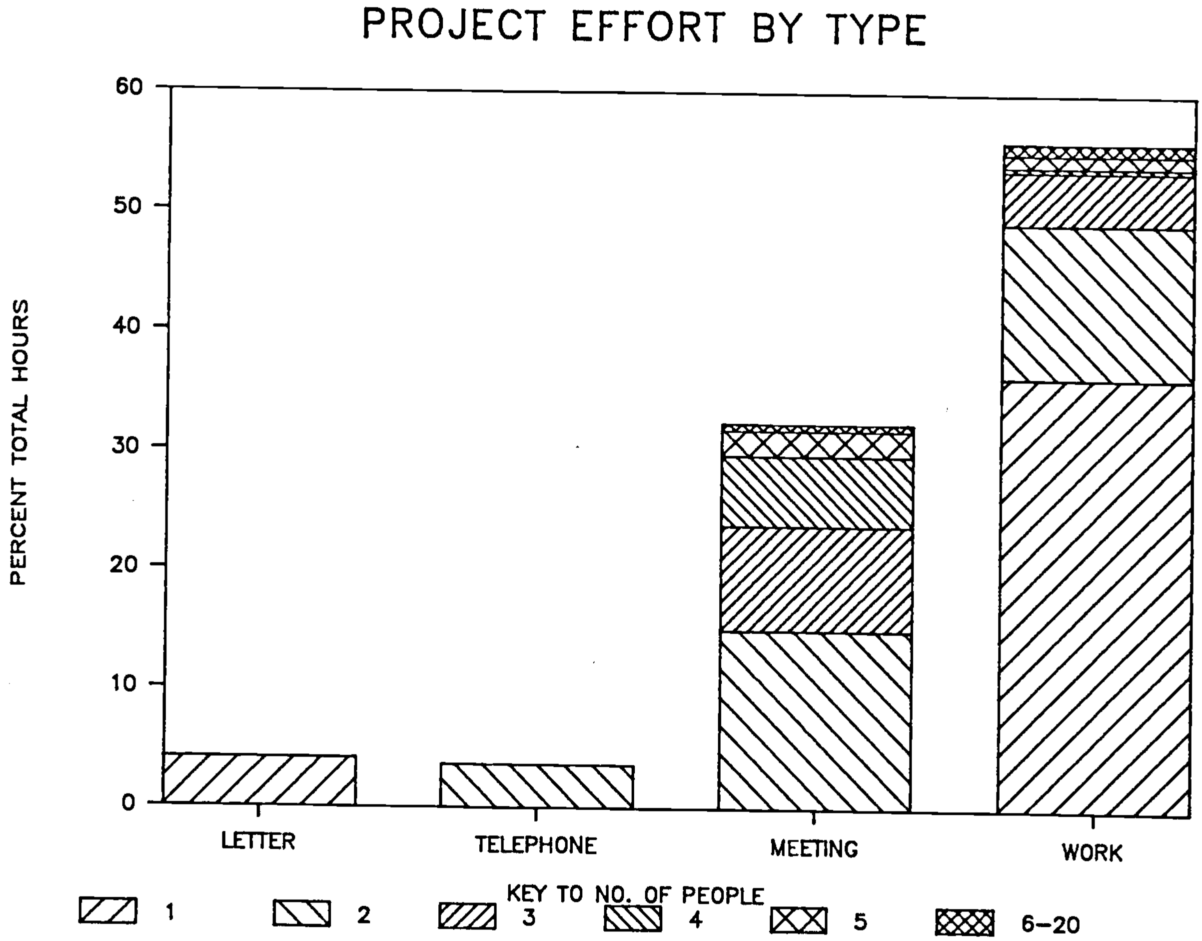
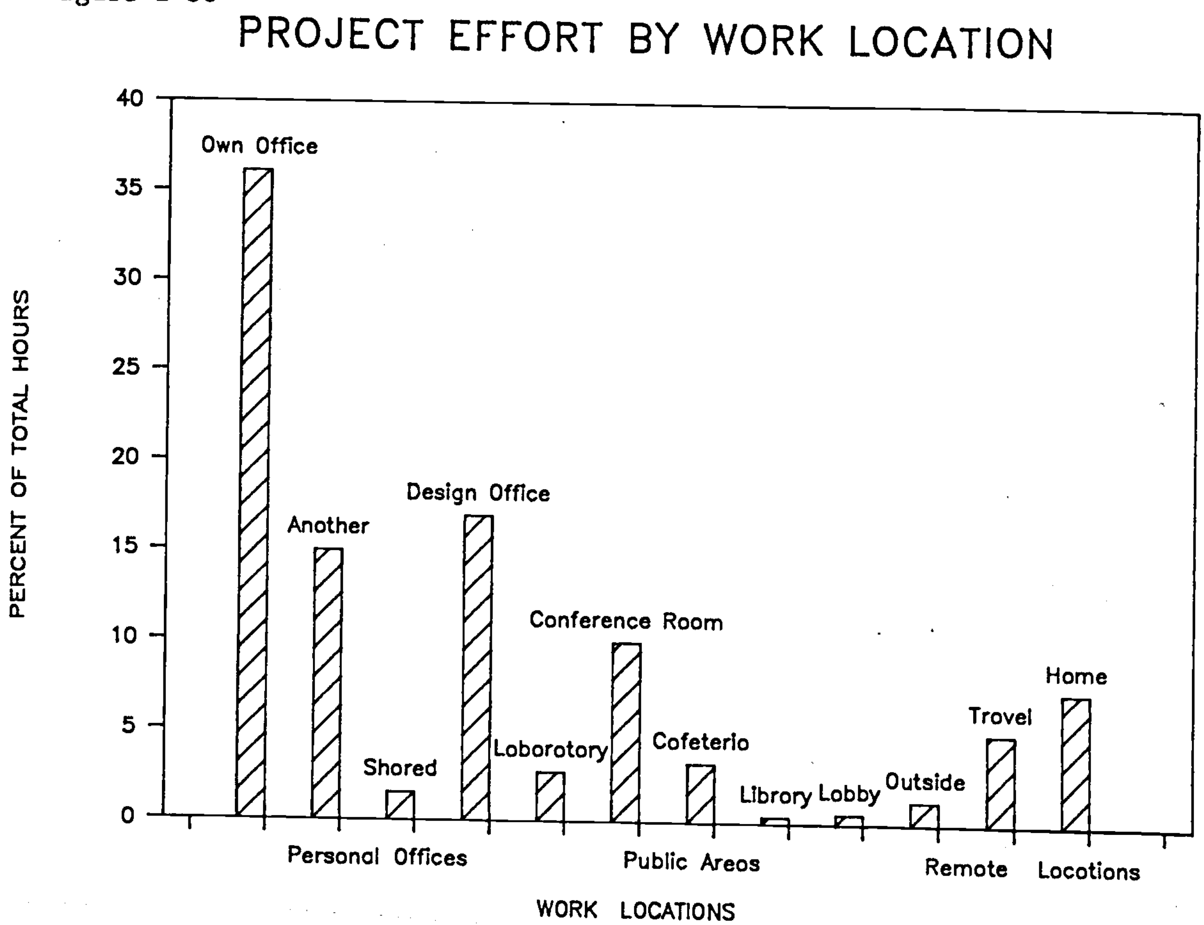


Figure 2-37

Figure 2-38



PROJECT GROUP	MONTH / PERSON	YEAR 1												YEAR 2												YEAR 3										MEAN OF MOOD
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	
DIRECTORS	D_G																	0.0	-1.0		0.0		0.0	0.0			0.5									-0.1
	D_R											1.0	0.0		1.0				-1.0	0.0			1.0	1.0												0.4
	AD1_R										-1.0																			-1.0	0.0			1.0		-0.3
	AD2_R																						1.0	1.0			-1.0	1.0	-1.0		-1.0			0.0		0.0
MANAGERS	M_A	1.0	1.0		1.0				1.0	0.7	0.5	1.0				1.0	1.0	1.0	-1.0		0.5	1.0	0.7	-0.5	0.0	0.7	0.5	0.5	0.0	0.8	0.0	0.0	-0.3	0.0	0.0	0.5
	M_S								1.0	0.0		1.0									0.5				0.0	1.0		0.3	-0.5	0.0	0.0	0.0		-1.0	0.5	0.2
	AM_A	1.0	1.0	1.0	0.5	0.7	0.5	-1.0	0.5	0.5	0.5	0.0	0.5	0.0	0.5	0.5	0.0	0.8	0.0	1.0	0.3	0.3	0.7	0.5	0.0		0.1	0.6	0.2	-0.2	0.3	0.5	0.0	-0.1	0.0	0.4
	AM_S									-0.3	1.0	1.0				0.0				0.3	1.0				0.2	0.3	1.0	0.4	0.7	0.2	1.0	0.0	0.3	0.0	0.5	0.4
RESEARCH STAFF	SL_A	1.0		1.0	0.0			0.0	0.2	0.4	0.4	0.6	0.1	0.5	0.3	0.0	0.0	-0.4	0.0	0.2	0.2	0.4	0.0	0.3	0.5	0.3	0.0	0.2	0.2	0.3	0.1	-0.3	0.0	0.2	-0.3	0.2
	SL_P																					0.5		1.0	1.0	0.0	1.0	1.0					1.0	0.7	0.5	0.7
	ASL_A									1.0	1.0				0.8	0.5	1.0	-1.0	0.0	1.0	1.0		1.0		1.0	1.0		-1.0	0.0	1.0	1.0	0.0	1.0	1.0	-1.0	0.5
	R1_A								0.5	1.0	1.0	1.0		1.0		-1.0				0.0	1.0	1.0			1.0	1.0	1.0	0.8	0.4	0.3	0.1	0.5	0.6	1.0	0.5	0.6
	R2_A								0.5	1.0	0.0	1.0						0.0	1.0	1.0			1.0		1.0	1.0	0.9	0.8	0.5	0.0	0.8	0.3	0.8	0.0	0.5	0.6
	S1_A			1.0					1.0		1.0	1.0			1.0	1.0		0.0	1.0			1.0			0.0						1.0					0.8
	S2_A															1.0												0.7	1.0		0.5					0.8
	S1_P									0.5						0.5		0.0						0.3	0.0	0.0					1.0					0.3
SERVICES STAFF	BPO_S								0.7	0.5	0.7					-1.0							1.0	1.0		1.0	1.0	0.8		0.2	0.5	1.0		1.0	1.0	0.7
	SO_S								1.0	0.0						1.0																			1.0	0.8
	DE_S									-0.7	1.0	1.0				1.0			1.0	0.4	1.0				0.0	0.2	-0.1	0.5	-0.6	0.4		-1.0	0.4	-0.1	-0.3	0.2
	DR_S																								1.0	0.1	0.8	1.0	1.0	0.7	0.4	-0.3	1.0	1.0	0.2	0.6
	G1_S																									0.5	1.0	0.9	1.0	1.0	1.0	-1.0	0.6	1.0		0.7
REMOTE SUPPORT STAFF	C_G																		0.0				0.0	0.0												0.0
	QAO_H																			0.5								1.0								0.8
	SO_H																											0.5								0.5
	DE1_W																	1.0	1.0			0.0						1.0	1.0		1.0					0.8
	DE2_W																										1.0									1.0
CONTRACT STAFF	CDE	1.0	1.0	0.7	0.8	0.8	0.7	0.0	0.4	0.6	0.4	0.5	0.4	0.6	0.6	0.4	0.2	0.3	0.6	0.5	0.3	0.6	0.7	0.5	0.8	0.6	0.3	0.8	0.3	0.3	0.5	-0.0	0.2	0.4	0.5	0.5
	CCE														0.0				1.0				-0.5			0.8	0.2	0.6		1.0						0.4
	CDD																			0.5	-1.0									0.7	0.4	-0.6	0.7	0.9	-0.2	0.2
SPECIALIST SUPPLIERS	SE_FE													1.0	1.0											0.5	0.6		0.0	-0.5						0.4
	SE1_VA																										1.0	0.6	0.0	0.0			1.0			0.5
	SE2_VA																											0.6		0.0			1.0			0.5
	SE_VE													1.0	1.0		0.0	1.0	0.0											0.0						0.5
	SE_FL									0.8	1.0		1.0		1.0					0.1	0.0						1.0	1.0	1.0	1.0	0.0		1.0		1.0	0.8
UNIVERSITY SUPPORT	RM_U			1.0		0.5	1.0	1.0	0.7	0.6	1.0	0.6	1.0		1.0					0.8			0.0	1.0	1.0		0.0	0.8		0.0	0.0					0.7
	LO_U									1.0			1.0		1.0			1.0		1.0					1.0		1.0	1.0								1.0
	DE_U														1.0																0.7					0.8
MONTHLY	MEAN 0	1.0	1.0	0.9	0.6	0.7	0.7	0.0	0.7	0.5	0.6	0.8	0.6	0.7	0.8	0.4	0.4	0.3	0.2	0.5	0.4	0.6	0.5	0.5	0.5	0.6	0.6	0.6	0.3	0.3	0.4	-0.1	0.6	0.4	0.3	0.5

Figure 2-39 Participant 'Mean Mood' by Month

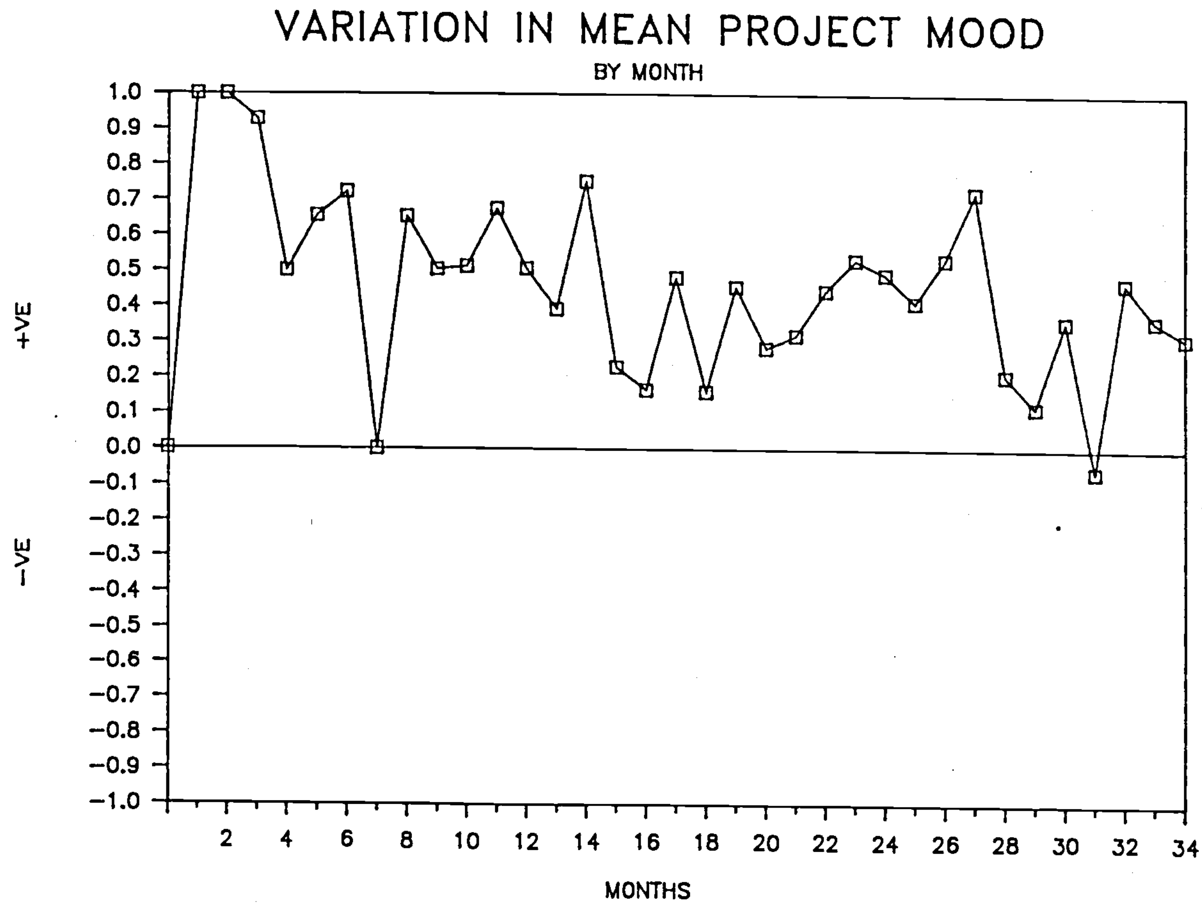
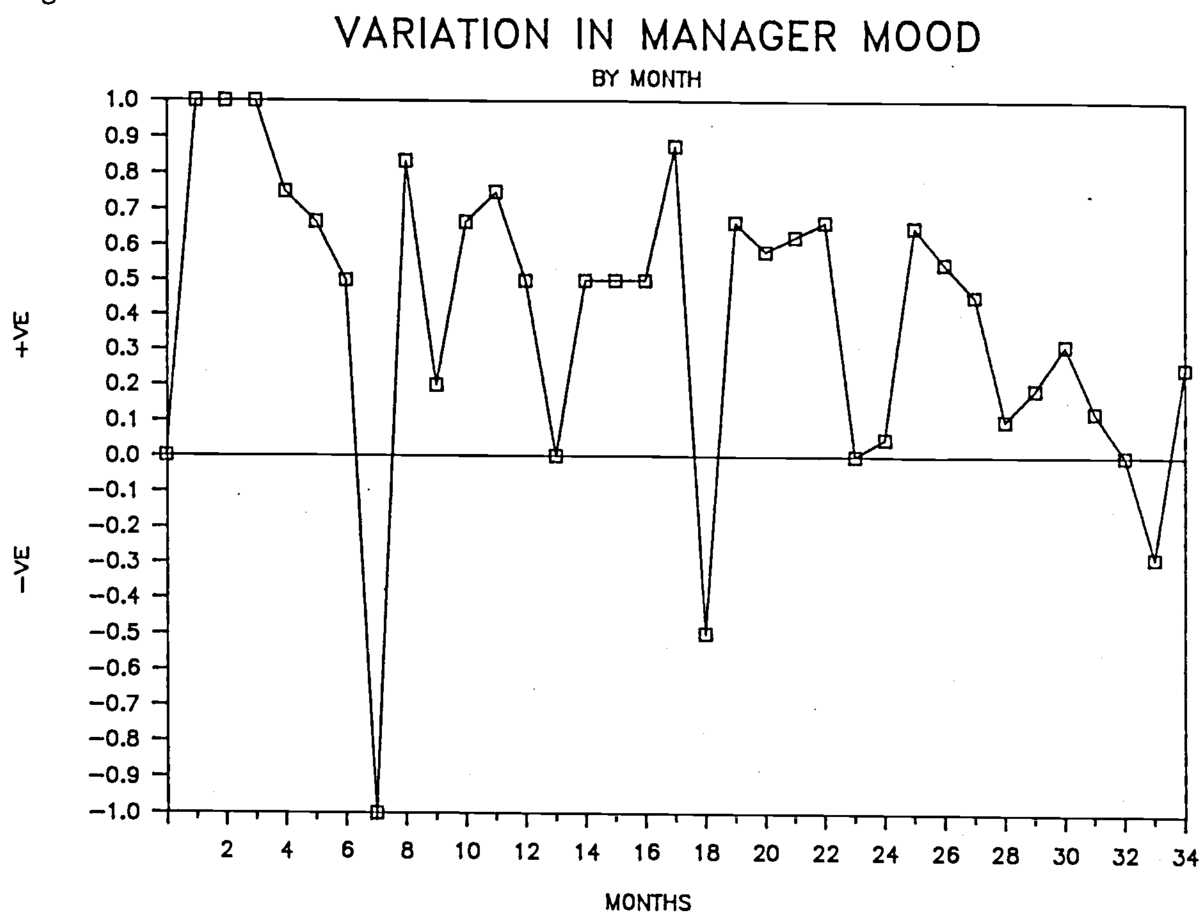


Figure 2-40

Figure 2-41



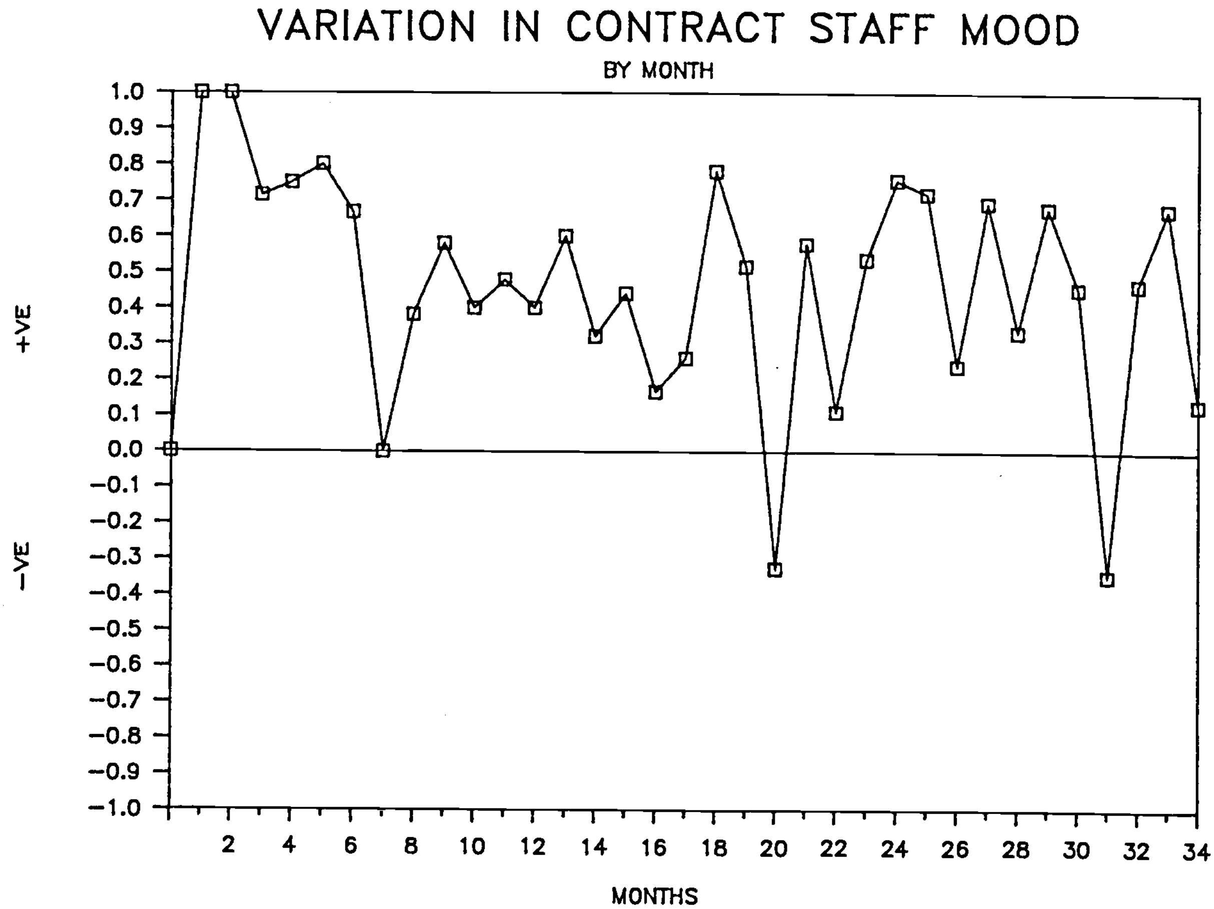

VARIATION IN CONTRACT STAFF MOOD
BY MONTH
+VE
-VE
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
−0.1
−0.2
−0.3
−0.4
−0.5
−0.6
−0.7
−0.8
−0.9
−1.0
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34
MONTHS

Figure 2-42

CHAPTER 3

QUALITATIVE ANALYSIS OF AN ENGINEERING PROJECT

3.1 Introduction

An analysis based on hours of work effort resulted in characterization of the project according to activities and outputs but it offered no reasons for why things happened the way they did. For example it did not explain why the project took longer than expected, nor why the embodiment design effort stayed at a low level for so long. To investigate such aspects a complementary approach was needed, using the same data but in a different way. Instead of categorizing activities and outputs for each phase of the project, various 'influences' acting on the project during each phase were identified and categorized, at five levels of resolution. This led to a qualitative characterization of the project in terms of its context, which could be used to support the quantitative results.

The Context Model used in Chapter 2, and reproduced in Figure 3-1 with the 'resolution levels' annotated, helped in structuring this more qualitative analysis. At each level the project is considered in terms of 'categories of influence' and 'contributing factors', identified from the literature as likely to be important in engineering design. Particular incidents or events from the project are described, which characterize the view of what happened from each resolution level and typify the influences which were observed. Based on this an attempt is made to assess the effectiveness and efficiency of the engineering design process and the success of the project, as seen from several viewpoints. Figures 3-1 to 3-7 have been grouped together at the end of the chapter for easy reference.

3.2 Influences and Viewpoints

3.2.1 Terminology and Background

Influences may be defined as 'people or things having power', with power as 'the ability to affect outcomes' [Lawrence and Lee (D12)]. The 'goal-orientated' engineering design process cannot be effective unless the balance of influence (as 'power in operation') favours the attainment of project goals as distinct from goals at other resolution levels. A five-year study in the U.S. by the Hughes Aircraft Company (D10) on improving productivity in technology-based organizations resulted in a practical set of checklists and guidelines for compensatory control of influences acting on particular research and development situations. Most of the influences identified during that study also apply in the case of engineering design, and advantage was taken of this in generating the lists used here. It was determined that influences may be categorized as slowly-changing (fixed) or continuously-changing (variable), and as favourable ('facilitators') or negative ('barriers') to the project [Rubenstein (C27)].

The concept of identifying and categorizing 'influences' for this project came from ideas suggested by Lewin's field theory in social psychology (D15) combined with Rodwell's set of scales for 'profiling' design tasks (D18) and Gregory's contingency model of design (C10). First attempts to list the influencing factors and so 'profile' the design context [Wallace and Hales (C33)] proved rather clumsy, but led to the better defined list reported two years later (C34). Humphreys (B33, B34) and Carter et al. (B12) have suggested taking longitudinal 'slices' through a project to map variable influences with time, and lateral or crossectional 'time slices' to map the balance of influences at a point in time. At each resolution level [Wallace and Hales (C34)] there appears to be a mixture of slowly-changing 'structure orientated' influences such as corporate organization, and continuously-changing 'process orientated' ones such as 'enthusiasm' and 'involvement'. If such influences could be more clearly defined, for example by using the assumption that individuals and groups tend to react in predictable ways to most influences [Handy (H14)], it might eventually be possible to use them as 'constants' and 'variables' for analytical purposes (D20). This would require data from many more projects and could not be attempted here. Analysis was limited to the identification of categories of influence and contributing factors within each category, with subjective assessments of their observed impact.

The following criteria were used in determining each contributing factor within each influence category:

(i) Did it seem to affect the engineering design process?

(ii) Was there evidence to show this?

(iii) Is the term used generally accepted and unambiguous?

(iv) Does it accord with the Context Model?

(v) Does it form a coherent set when combined with others?

(vi) Does it help characterize the project?

(vii) Could it perhaps be assessed on some qualitative scale?

3.2.2 Macroeconomic Level

Seven broad categories of 'external influences' are shown on the Context Model, and for the most part their inclusion is self-evident. The impact of all these is discussed in papers concerning the design of large plants such as the Three Mile Island nuclear power station [Coaker (F1)], and there are numerous examples in the literature concerned with the impact of individual ones. For example Kagan and Van der Water (F5) and Smith (F10) deal specifically with the impact of legal influences on the engineering design process. 'Random' influences are taken to include the effect of 'luck' and 'chance', it being assumed that there is usually an attempt to maximize the benefits of good luck and minimize the effects of bad luck.

External Influences

At the start of this project the political and economic forces in Britain favoured development of coal gasification as an alternative energy source, and within the Company there was emphasis on coal gasification research. In particular the group which originated the idea of the Gasifier Test Rig was concerned with evaluating materials for use in the components of full-scale slagging gasifiers, where the temperatures and pressures are extreme and the internal environment is corrosive and abrasive. The strength of the group lay in its expertise on material properties and the test rig was seen as necessary to provide data for its future research. It was on this basis that the original proposal was accepted and the project initiated.

At the end of the conceptual design phase a document describing the test rig concept was circulated within a company-wide 'materials working party' by the project manager, to find out what level of support for the project existed in other areas of the Company. The feedback from management most closely connected with Company policy on coal gasification was questioning rather than encouraging, and in a letter to the contract design engineer on 18 August 1983 the project manager wrote: "To some extent the climate has changed ... I am afraid it does mean that I cannot progress the A-form immediately as I had hoped..." With reference to Figure 2-10 it will be seen that in Month 18 (August 1983) embodiment design effort was building up, but one month later it fell off again and remained at a low level for the next five months. This was a period of indecision for the project management, resulting largely from changes in Company policy towards coal gasification research, and the project suffered. Although the project was continued through detail design the effect of these external influences grew stronger, and on 4 March 1985 (3 months after data collection had ceased) the project manager wrote: "This letter is to confirm that we are not able to go ahead with the gasifier test rig at this point in time." In the wider context this resulted from changes in Government policy for the purchase of natural gas from Europe, at prices making the use of synthetic natural gas (SNG) uneconomic well into the future.

By comparison with these political and economic influences, social, technological, ecological and legal influences were insignificant. However if construction of the rig had gone ahead as originally planned this would have been different. For example the immediate area around the Company's property was being rapidly developed from a run-down industrial zone to an 'up-market' residential zone, and there was increasing pressure on the Company to ensure that it released no pollutants. The gasifier test rig would generate a small volume of hydrogen sulphide and, despite inclusion of an efficient gas scrubber in the system design, additional precautions for operation under emergency conditions were being discussed.

Random influences affected the project in many small ways. An example was the chance interchange between the contract design engineer and a Company director for SNG during a visit on 18 April 1984, when, despite his lack of support for the gasifier test rig project, the director said that he had passed the reactor assembly drawing on to one of his senior engineers who had commented favourably on a number of technical features. This gave some welcome encouragement in Month 26, just as a final push on embodiment design was beginning. Bad luck also took its toll. The most significant event was the hopitalization of the contract design engineer due to peritonitis in Month 16, just at the end of the Conceptual Design phase when the A-Form (cost justification) was to be submitted. As noted in Chapter 2 and shown in Figure 2-10 the project effort was zero for this month, and the momentum built up during conceptual design was lost. If the A-Form had been submitted when planned it may well have been approved before the negative political and economic influences had an impact on the project.

Figure 3-2 lists the external influences identified, with a subjective assessment of their observed impact on the project. Literature sources coded against each item are detailed in the References and Bibliography following Chapter 5.

3.2.3 Microeconomic Level

Economics as a discipline has a well-defined and accepted terminology and this made it relatively easy to list categories of influence at the micro-economic level, but identifying contributing factors from an engineering design viewpoint was difficult. The list in Figure 3-3 was found adequate for this project, with contributing factors grouped according to three main categories of influence: Market; Resource Availability and Customer.

Market

Although the market for the Gasifier Test Rig was within the Company, it was not confined to the research group that initiated the project. On offer to potential customers was the possibility of doing experiments in an operational high-pressure, high-temperature facility, tailored to their specific needs at minimal cost. The general demand for such a facility was never actually quantified, as the cost justification had been based on the need for particular long-term materials tests. This need diminished during the course of the project, and so went the purported justification for building the rig. It did not mean that the rig had no market but that the marketing approach which seemed the best at the time turned out to be a poor choice in the end. Various groups in the Company were interested in the rig, the competition being from simpler equipment often unable to provide adequate simulation of the real environment. The problem was that if the rig was dedicated to long-term materials tests the availability for other work was too low for other groups to contemplate helping to fund the project. This point was raised during the tape-recorded meeting held on 9 February 1984: an enquiry as to the cost of building additional reactors.

Resource Availability

Sufficient resources were available for the design effort except for the lack of a qualified detail designer, and a problem in obtaining accurate information regarding gasifier operating conditions. Unlike the control system design, where it was up to the project team to secure the services of a design engineer, detail design was under the control of a Services Group, and the recruiting of individuals for this was outside the control of the project team. When the time came for detail drawings to be done no qualified person was available to do the work. What is more it took six further months to attract a suitable person and, as shown in Figure 2-10, this caused a severe discontinuity in the project effort. The project had not been funded for construction so the project team had little power over the situation. With regard to information needed on gasifier operating conditions there was strict confidentiality on such information within the Company. It was taken to such lengths that the rotational speed of a major component, essential for calculating the specimen movement in the rig, was wrong by a factor of 4 when told to the contract design engineer. The point here is not only that the contract design engineer wasted design effort because of wrong information, but that this information was being used by permanent Company staff in the absence of anything better.

Customer

The customer for the Gasifier Test Rig was the Company itself, but represented by individuals within the Company. The research scientists who planned to operate the rig themselves were classified as 'users', and the directors responsible for the funding were classified as 'customers'. Between these were four hierarchical levels: Assistant Director; Manager; Assistant Manager and Section Leader. At each level there were people involved who would see themselves as part 'user' and part 'customer'. To simplify the matter all those at Manager level and above were regarded as the customer, while all those at Section Leader level and below were regarded as users. Assistant Managers, as they would neither use the equipment directly nor sign for the funding, were considered project managers but not users or customers. Based on these assumptions it was established that in the first instance the customer's need was not quantified and that the project could not be considered urgent. The customer was keen to be involved with technical aspects of the design, helping in the development of the design specification for example, but had over-optimistic expectations regarding the capabilities of such a rig. This is illustrated by a chance interchange involving a Section Leader, the Contract Design Engineer and an Assistant Director in the lobby on 30 January 1984 (Month 23) during which the Assistant Director suggested that the name of the rig be changed to Gasifier 'Simulator' to reflect what he felt its capability would be.

Figure 3-3 summarizes the observed impact of factors within the categories of influence identified at the microeconomic level, together with the coded list of relevant literature sources.

3.2.4 Corporate Level

Organization theory is not a unified whole but a loosely associated set of theories based on various viewpoints and concerned with different aspects [Dunkerley (H5)]. Opinions and terminology vary widely, and the number of influencing factors is large. From an engineering design viewpoint it was found difficult to determine which influencing factors were likely to be important, because although the production process is referred to in many organization theories very few even mention the engineering design process [Wearne (H46)]. By drawing from a wide variety of sources the list shown in Figure 3-4 was compiled, and the contributing factors were categorized according to the 'McKinsey 7-S Framework' from Peters and Waterman (H35). Other sources found particularly helpful at this level were:

- Power and influence: Handy (H14); Lawrence and Lee (D12);
- Structure of organizations: Mintzberg (H25); Pugh (H37);
- Management style: Likert (H37); Lupton (H24);
- Management skills: Dale (H4); Topalian (H42).

Corporate Structure

The project setting was in one small part of a large national corporation, and although this did not change during the course of the project it did influence the project context. For example, if the Company had not been a monopoly or had it been international, it is unlikely that the five-month period of indecision over the future of the project would have lasted so long, or that detail design would have continued without a final decision. Further criteria such as market potential for commercial materials testing would most likely have forced the decision one way or the other. Other factors observed to contribute to the effect of corporate structure on the project were: the complexity of the Company; the low organizational flexibility afforded the project; the mixture of help and hindrance from centralized services such as Safety and Quality Assurance and the low level of project autonomy allowed the project.

Corporate Systems

Six factors related to the way the Company operates were observed to have an effect on the project:

(i) The integration or lack of integration between various groups;

(ii) The degree to which available information was used;

(iii) The technical complexity of the whole area of coal gasification;

(iv) The physical environment in which the design effort took place;

(v) The social environment existing within the Company;

(vi) The payment and benefit system.

The positive and negative effects of each of these was demonstrated many times during the course of the project. A few examples are given below:

(i) *Integration* - The element of competition between various research groups in the Company was not found beneficial from the engineering design viewpoint as the available technical support could not be used to full advantage and information tended to be witheld.

(ii) *Use of Information* - Outside companies were used extensively for obtaining technical information, and in general the response was excellent. For example from the field notes on 22 September 1983: "Wrote 9 letters for information: Fine Tubes; BSC; ICI; Carbolite; Carborundum; Henry Wiggins; Wainwright; Holo-Krome and Unbrako." All replied within 7 days. Actually, almost all the information required for the design of the test rig existed within the Company, but it was often difficult to locate and obtain at the time. In addition there was the problem of confidentiality mentioned before.

(iii) *Technical complexity* - When coal is heated (without excess oxygen) it continuously and irreversibly changes in character going through defined stages. It devolatilizes, swells, plasticizes, hardens and breaks up, at temperatures which depend on the type of coal and the pressures involved. The process of coal gasification depends on so many factors and the conditions are so extreme that design issues for the test rig were inherently complex.

(iv) *Physical Environment* - It was shown in Chapter 2 that only 17% of the design effort took place in the 'design office' while most took place in individual offices, and at certain times the effect of the physical environment was observed to be important. In particular the need for space to lay out drawings during embodiment and detail design was a problem, as recorded in the field notes on 13 April, 1984: "Persuade DE_S and DR_S to clear top of drawing file with my assistance - no flat surface to lay things out in whole office."

(v) *Social Environment* - The sociable environment in which the project took place had the advantage of encouraging informal communication between participants and groups, which helped overcome the problems of obtaining information within the Company.

(vi) *Pay and Benefits* - Both the pay and the benefits offered by the Company were considered good by most team members, and in the case of one or two were the main reason for them staying in their jobs. From the Gasifier Test Rig viewpoint, however, the influence of pay was quite different from the influence of benefits. Whereas the level of pay was observed to act as an incentive ('facilitator'), particularly with the contract staff, the benefits in the form of vacation time, holidays, 'sick time', 'flexitime' and personal freedom were observed to cause unpredictable disruptions in project progress ('barriers'). The type of problem this caused within the project team is illustrated by a notebook entry on 9 April 1984: "Holiday schedule: J__ in until 19th, then away 1 or 2 weeks; R__ in until Easter; F__ away 16-27 April and again 13 May to 23 June; H__ away 2 weeks after next week; Easter Holiday 20-23 April; Bank Holidays 7 & 28 May."

Corporate Strategy

The five-month period of indecision regarding funding of the project would suggest that, at the time, the corporate strategy on coal gasification research was not clear, at least not to those responsible for approving funding for the Gasifier Test Rig. It also indicated a reluctance to take risks. To proceed with the detail design work but not the application for construction was a way of 'hedging one's bets'. These were important factors, as a slightly clearer strategy might have forced the decision against the project much earlier, and a slightly less cautious approach would almost certainly have favoured construction. In the literature [particularly Peters and Waterman (H35)] 'innovation' (implementation of a design or new ideas) is seen as an important influencing factor at the corporate level. The Gasifier Test Rig was regarded as 'novel' in design but until built and operating it could in no way demonstrate 'innovation', so although this contributing factor was considered important the data from this project could provide no evidence for this. It would seem that innovation and risk-taking are interdependent: had the more risky decision to build the rig been taken, and had the rig performed as expected, then it is likely that the project would have been seen as innovative. Another factor often stressed in the literature is corporate 'involvement'. For this project such 'corporate involvement' (i.e. higher level than project management) was intermittent, as was seen in Figure 2-15, and it was either at the request of the project team or as a result of a chance interchange. No unsolicited corporate involvement was observed, and as far as the project team was concerned this was seen to indicate a lack of commitment towards the project, acting as a negative influence.

Shared Values

As with corporate involvement, the 'commitment' and 'enthusiasm' that are regarded as important factors in Company 'shared values' were observed to be intermittent and variable as regards the Gasifier Test Rig project. This was a common topic of conversation within the project team, as it clearly affected the future of the project. For example on 7 February 1984: "...M. thinks we would be on a sticky wicket if we rode along on the director's enthusiasm." (Field Notes). To confirm such statements more data was required and it was not difficult to obtain. Several 'chance' interchanges were used to test the level of commitment and enthusiasm, and the project team members were found to be accurate in their assessment.

Management Style

The approach regarding factors categorized under management style was to include four main 'styles' commonly referred to in the literature and to assume that in the real case a mixture of these would exist. The interest was then in the dominant style observed, and its possible effect on the project. Of the four styles: autocratic; benevolent; consultative and participative, the benevolent style was most in evidence. It was observed at all levels of management. Concern for an employee's personal problems and health sometimes took precedence over concern for the project, and personal vacations could be scheduled at any time. 'Flexitime' gave additional personal freedom, and the working atmosphere was generally relaxed. Thus the predominantly 'benevolent' style of management tended to favour the team members at the expense of the project, and this acted as a negative influence as far as project progress was concerned.

Management Skills

Traditionally management skills have been grouped under headings such as planning, organizing, directing, coordinating, and controlling, but more recent studies of what managers actually do [Mintzberg (H25); Peters and Waterman (H35)] have turned attention towards communicating, representing (e.g. project or product 'champions'), and using resources effectively. As far as the Gasifier Test Rig project was concerned the more traditional group of headings was seen as the management *output* needed for the project to exist, while the latter group was seen as the management *activities* to produce such output. All the headings were seen as factors which would influence the project, but as the study was concerned with the engineering design process rather than overall project management the data collected on these factors was limited. Management planning, organizing and coordinating were clearly in evidence as positive influences, but with the complexity of the corporate structure and systems it was not possible to specifically identify the effects of 'direction' and 'control'. For example the project manager's monthly cost sheets were in terms of people rather than projects, and in terms of 1/10th days rather than hours. The measurement of project effort in 1/10th days would have been virtually impossible from a field research viewpoint, especially with Fridays having shorter hours than other days. Although an attempt was made to flag all the costs and effort attributed to the Gasifier Test Rig by means of an extra digit on the job number, this digit was not recognized by the computerized accounting system. The project manager was surprised at the small number of total hours (2368) recorded by the participant observer: "It had seemed to be more than that", but an approximate check through the manager's cost sheets confirmed that the total project effort was about 1 1/2 'man-years'.

There was evidence to show the influence of communication, represention and resource utilization on the project. In general communication and representation at the corporate level were positive influences, but the effects were intermittent. Resource utilization, judged on the basis of numerous comments from project team members, could have been considerably higher had circumstances been different, and this would have helped to overcome the various delays encountered.

Management Staff

The literature suggests that the number of management staff, and their awareness, judgement (decision-making), motivation, morale and confidence, would be likely to influence the project. In general terms this was found to be so, but as the data was from only one project with relatively little manager input, there was insufficient evidence to more than confirm that these factors did have some effect. For example, if the management had been more confident in the operability of the rig, and the availability of staff to run it, the potential risk may have been perceived as lower, and the application for funding might have been approved. This is hinted at in the final letter from the project manager dated 4 March 1985: "Another matter which concerned us and led to some hesitation on my part... was the knowledge that the effort in terms of manpower that would be needed to get it off the ground and running successfully would be difficult, if not impossible to find within our Group. Experience has taught us that it would be unlikely to be forthcoming from anywhere else..."

The influence categories and contributing factors at the corporate level are summarized in Figure 3-4, together with an assessment of their observed impact and a literature source list.

3.2.5 Project Level

At the project level it was found that the factors could be grouped into four categories of influence: Task; Team; Techniques; and Output [Rodwell (D18)]. Useful sources from the literature were:

- Design Task: Rodwell (D18); Hykin (C13); B S 6046 (I5);
- Design Team: Belbin (I2); Biddle (I3); Hales (I12); Lee (D13);
- Design Tools: Leech & Turner (A38); Finkelstein (B23); Jones (B36); Pahl & Beitz (B48); Hajek (I11); Rodwell (I22).
- Design Output: Rodwell (I22); Arup (I1).

The factors identified within each category are shown in Figure 3-5, and are discussed below with some examples from the project.

Design Task

Hykin and Laming (C14) suggested preliminary scales for the measurement of the 'complexity' and 'magnitude' of engineering design projects, while also considering the effects of production quantity and novelty. At the same time Rodwell (D18) was interested in developing a way of classifying different types of project, and proposed an approximate set of comparative 0-5 scales for profiling a project in terms of Magnitude (M), Complexity (C), Novelty (N) and Production Quantity (Q). The variable 'commercial and design progress' was also mentioned, but did not fit the pattern as it is dependent on time, and it has been categorized here as 'design output'. The profile for a particular project was considered fixed (theoretically the values could vary with time), and was expressed as a letter and number sequence. Using Rodwell's notation the Gasifier Test Rig design task profile was assessed by the project team as being M3-C4-N4-Q1, or medium magnitude, high complexity, high novelty and very low production quantity. Previous projects completed by the same project team, but excluding the participant observer, ranged from M1-C1-N3-Q1 to M2-C2-N2-Q1. Assuming that the capability of the team had matched the design task profiles for previous projects, the inclusion of the participant observer in the design team for the Gasifier Test Rig could be seen as an attempt to reduce a mismatch between perceived capability and the new task profile.

Two other contributing factors were identified in this category, these being 'technical risk' and 'urgency' or delivery time. Both were found to influence the project, the high technical risks weakening the resolve of the management to see the project through, and the lack of urgency making it difficult to sustain sufficient project momentum.

Design Team

It is suggested in the literature that an ideal engineering design team should be: competent; experienced; well-balanced; cooperative; committed; and motivated! Other contributing factors identified were: morale level; negotiating ability; strength of power base within the company; end-user involvement in the design effort; and the match of design team composition to project requirements in each phase of the work.

With so many 'team' factors likely to affect the project it appeared that the design team composition would be an important aspect, and the evidence supported this. Expertise and experience, closely followed by motivation and commitment, were observed to be critical factors. When the team had suitable expertise and experience the project progressed, when it lacked these it stood still. To some degree this was shown in Figure 2-10, and it helps to explain the 'peaky' nature of the work effort. The month when almost twice the effort went into the project than in any other was when the contract controls engineer from Chicago temporarily joined the team. This engineer had not worked outside the U.S.A. before and was therefore operating in a foreign environment. However he had both the expertise and experience needed for designing the control system, and the motivation and commitment to see this part of the project through. From the morning of Saturday 12 May 1984, when he was met at Gatwick Airport by the contract design engineer, to the Saturday morning two weeks later when he flew back to Chicago, there was a marked change in the performance of the team. He was immediately accepted for the missing expertise and experience which he could provide, and for those two weeks he brought to the project a sense of purpose and urgency strong enough to ensure that the entire control system was designed within the two weeks. The Process and Instrumentation (P & I) diagram involving over 100 valves was completed; the seven control panels were detailed; sensor tables, valve operating sequences and shutdown procedures were drawn up; a report was issued for use in the hazards analysis and in obtaining bids for construction; and a 2-hour presentation meeting was held. Vacations were rearranged, a valve manufacturer offered enthusiastic help, management interest in the project was revived, and the project manager wrote to the contract controls engineer on 29 May: "The amount you accomplished in such a short time is beyond belief...it is very reassuring to have this essential part of it (the rig) defined with such skill and expertise."

As the participant observer had carefully set up this 'experiment' to make sure that it benefited the project, the field data from it was considered to be more that of 'action research' than of participant observation, and the high peak on the graph in Figure 2-10 was regarded as an indication of the success of the experiment rather than an effect of normal influences. However the second highest peak, in Month 30, demonstrated the same effect in a situation not manipulated by the participant observer. In this case the arrival of a qualified contract detail designer within the Services group dramatically increased the design productivity. Within one week the detail design of the scrubber was progressing well, and by the end of the following week the detail drawings for the scrubber were almost complete. For two months the project progressed rapidly again, but in Month 31 the contract detail designer was required on higher priority work, and project momentum was lost. From then on progress depended on negotiations between the project management and the Services group, and the low priority of the project without construction approval meant that the final drawings were completed in a piecemeal fashion over a long period of time.

Although the most important factors observed were to do with 'functional roles' (or expertise) in the team, an attempt to assess the influence of what Belbin calls 'team roles' (I2) was also made. A team may be adequate in a functional sense, having the right expertise and experience, yet may not have the right balance of personalities to be productive. Belbin's research on management teams suggests that, to be productive, teams need a mix of personalities covering eight basic 'team-roles', with the addition of a ninth ('specialist') role in technical situations. Using Belbin's terminology these nine roles are:

Company Worker (practical organizer);

Chairman (goal-setter and motivator);

Shaper (dynamic pusher);

Plant (creative problem-solver);

Resource Investigator (information-gatherer and negotiator);

Monitor-Evaluator (option-analyser);

Team Worker (perceptive listener);

Completer-Finisher (conscientious perfectionist);

Specialist (dedicated professional).

Almost identical team-roles have been proposed by Ryssina and Koroleva (I24) in the USSR, based on their study of team performance in engineering research institutes. They found that for teams involved in technological innovation the roles which were the key at any particular time depended on the phase of the project.

To obtain some 'team-role' data from the Gasifier Test Rig project those participants contributing the most hours to the project effort were asked and encouraged to complete the 'Self-Perception Inventory' developed by Belbin (I2, pp.153-158). Although the questionnaire was completed without adverse reaction by the contract staff it was regarded with some suspicion by Company staff, and the plans to gather such data for each phase of the project had to be abandoned. Nine questionnaires were returned, of which seven were complete. Despite the dubious response from the Company staff, including a written commentary from one who felt that the questionnaire was biased in certain directions, the results were sufficient to indicate team-role differences between participants and the influence these had on the project:

(i) Contract staff had relatively even scores across all team-roles, which indicated more of an ability to switch from role to role than to provide strength in one or two. The average score for all three contract staff showed most strength in the role of Company Worker and least in that of Monitor-Evaluator. Scores for two of these design engineers were virtually identical for six of the roles.

(ii) Company staff scores showed more spread than those for contract staff, but the average scores for the group were uniform, as the highs and lows cancelled out. The group appeared to be marginally stronger in the role of Plant over other roles, and slightly weaker in the roles of Company Worker and Completer-Finisher.

(iii) The average scores for the seven Self-Perception Inventories varied very little from role to role, as the strengths shown by the scores of the contract staff tended to complement those shown by those of the Company staff. This is somewhat academic, as two of the three contract staff were involved in the project only for short periods of time, but the project seemed to rapidly progress when these contract staff were present. It leads to speculation that they not only supported the team through functional roles, but also through an improvement in the overall balance of team-roles.

(iv) All three contract staff were professionally involved in design yet their scores for the role of Plant (creative problem-solver) were lower than for most other roles. As the concept for the rig was considered satisfactory it suggests that for this project the role of the creative problem-solver was less important than other roles.

(v) Credibility of the participant observer as a design engineer did not extend to that needed for obtaining social psychology data.

Design Techniques

A more systematic design approach was used for this project than had been used before by the team, and it included the use of procedures recommended by Pahl and Beitz (B48). These were important influencing factors as they provided an overall structure for the work and a selection of techniques to use in each phase. The techniques used were detailed in Chapter 2 and the effect of their use is illustrated by one or two examples here. When the project started the management staff were enthusiastic, but later this enthusiasm declined as was shown in Figure 2-41. However, with others in the project team the opposite happened; enthusiasm increased with time. The evidence is that this came from an increasing appreciation of what the systematic design approach, and the techniques, had to offer. A sign of this was on 22 December 1982, when the design specification was about to be circulated for review. One team member who had been sceptical of the whole design approach up to that point asked: "... why don't I (contract design engineer) just get on and design the rig; why the big act with paperwork? I showed him that the specification puts it all down on paper and no-one can then come back later and say that this or that was not discussed. He suddenly saw what this meant and regarded the whole thing in a new light - said he would look at it much more carefully now." [Notes]

Of all the techniques used, the one which had the most influence was the procedure for preparing a design specification. By the end of the detail design phase it had been used for three other projects (not within the same group), had been adopted personally by the contract detail designer and had prompted a manager to say that everyone was going around talking about 'Demands and Wishes'! The technique of brainstorming had been tried unsuccessfully before by the same group, but the more carefully organized brainstorm during the Gasifier Test Rig project produced over 400 ideas in 40 minutes and was felt to be well worthwhile. With regard to discursive techniques for concept selection and evaluation as recommended by Pahl and Beitz, the following interchange was tape-recorded on 18 April 1983:

SL_A: "After a somewhat tortuous process I feel that we have produced a concept which in many respects is similar to the way I would have done it if I had been sitting down and having to draw it out from square one. I think this illustrates the fallibility of the technique at generating ideas when you are up against certain really insuperable technological difficulties."

CDE (Participant Observer): "The thing is, has it helped us clarify the ideas behind the concept?"

SL_A: "Well I think the great thing about it is that one feels that there isn't really a better way, and that's a great comfort to anyone who is doing design. You feel that you've covered all the angles and that, within the limits of one's own abilities you've not let anything slip by. There possibly were some different solutions which have been rejected simply because we feel that those on their own would mean a research programme to solve or which would have added significantly to the cost of pressure vessel construction...I feel with the financial and time barriers against us we have come up with the most appropriate design."

Three other influencing factors observed were the 'working techniques', 'communicating techniques' and 'motivating techniques' which were detailed in Chapter 2 (Figures 2-24 to 2-30). Some observed effects were:

(i) Questioning people to gain more information was continually used, accounting for 7% of the recorded hours.

(ii) Personal views had a large influence on the project proposal but almost none during task clarification.

(iii) Negotiations between people accounted for 8% of the project effort and was a continual influence.

(iv) As 14% of the work effort was spent in reporting and reviewing progress, the way this was done certainly influenced the project.

(v) Occasionally the personal involvement of a particular participant helped to helpedto overcome difficulties which otherwise would have caused serious delays to the project.

(vi) By a conscious effort to maintain enthusiasm within the design team the effect of the low morale of several team members was overcome and, even though management interest in the project slowly fell off with time, the enthusiasm of the design team was gradually raised.

(vii) Humour was rarely a feature of the project during the first phases, but during detail design it helped to defuse some potentially tense situations.

Within the Company the use of computers was commonplace but no computer-aided design facilities were available at the time and, as the project was a 'one-off', there were only a few design tasks which could have been done more quickly by using a computer. One was the design of the pressure vessel to BS 5500 or ASME VIII, Division 1 (pressure vessel code), and the participant observer attended the Whessoe training course to investigate this possibility. However, the design of vessels having flat 'heads' and Grayloc or O-ring closures was not within the scope of existing software (requires use of Appendix-Y in ASME VIII), and in the end all calculations were done by hand. (See Appendix A-3, Report GTR-5). Had some appropriate computer assistance been available for the reactor vessel design, it would have considerably reduced the time required for this part of the the work, and the effect would have shown as a smaller 'hump' for the Detail Design phase in Figure 2-10. The use of computers, with the ease of working in different systems of units, would also have alleviated the problem over units mentioned below. As more work effort went into detail design than in any other phase, it was the Detail Design phase where the best return could have come from the use of computer aids, if they had been available.

With regard to the use of standards and codes, a time-consuming debate arose as to whether the Gasifier Test Rig should be designed in metric or imperial units. BS 5500 is in metric, and was the preferred pressure vessel 'code' but for the design of the flat-faced flanges BS 5500 refers the designer to ASME VIII, Div.1, Appendix-Y which is in imperial units. Standard metric bolting was not available in the sizes required for the vessel, and although the Company's policy is generally to use metric it appeared that as far as valves and fittings were concerned imperial sizes were preferred. Team members used whichever system they personally chose, and for the Gasifier Test Rig no firm decision was ever made. The result was that the final drawings were in a mixture of units! This problem of units was by no means simple. For example to reduce the danger of mixing non-compatible metric and imperial-sized standard components the tendency is for only imperial-sized items to be stocked in the stores, despite the change to metric elsewhere in the Company.

Design Team Output

Two factors regarding work output influenced the course of the project. One was team productivity, which varied considerably depending on factors previously discussed, and the other was the quality of the work, which depended largely on the expertise and experience of the people. In a sense team output was seen as the resultant of all influencing factors, and it leads to the assessment of effectiveness, efficiency and success.

The observed influences at the project level are summarized in Figure 3-5, with an assessment of their impact and a list of literature sources.

3.2.6 Personal Level

Influences at the project level are dependent on those at a personal level and although the capability and personality of each individual was not the concern of this study, factors which influenced the project were recorded. The tentative influence categories and contributing factors identified are shown in Figure 3-6, together with relevant literature sources.

3.3 Project Assessment

3.3.1 Effectiveness

In Chapter 1 a review of the literature suggested that effectiveness is concerned with the productivity and quality of output from an activity, and that it is dependent on viewpoint. For the Gasifier Test Rig project an attempt was made to assess effectiveness of the design effort in terms of the phases of the design process as used in Chapter 2, and the five levels of resolution as used in Chapter 3. At the Macroeconomic Level the impact of the project was insignificant, and no evaluation was possible. At the Microeconomic Level, which for this project was the same as the Corporate Level, the field data indicated that although construction of the test rig did not go ahead the design process was considered effective for all phases except Detail Design. The viewpoint at this level was a long-term one, in which the project timescale was small, and whether or not the test rig was ever built was of little consequence. What was seen as important was that new ideas had been developed, and the approach used for the engineering design process had been better than that used before.

At the Project Level, where the concern was with the test rig itself, a more objective assessment of effectiveness was attempted with reference to the Ideal Phase Diagram shown in Figure 2-11. In addition to the two assumptions made in Chapter 2, a third one was added as follows:

(i) Project cost directly proportional to project effort in hours.

(ii) All hours contributed equally to the project effort.

(iii) Design effort shown within the ideal envelope for a phase contributed directly to the necessary effort for that phase.

These assumptions were considered reasonable approximations according to the data and, based on them, effectiveness as 'doing the right things' could be regarded as: 'completing design work within the envelope of the Ideal Phase Diagram'. A measure of effectiveness for each project phase was then the proportion of design effort completed within the ideal curve for that phase. Overall effectiveness was considered to be the proportion of overall design effort completed within the envelope of the Ideal Phase Diagram, and was measured as 70%. Assessments of effectiveness by phase, using graphical area comparisons, were as follows:

(i) The project proposal effort was completed within the ideal envelope and was assessed as 100% effective.

(ii) Task clarification effort was almost wholly completed within the ideal envelope and was assessed as 90% effective.

(iii) Conceptual design was considered adequate, but it was not completed within the ideal envelope due to factors such as a loss of effort through vacations. This reduced the effectiveness of the effort: the cost justification for rig construction was late and lacked strength. Conceptual design effort was assessed as 75% effective.

(iv) The low level of effort during embodiment design, mainly due to the effect of external influences stalling the decision on construction funding, resulted in poor effectiveness during the phase. Even the massive effort on the control system design, completed outside the ideal envelope, did not compensate for the previous loss in effort. Embodiment design effort was assessed as 50% effective.

(v) Detail design started near a holiday period when motivation was low and the project team lacked a qualified detail designer. Much of the work effort was outside the ideal envelope, and momentum was lost. Detail design effort was assessed as 70% effective.

At the Personal Level there seemed to be general agreement that the first three phases of the engineering design process were effectively carried out, but for embodiment and detail design it depended on the the role of the assessor. For example the participant observer saw the the design of the control system as an extremely effective 'project-within-a-project', even though it came too late to ensure that the overall embodiment design effort was effective.

3.3.2 Efficiency

From the literature review in Chapter 1 it was suggested that a system is efficient "when it does well what it does" (A41), and that assessment of efficiency depends on the viewpoint taken. To attempt an assessment for the engineering design process in the case of the Gasifier Test Rig the project was again considered in terms of its phases and the five levels of resolution. At the Macroeconomic Level the assessment of efficiency depended on comparison with other similar projects, and no suitable data was available for this. At the combined Microeconomic and Corporate Level there was enough data available from previous projects to indicate that the proposal and task clarification design effort on this project could be considered comparatively efficient. For the other three phases there was insufficient data for an assessment, although the design effort on the control system was assessed as highly efficient from all viewpoints.

At the Project Level reference was again made to the Ideal Phase Diagram in Figure 2-11, to attempt a more objective assessment. Based on the same three assumptions as used for assessing effectiveness, a tentative measure of efficiency as 'doing things right' was considered to be: 'completing the design effort for each phase to match the time-span and overlap in the Ideal Phase Diagram'. This offered a measure of efficiency not in terms of how quickly the whole project was completed (which was irrelevant) but to what extent the work in each phase was completed within the agreed schedule for that phase. It took account of the fact that conditions laid down at the outset made the work schedule for each phase contingent on the outcome of the preceding phase. Thus a tentative measure of 'efficiency' for each phase of the engineering design process was seen as the ratio of 'ideal time-span' to 'actual time-span' for each phase. From this an average efficiency of 75% was assessed for the overall design process, and the results for each phase were:

(i) Proposal effort 95% efficient.

(ii) Task clarification effort 95% efficient.

(iii) Conceptual design effort 70% efficient.

(iv) Embodiment design effort 65% efficient.

(v) Detail design effort 65% efficient.

It is emphasized that this was just a preliminary attempt at trying to measure 'efficiency' of the engineering design process from this project data, and further research is needed on this.

At the Personal Level the assessment of efficiency varied widely depending on previous project experience. For example the participant observer saw the overall work effort as inefficient by comparison with similar projects carried out in other circumstances, but as comparatively efficient within this particular context.

3.3.3. Success

In Chapter 1 it was concluded that success is seen to be dependent on time and on viewpoint, and that perhaps in regard to the engineering design process it could be assessed at the end of each phase. Based on evidence from the field data the following summaries indicate what appeared to be the relative success for each project phase, as seen from the combined Microeconomic and Corporate Level, the Project Level and the Personal Level. No general assessment could be made at the Macroeconomic Level.

Corporate Level

It was mentioned above that the viewpoint at this level was a long-term one in which the Gasifier Test Rig itself was a very minor part. Even at the beginning, the project objectives included wider aspects than just the engineering design of a test rig (see Appendix A.2), and it was generally in regard to these that the success of the project was evaluated from the corporate viewpoint. The Proposal, Task Clarification and Conceptual Design Phases were considered successful in a technical sense for this particular rig, but also because they introduced new ideas regarding the approach to the design of any such rig. In particular the technique for producing the design specification was later used for other projects. The Embodiment and Detail Design Phases had little impact at the corporate level, and only the rapid completion of the control system design resulted in evidence to indicate that the project was considered successful at this stage. A series of discussions were held regarding the lack of resources available to the project for detail design, and later there was evidence that major improvements had been made for the benefit of future projects.

Project Level

At the project level the first three phases were considered successful when compared with previous projects carried out by the same project team. The design specification was considered better, concepts were more fully explored and the final concept allowed for various reactor configurations to be tried without modifying the vessel or its controls (i.e. low 'concept vulnerability'). Communication within the project team was better and the design work was better recorded. This also applied to the embodiment and detail design effort but, from the project viewpoint, the failure to secure the funding for construction was in fact a failure of the project. Even the technical success of the control system design could not be evaluated as 'successful' from the project viewpoint while funding for construction was not forthcoming. As mentioned before, this stemmed more from the effect of external influences than from weaknesses in the design effort, and it illustrates a situation often encountered by engineering design teams in industry.

Personal Level

Each person involved with the project had a different interest in it, and different expectations from such involvement. To the Directors it was a matter of research policy; to the Managers a project which could enhance or reduce future prospects depending on many factors; to Research Staff it offered improved materials test equipment; to the Services Staff it was another project to be accommodated somehow; to the Contract Staff it was a design project to be completed as well as possible; and to the Specialist Suppliers it was a chance to sell more of their products. To others it was only of passing interest.

The 'success' of the project from each individual viewpoint ranged from complete failure (Suppliers who provided design help at their own expense but received no orders) to complete success (Contract Controls Engineer who received payment and congratulations for a job well done). The only generalized assessment which could be made at this level is that up until it became known that construction of the rig would be deferred there was a feeling that the project had been successful, and thereafter the opposite feeling prevailed. The evidence for this could be seen in the change of 'mood' of team members as they gradually became aware of the situation.

3.4 Conclusions

(i) A qualitative analysis of the field data for the project provided contextual evidence to support the quantitative analysis of the engineering design process.

(ii) The Context Model described in Chapter 2 was used to define five levels of resolution for structuring the qualitative analysis.

(iii) A list of 103 influencing factors likely to affect the engineering design process was generated from relevant literature, grouped by resolution level into 20 categories of influence.

(iv) Evidence from the field data was used to determine the effect of each influencing factor on the engineering design process for this project, and the overall results are summarized in Figure 3-7.

(v) The greatest effect on the project was observed to have come from: External Influences; Availability of Resources; Corporate Systems; Management Style; the Design Team; and Design Techniques used.

(vi) The average effectiveness of the engineering design process during the project was assessed as 70% based on design work completed within the envelope of the Ideal Phase Diagram for the project. Three project-specific assumptions were used.

(vii) The average efficiency of the engineering design process during the project was tentatively assessed as 75%, based on the ratio of the sum of ideal phase time-spans to the sum of actual phase time-spans. Three project-specific assumptions were required for this.

(viii) The Proposal, Task Clarification and Conceptual Design phases of the engineering design process were seen as successful from all viewpoints. The Embodiment and Detail Design phases were seen as successful from the Corporate viewpoint, less successful from the Project viewpoint, and Personal viewpoints varied widely.

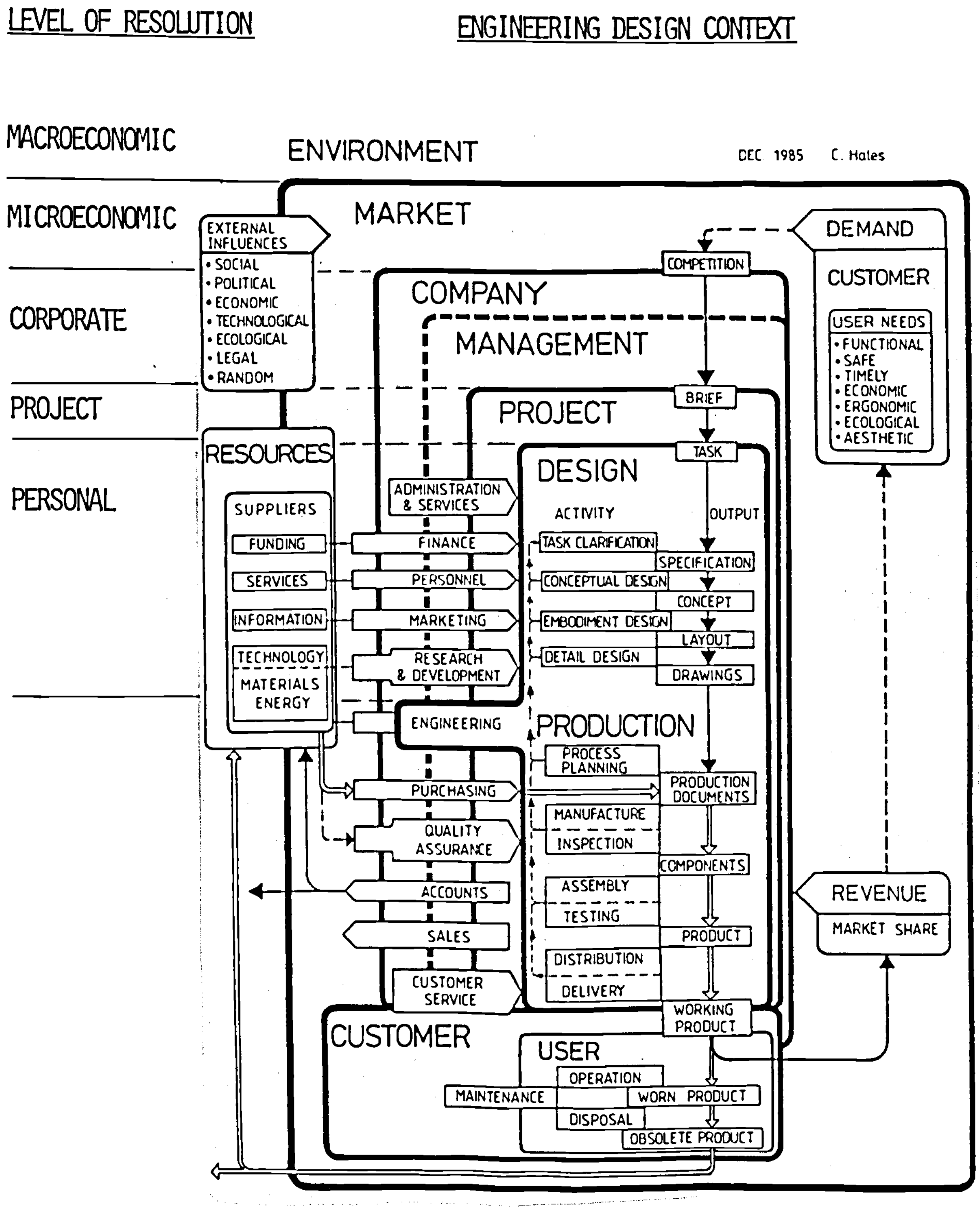


Figure 3-1 Context Model Showing Levels of Resolution

MACROECONOMIC LEVEL

INFLUENCE CATEGORY	CONTRIBUTING FACTORS	OBSERVED IMPACT High	Med	Low	REFERENCES
External Influences	Social			X	[A34,38,44;B36;D10; F2,8;G3;H47;I28]
	Political	X			[A38,44;B36;D10;F8,9; H6,16,47]
	Economic	X			[A34,44;B36;D10;F7,8, 9;G3;H43,47]
	Technological		X		[A34,44;B36;D10;G3; H6,34; I6,7]
	Ecological		X		[A44;F6;I28]
	Legal		X		[A38,44;C13;F3,4,5,9, 10;I27]
	Random		X		[A34;B36;C34;H16;I6, 27]

FIGURE 3-2 MACROECONOMIC LEVEL INFLUENCES

MICROECONOMIC LEVEL

INFLUENCE CATEGORY	CONTRIBUTING FACTORS	OBSERVED IMPACT High	Med	Low	REFERENCES
Market	Demand	X			[A14,33,34,38,44;D10; G4,5,6,9,11;H16,19, 43,46,47;I6,7,9,10.]
	Competition	X			
	Financial Risk		X		
Resource Availability	Services (Human)	X			[A33,38,44;B51;C17, D8,10;G4,7,9,10;F9; H6,21;I6,7,9,11;I15, I28.]
	Finance (Capital)		X		
	Information	X			
	Technology			X	
	Materials			X	
	Energy			X	
Customer	Clarity of Need	X			[G2,3;H32;I9]
	Urgency of Need	X			[A33;H44;I9]
	Expectations	X			[A14,38;B40,51;C13; D19;H44;G1,8,I10,21]
	Involvement	X			

FIGURE 3-3 MICROECONOMIC LEVEL INFLUENCES

CORPORATE LEVEL

INFLUENCE CATEGORY	CONTRIBUTING FACTORS	OBSERVED IMPACT High	Med	Low	REFERENCES
Corporate Structure	International Span			X	[D6,10;F8;H8,9,14,16, 17,19,20,30,32,35, 39,41;47.]
	National Span		X		
	Overall Size		X		
	Local Size			X	
	Complexity		X		[A18,44;C13;D2,3,4,6, 10,16,F8,9;H1,6,8,9, 26,23,30,35,36,37, 40,41,42,46;I9,14.]
	Flexibility		X		
	Centralization		X		
	Project Autonomy	X			
Corporate Systems	Integration		X		[A18;H14,35,38;I28]
	Information Use	X			[B57;C16;D10;H21;I6]
	Technical Complexity		X		[A49;D10;H14,H39]
	Physical Environment	X			[C13;D10;F9;H1,18,47]
	Social Environment	X			[C13;D10;F9;H7,11,18]
	Pay and Benefits	X			[D10;F8,9;H1,14,31]
Corporate Strategy	Clarity of Objectives	X			[A19,44;D10;H6,14,35]
	Risk-Taking	X			[D10;H6,16,25,32,42]
	Innovation		X		[D10;F9;H4,6,32,35]
	Involvement	X			[A19;C23,33;H6,35;I6]
Shared Values	Commitment	X			[A19,44;C7,34;D10,15; G7;H8,9,13,15,23,33, 34,35,47;I1,22,28.]
	Enthusiasm	X			
Management Style	Autocratic Element			X	[H2,14,22,25,33,37]
	Benevolent Element	X			[H22,24,37]
	Consultative Element			X	[H7,22,24,33,35,37]
	Participative Element			X	[A18,19;D10;F8;H2,8, 14,23,26,37;I1,28]
Management Skills	Planning		X		[A18,38;H4,6,23,34]
	Organizing		X		[D10;H4,33,42;I5,22]
	Directing			X	[D10;F9;H4,40;I5,9]
	Coordinating			X	[D10;F8;H4,25,42;I5]
	Controlling			X	[A38;D10;H4,8,32,42]
	Communicating	X			[A18;C13,30;D10;H4,6]
	Representing (Champion)	X			[A19,34;D10;H4,6,35]
	Resource Utilization	X			[A33,38;C17;D10;H6, 12,14,23,25;I5]
Management Staff	Number	X			[A18,19,44;D10;H6,35]
	Awareness		X		[A19;D10;H4,9,30,32]
	Judgement (Decisions)	X			[D10;H27,28,36;I1,6]
	Motivation		X		[A19,34;D10;H1,14,45]
	Morale		X		[A19;D10;H1,14,19,35]
	Confidence	X			[A19;H8,9,35,42]

FIGURE 3-4 CORPORATE LEVEL INFLUENCES

PROJECT LEVEL

INFLUENCE CATEGORY	CONTRIBUTING FACTORS	OBSERVED IMPACT High	Med	Low	REFERENCES
Design Task	Magnitude		X		[C13;D18;H26,46]
	Complexity		X		[C13;D18;I23,25,27]
	Novelty	X			[A38;C13;D18;I9,10]
	Production Quantity		X		[A49;C13;D18;I10,27]
	Technical Risk	X			[C13;D10;H47;I10,27]
	Delivery Time (Urgency)		X		[D5;H44;I11,20,28]
Design Team	Expertise (Competence)	X			[A44;C15;I9,22,28]
	Experience	X			[A44;C15;D10;I28]
	Role-Balance	X			[D11;I2,3,9,12,24]
	Cooperation		X		[A33;B36;D19;H6,38]
	Commitment	X			[A19;D10;H8;I4]
	Motivation	X			[A34;D10;H26;I22]
	Morale		X		[A19,34;D10;H15;I22]
	Negotiating Ability		X		[A18;D10;H25;I4,28]
	Power-Base			X	[D12,13;H1,8,9;I28]
	User-Involvement	X			[A14;C7;H6,8;I21,27]
Design Techniques	Systematic Approach	X			[A38;B31,48,51;C33]
	Formal Procedures	X			[C24;B23,36;I16,18]
	Working		X		[A38;C13,15;B48;I26]
	Communicating	X			[C30;H6;I11,15,22,28]
	Motivating	X			[A19,34,44;D10;H14]
	Computing			X	[D1,10;I28;J8]
	CAD			X	[A44;D10;I9,28;J8]
	Standards and Codes		X		[A38,44;B48;H47;I10]
Design Output	Productivity	X			[D16,17;H23,34;I22]
	Quality of Work	X			[B9,D5,6,7,9;I1,22]

FIGURE 3-5 PROJECT LEVEL INFLUENCES

PERSONAL LEVEL

INFLUENCE CATEGORY	CONTRIBUTING FACTORS	OBSERVED IMPACT High	Med	Low	REFERENCES
Personal Knowledge	Knowledge-Base			X	[G7;H44;J1,2,3,4,6]
	Applicability	X			[G7;H44;J1,2,3,4,6]
Personal Skills	Judgement/Perception		X		[D10;G7;H3;I8;J11]
	Competence	X			[D10;H1,29;I22,28;J2]
	Communication		X		[C30;D10;H3;I8;J1]
	Creativity/Imagination		X		[D10;H42,44;I8;J8]
	Versatility	X			[A18;D10;H47;J4]
	Negotiating Power		X		[D13;H3,25,31;I4,28]
Personal Attitude	Work Standards	X			[D10;I28;J10]
	Self-Discipline/Habits	X			[B52;D10;I28;J1,7]
	Integrity		X		[I4,9;J10]
	Role-Compatibility		X		[A18;H42,44,47;I2;J9]
Personal Motivation	Enthusiasm	X			[A19;C33,34;D10;H35]
	Involvement	X			[A19;C23,33;D10;H10]
	Tenacity/Determination	X			[A34;D10;I4,8,28;J10]
	Anxiety			X	[A34;J5,9,11]
	Humour		X		[J2,9]
Personal Output	Productivity	X			[B52;D10;H34,44;J10]
	Quality of Work	X			[A44;D10;H11,34;J10]

FIGURE 3-6 PERSONAL LEVEL INFLUENCES

SUMMARY OF INFLUENCES AT FIVE LEVELS OF RESOLUTION

RESOLUTION LEVEL	INFLUENCE CATEGORY	CONTRIBUTING FACTORS
Macroeconomic	External Influences:	Political; Economic.
Microeconomic	Market:	Demand; Competition
	Resource Availability:	Information; People.
	Customer:	Clarity and Urgency of Need; Expectations; Involvement.
Corporate	Corporate Structure:	Project Autonomy.
	Corporate Systems:	Information Use; Environment; Pay and Benefits.
	Corporate Strategy:	Clarity of Objectives; Risk-Taking; Involvement.
	Shared Values:	Commitment; Enthusiasm.
	Management Style:	Benevolent Element.
	Management Skills:	Communication; Utilization of Resources; Representation.
	Management Staff:	Number; Decision-Making; Confidence.
Project	Design Task:	Novelty; Technical Risk.
	Design Team:	Expertise; Experience; Role-Balance; User-Involvement; Commitment; Motivation.
	Design Techniques:	Systematic Approach; Listing Requirements; Questioning; Negotiating; Reviewing and Reporting; Raising Enthusiasm.
	Design Output:	Productivity; Work Quality.
Personal	Knowledge:	Applicability.
	Skills:	Competence; Versatility; Negotiating Power.
	Attitude:	Self-Discipline; Standards.
	Motivation:	Enthusiasm; Involvement; Tenacity.
	Output:	Productivity; Work Quality.

FIGURE 3-7 MAIN FACTORS INFLUENCING GASIFIER TEST RIG PROJECT

CHAPTER 4

CONCLUSIONS AND APPLICATIONS

4.1 Overall Conclusions

4.1.1 Context of Engineering Design

The engineering design process is highly dependent on the context in which it takes place, and to analyse an engineering design project in industry it was found necessary to categorize the field data obtained according to hierarchical levels of context. A diagrammatic model with five levels of resolution was developed for this purpose, showing the Engineering Design Process set within the Project, within the Company, within the Market and within the External Environment. For the quantitative analysis the model helped in identifying the engineering design work effort within the total project effort, and for the qualitative analysis it provided a framework.

4.1.2 Quantitative Project Analysis

The one easily and accurately measured quantity in the engineering design process is work effort in hours. From it the related project costs may be derived, and resource utilization assessed. However, from an engineering design viewpoint the measurement of work effort in hours has no meaning without context. For this thesis a hybrid analytical approach was adopted which included the context. It was based on detailed quantitative data in terms of work hours, but complemented by qualitative data on the people, dates, type of work, location, topic, and mood. Work effort was analysed according to these qualitative data categories as well as by 'activities' and 'outputs' observed during the engineering design process. From the results it was possible to draw the following conclusions:

(i) The hourly work effort input to an engineering design project may be categorized in terms of five overlapping phases each consisting of a particular mix of procedüral steps and general activities.

(ii) When the work effort in each phase is plotted along a time-axis, a characteristic 'phase diagram' is obtained for that particular project. This may be compared with an 'Ideal Phase Diagram' for the same project, created assuming an idealized project situation, and the differences between them measured.

(iii) A plot of cumulative effort against time provides an approximate measure of 'percent completion' for an engineering design project, and comparison of this against an equivalent plot derived from the project's Ideal Phase Diagram gives a measure of achievement.

(iv) Design work not completed within the envelope of the Ideal Phase Diagram for a particular project will have to be completed at a later time, causing diversion of effort and increased costs.

(v) Changes to the design specification outside the ideal phase curve for Task Clarification cause increases in project effort and cost which may be measured partially by comparison of the actual and ideal phase diagrams for the project.

(vi) For the particular project studied, the procedural steps of the engineering design process as modelled by Pahl and Beitz accounted for 47% of the engineering design effort. Six other categories of general design 'activity' were added which accounted for the remaining 53%.

(vii) The Pahl and Beitz list of 'methods and aids' accounted for 22% of the observed engineering design effort. Thirteen additional categories of design-related techniques were identified which accounted for a further 74%. Four percent remained unclassified.

(viii) The activity which accounted for the highest proportion of the engineering design effort (22%) was found to be reviewing and reporting, and the most used design-related technique (15%) was found to be communicating by means of reviews and reports.

(ix) Theoretical and observed outputs were compared for each phase of the engineering design process, and actual outputs were evaluated in terms of quality and quantity. Those from the Proposal, Task Clarification and Conceptual Design phases were assessed as satisfactory in both quality and quantity. Those for the Embodiment Design and Detail Design phases were satisfactory in quality but productivity was low. In general the observed outputs were found to match those in theory except for the added cost justification documentation and the control system design in Embodiment Design.

(x) Over 50% of the observed project effort was carried out by people working alone or in pairs on specified tasks, 30% was spent in meetings involving 2, 3 or 4 people, and 9% was evenly divided between telephone calls and the writing or reading of letters.

(xi) Over 50% of the observed project effort took place in the personal office of one or other member of the project team, the remainder taking place in a variety of locations including conference rooms, cafeterias, passageways, at home and while travelling. Only 17% took place in the 'design office'.

(xii) A preliminary way of assessing the variations in 'mood' of project team members was developed and the results plotted for the project reflected the subjective assessments given by the team members.

4.1.3 Qualitative Project Analysis

The qualitative data obtained from the field study was used to provide an explanation for why things happened the way they did, and this was done by considering the various influences acting on the project at five different 'levels of resolution' according to the Context Model. From the relevant literature a tentative listing of 103 possible Contributing Factors was generated, and this was divided into 20 'Influence Categories'. Evidence from the field data was used to make judgements as to which of the factors had an effect on the project and to what extent. Those observed to have affected the project most strongly were as follows:

Macroeconomic Level -Political and Economic External Influences;

Microeconomic Level -Demand, Competition, Availability of Information and People, Clarity and Urgency of Need, Expectations;

Corporate Level -Risk-Taking and Clarity of Objectives;

Project Level -Expertise, Experience, Commitment, Motivation, Systematic Design Approach, Team Productivity and Work Quality;

Personal Level -Competence, Enthusiasm, Involvement, Tenacity, Self-Discipline, Personal Productivity and Work Quality.

An assessment of the effectiveness and efficiency of the engineering design process, and the success of the project, was attempted. Assuming that project costs were proportional to work hours, all hours were of equal contribution and that all hours were necessary, conclusions were:

(i) The average effectiveness of the engineering design process was assessed as 70% based on actual design work completed within the envelope of the Ideal Phase Diagram for the project.

(ii) The average efficiency of the engineering design process was tentatively assessed as 75%, based on the ratio of the sum of the ideal phase time-spans to the sum of the actual phase time-spans.

(iii) The overall degree of success was regarded as how well expectations of customer satisfaction, design output and project costs were met during each project phase. The Proposal, Task Clarification and Conceptual Design phases were considered successful from all view-points. While the Embodiment Design and Detail Design phases were considered successful from the combined Microeconomic and Corporate viewpoint, they were not from the Project viewpoint. Personal Level assessments ranged from successful for some participants to unsuccessful for others, depending on involvement and expectations.

4.1.4 Field Research Methods

Participant observation, the main field research method used during this study, enabled suitable data to be gathered for analysing the engineering design process. However there were a number of drawbacks to the method, which was based on the use of notebooks and audio tape-recordings.

(i) The method was found to be excessively time-consuming. For every hour of recorded design effort put in by the participant observer, about another hour (not recorded) went into writing up the field notes after the day's work. The stretched schedule planned for the project was an advantage from a design research point of view. Had the timescale had been shorter, another participant observer would have been needed to keep up with the data flow.

(ii) The method was found to be inefficient in that a lot of background and repetitive information was collected. This helped in verifying the data by 'triangulation' (cross-checking using data from several sources), but there was more redundancy than necessary.

(iii) The credibility of the participant observer as a design engineer did not extend sufficiently for the collection of team-role data. It would have been a great advantage to have had a second observer with the necessary credibility for collecting such data.

(iv) The participant observer had two separate types of work to perform in parallel: engineering design and 'social science' research. The two require different types of thinking and it was was necessary to alternate between them on a 'week-about' basis. This was found to be arduous, with conflicting demands on time.

(v) As the test rig was not built within the research timescale there was no performance data available to help in analysing the outputs from each phase of the design process. It was concluded that while participant observation of a project as it proceeds is probably the only way of obtaining data for analysing the design *activities*, a better way of obtaining data for analysing the design *outputs* might be to take the performance data from an operational system and work backwards through the project, considering the output of each phase in terms of the performance of the system in service.

In general the field notes, together with the usual type of design work output, provided adequate data for this study. At the time it had seemed important to also tape-record as much as possible, but the recordings were found necessary only for occasional reference, in particular where it had not been possible to keep up with the data flow by taking notes.

The overall conclusion with regard to the field research method was that the approach was appropriate for this study and that the effects of bias and distortion were lessened by the collection of redundant data over the 3-year timescale. However a more efficient way of recording and handling the field data would have greatly reduced the research effort required.

4.1.5 Data Reduction and Analysis

The task of reducing and analysing 1180 pages of field data was not easy. A manual method of colour-coding information and transferring it to data-sheets was devised, and this reduced data was fed into a computer database for sorting and analysing. The complete project is summarized on 48 pages of coded interchange records (Appendix A.1), and the 2368 hours of work from the 37 people can be detailed in a single table (Figure 2-14). The main database could be stored on two floppy discs. By using the computer to create summary databases, graphs and tables could be produced based on many more combinations of data than have been considered in this thesis. Overall conclusions regarding data reduction and analysis were as follows:

(i) A time-consuming but effective method for reducing the field data by a factor of 24 was developed, using interchange data sheets.

(ii) Commercially available software packages were suitable for handling the data, analysing the data and producing final tables and graphs.

(iii) The Interchange Data Sheet system developed could be used to record field data from a project directly, thus eliminating the need for detailed field notes and all subsequent compiling, coding, and data reduction. If this had been possible for the current project, the research effort would have been reduced by one year.

(iv) Using the Interchange Data Sheet system, it would be possible for field data to be fed directly into a computer database and analysed as it was generated. This could lead to a dynamic modelling of the engineering design process in the future.

(v) The data for this project is stored on standard floppy discs, using standard hardware and software. It could therefore be used by other design researchers (subject to data protection agreements) wishing to do comparative studies or to analyse the data further.

4.2 Applications of Findings

4.2.1 Management of Engineering Design

The conclusions from this study suggest that the effectiveness and the efficiency of the engineering design process are strongly influenced by the way the process is managed. A preliminary approach to the monitoring of design projects by phase has been developed and this, in conjunction with the tentative list of influencing factors identified, offers a more structured way of thinking about engineering design situations. With some development it is possible that a simple quantitative/qualitative analysis approach could help in the control of engineering design projects through 'compensatory tracking' of key influences.

Over 80% of the design effort on this project was done outside the 'design office', over 50% was done by people working alone or in pairs, and 9% involved letters or telephone calls. This suggests that in managing the engineering design process such things as individual working space and ready access to communication facilities are important factors.

4.2.2 Engineering Design Practice

As modelled in theory the engineering design process generally consists of a series of phases within which there are iterative steps. In practice the situation is more complicated than this, and it was found that if six general categories of 'activity' were added to the commonly used 'steps' within each phase, a more realistic model of what actually happened was produced. As over half the design effort for this project fell into the general categories of activity, rather than into the steps, the indication is that in order to improve the effectiveness of the engineering design process more emphasis needs to be put on how such activities as collecting information, cost estimating and reporting are carried out. Similarly, use of the 'methods and aids' often associated with the engineering design process accounted for less than one-quarter of the work effort on this project, while almost three-quarters was accounted for in the use of other working', 'communicating' or 'motivating' techniques. This suggests that the development of techniques for such things as questioning, negotiating, reviewing, reporting and motivating may be of importance.

4.2.3 Engineering Design Research

The possibility of using the techniques developed for collecting, coding, reducing and analysing field data in future studies has been mentioned. By building up compatible databases for different projects, higher level comparative studies and even higher level surveys could be provided with more reliable and uniform data than have been available in the past. It is likely that some of the additional engineering design 'activities' and 'techniques' observed during this project would be common to other design projects, and the aim has been to present the results in such a way that they may be compared with those from different projects in the future.

The Context Model, the Ideal Phase Diagram concept and the preliminary Checklist of Influences were developed also to try and help classify or 'profile' the project. Although much more research is needed in order to develop a simple way of doing this, the results so far indicate that it may be possible to classify engineering design projects in terms of their context, the relative work effort needed for each phase, the extent of phase overlap and the key influences acting at any particular time.

CHAPTER 5

RECOMMENDATIONS FOR FUTURE RESEARCH

5.1 Engineering Design Process

From the quantitative analysis of this project a number of possibilities and areas needing further research were identified:

(i) Development of the 'ideal phase diagram' approach for engineering design projects, possibly using statistical methods.

(ii) The monitoring of engineering design projects based on comparisons between ideal cumulative effort and actual cumulative effort.

(iii) Assessment of the effect that design work completed outside the 'ideal curve' for one phase has on other phases.

(iv) Investigation into the consequences of changing the design specification outside the 'ideal curve' for Task Clarification.

(v) Comparative studies of the 'activities' of the engineering design process for various types of project.

(vi) Comparative studies of the design-related 'techniques' used during the design process for various types of project.

(vii) Analysis of working products or equipment in terms of the output quality and quantity for each phase of the design process.

(viii) Analysis of relationships between design-related techniques used and the final design of a product or system.

(ix) Study of communications during the engineering design process.

(x) Investigation into relationships such as between techniques used and interchange type, and between design activities and location.

(xi) Development of techniques for assessing and monitoring the 'mood' of design project teams.

The results of the qualitative analysis also indicated a number of areas needing further investigation:

(i) Development of a 'checklist of influences' by detailed studies of particular 'categories of influence' and 'contributing factors' at each of the five levels of resolution shown by the Context Model.

(ii) Identification of key influences governing particular engineering design situations, and assessment of their impact on the project.

(iii) Profiling or characterizing engineering design situations by key influences according to a 'checklist of influences'.

(iv) Analysis of influences as 'constants' and 'variables', and also as project 'facilitators' (promoting the design effort) or 'barriers' (inhibiting the design effort).

5.2 Compensatory Tracking

It was concluded that a combined quantitative/qualitative analysis might be useful in the management of engineering design projects. The only way to prove this is by trying such approaches on real projects in industry. To collect the necessary data, 'action research' could be used instead of participant observation, with the researcher planning a design project and actively controlling it according to the results of ongoing data analysis. It is possible that from such research, techniques for the 'compensatory tracking' [Kempner (H19, p.409)] of design projects could be improved. Of particular interest would be the design team composition and how it may be adjusted to meet varying needs during each phase of a project.

5.3 Project Assessment

Although assessments of 'effectiveness', 'efficiency' and 'success' were attempted for the Gasifier Test Rig project the approaches used were based on assumptions specific to the project, and the results were tentative. A great deal more research is needed to help define the terms more precisely and to develop better assessment techniques for each one.

5.4 Project Classification

No accepted taxonomy exists for classifying design projects, which makes coordination of research effort and comparison of findings difficult. As concluded from this study, classification based on context, project phase characteristics and influences might prove feasible, but further research is needed. At the start of a design project many of the characteristics are already known, and perhaps a preliminary 'project profile' could be compiled [Mateev et al. (D17)], with blank spaces left for unknowns. The profile at this stage would consist mostly of those factors regarded as constant. This could be used as a general project classification, stored in a computer database. Assuming that many different projects had been classified in this way it would then be possible to search for projects having a particular combination of general characteristics, say: medium market demand; large company size; low project magnitude; high technical risk. More useful to the design researcher would be a classification which included a general assessment of the 'variable' characteristics as well. No data for this would exist until the project was in progress, but then full profiles could be compiled, perhaps at the end of each phase of the design process, allowing a more detailed classification at the end.

5.5 Literature Classification

Much of the development effort for the Context Model and the checklist of influences was spent in discovering and obtaining the relevant literature. The terminology problems referred to in Section 1.6 have tended to result in a poor choice of keywords for bibliographic databases in engineering design. Computer literature searches are currently of less help than they might be, and the manual scanning of literature in various disciplines is extremely time-consuming. A classification system more suited to the interdisciplinary nature of design is needed, as discussed by Hubka (B30). Archer (B5) suggested that 'Design' should be considered as a discipline in its own right, divided into sub-disciplines. Such an approach helps to classify types of design research, but is less helpful when it comes to classifying the literature related to design projects. From the project viewpoint it might be more appropriate to develop a classification system based on 'levels of resolution' and 'phases of the design process'. If a graphical mapping technique was feasible the research interest could be defined in these terms and the literature computer-searched for sources within the selected boundary.

5.6 Terminology for Design

As discussed in Section 1.6, engineering design terminology was found to be a difficult problem. Further research is needed to help develop a more universal terminology for design, compatible with the terminology in other disciplines.

5.7 Research Methods

Participant observation of projects in industry is adequate for obtaining the wide variety of data needed to gain a better general understanding of the engineering design process, but more efficient data collection methods are needed for dealing with different types of project and more than one project at a time. Techniques for investigating specific aspects, such as design 'quality' also need development through further research.

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H. CORPORATE LEVEL
I. PROJECT LEVEL
J. PERSONAL LEVEL

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APPENDICES

A. ii
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APPENDIX A.1

GASIFIER TEST RIG PROJECT - CASE DATA

A chronological listing of the database records for the complete project (excluding original 'mood' and 'remarks' columns) is provided in this section of the appendices. From this the database may be recompiled on any computer system and further analysis or comparison with data from other projects could be carried out. The key to the various column headings and codes used is given below, and further details on use of the database is given in Appendix C.

COLUMN	DESCRIPTION & CODES
INT_NO	- Interchange Number [See Appendix C].
PERSON	- Participant Code [See Fig. C-1 (p.C6) and Fig. 2-14 (p.63)].
DATE	- Date of Interchange by Month/Day/Year.
TYPE	- Interchange Type + Number of Participants + In or Out for L & T. [M - Meeting W - Work L - Letter T - Telephone I/O - In/Out] [See p.48 for details].
L	- Location [See p.49 for details]. [O - Own Office A - Another's Office N - Noisy Office] [D - Design Office L - Laboratory R - Conference Room] [C - Cafeteria B - Library P - Passageway/Lobby] [E - Outside T - In Transit H - Home/Hospital]
TOPIC	- Topic of meeting, work, letter or telephone call.
HRS	- Hours, rounded to one decimal place [0.1 hr].
£/H	- Cost/hour for participant including overheads [£ Sterling].
P	- Phase of engineering design process [See pp.34 & 35]. [P - Proposal T - Task Clarification C - Conceptual Design] [E - Embodiment Design D - Detail Design]
ACT	- Activity or 'step' within a phase of the design process. [For code list see Fig. 2-23 (p.69)].
TQ	- Design-related technique being used during interchange. [For code list see p.36 and Figs. 2-20 & 2-21 (p.65)].
M	- 'Mood' of participant project from project viewpoint [See p.51]. [+ - +ve 0 - neutral - - -ve]

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GTR PROJECT INTERCHANGES BY DATE AND NUMBER

INT/NO	PERSON	DATE	TYPE/L	TOPIC	HRS	£/H	P/ACT	TQ	M
1	M_A	03/01/82	M 4 O	PROJECT PROPOSAL	1.0	22	P ST	YQ	+
1	AM_A	03/01/82	M 4 A	POSSIBLE PROJECT	1.0	19	P ST	YQ	+
1	SL_A	03/01/82	M 4 A	PROJECT PROPOSAL	1.0	17	P ST	YQ	+
1	CDE	03/01/82	M 4 A	PROJECT PROPOSAL	1.0	17	P ST	YQ	+
2	M_A	04/23/82	T 2 OO	PROJECT PROPOSAL MEETING	0.1	22	P ST	YN	+
2	CDE	04/23/82	T 2 IO	PROJECT PROPOSAL MEETING	0.1	17	P ST	YN	+
3	AM_A	04/26/82	T 2 OO	ARRANGE MEETING	0.2	19	P XP	YN	+
3	CDE	04/26/82	T 2 IO	ARRANGE MEETING	0.2	17	P XP	YN	+
4	AM_A	05/04/82	M 4 R	PROPOSED PROJECT	2.0	19	P PP	YE	+
4	SL_A	05/04/82	M 4 R	PROPOSED PROJECT	2.0	17	P PP	YE	+
4	CDE	05/04/82	M 4 R	PROPOSED PROJECT	2.0	17	P PP	YE	+
4	RM_U	05/04/82	M 4 R	PROPOSED PROJECT	2.0	17	P PP	YE	+
5	SL_A	05/04/82	M 2 R	FUNCTION OF RIG	1.0	17	P ST	YQ	+
5	CDE	05/04/82	M 2 R	FUNCTION OF RIG	1.0	17	P ST	YQ	0
6	SL_A	05/04/82	M 3 R	CHARACTERISTICS OF COAL	2.0	17	P XI	YQ	+
6	S1_A	05/04/82	M 3 R	CHARACTERISTICS OF COAL	2.0	13	P XI	YQ	+
6	CDE	05/04/82	M 3 R	COAL CHARACTERISTICS	2.0	17	P XI	YQ	0
7	CDE	05/06/82	W 1 O	PROPOSAL PREPARATION	9.0	17	P XR	YP	+
8	CDE	05/11/82	W 1 O	PROPOSAL PREPARATION	5.0	17	P XR	YP	+
9	CDE	05/14/82	W 1 O	PROPOSAL REVISION	6.0	17	P XR	YP	+
10	CDE	05/18/82	W 2 A	PROPOSAL PREPARATION	9.0	17	P XR	YP	+
10	RM_U	05/18/82	W 2 O	PROPOSAL PREPARATION	9.0	17	P XR	YE	+
11	M_A	06/28/82	T 2 OO	PROJECT PROPOSAL	0.5	22	P PP	YN	+
11	CDE	06/28/82	T 2 IO	PROJECT PROPOSAL	0.5	17	P PP	YN	+
12	SL_A	06/28/82	T 2 OO	TECHNICAL PROBLEMS	0.2	17	P PP	YQ	0
12	CDE	06/28/82	T 2 IO	TECHNICAL PROBLEMS	0.2	17	P PP	YQ	+
13	AM_A	06/29/82	T 2 IO	PROJECT FUNDING	0.5	19	P PP	YE	+
13	CDE	06/29/82	T 2 OO	PROJECT FUNDING	0.5	17	P PP	YN	+
14	AM_A	06/30/82	T 2 IO	FUNDING FORMS	0.1	19	P XC	YC	0
14	CDE	06/30/82	T 2 OO	FUNDING FORMS	0.1	17	P XC	YC	0
15	CDE	07/11/82	T 2 IR	DETAILED COSTS	0.3	17	P XC	YC	+
15	RM_U	07/11/82	T 2 OO	DETAILED COSTS	0.3	17	P XC	YC	+
16	AM_A	07/12/82	T 2 IO	PROJECT PROPOSAL	0.3	19	P XR	YN	+
16	CDE	07/12/82	T 2 OO	PROJECT PROPOSAL	0.3	17	P XR	YN	+
17	AM_A	07/15/82	T 2 OO	PROPOSAL COSTING	0.2	19	P XC	YN	+
17	CDE	07/15/82	T 2 IO	PROPOSAL COSTING	0.2	17	P XC	YN	+
18	CDE	07/20/82	M 2 E	FINAL DETAILS	1.0	17	P PP	YN	0
18	RM_U	07/20/82	M 2 E	FINAL DETAILS	1.0	17	P PP	YN	0
19	AM_A	07/26/82	T 2 IO	PROJECT FUNDING	0.2	19	P XC	YN	0
19	CDE	07/26/82	T 2 OO	PROJECT FUNDING	0.2	17	P XC	YN	+
20	AM_A	08/02/82	L 1 OO	FUNDING APPROVAL	1.5	19	P XC	YN	+
21	CDE	08/03/82	L 1 IO	FUNDING APPROVAL	0.5	17	P XC	YN	+
22	CDE	08/11/82	T 2 OO	PROPOSAL ACCEPTANCE	0.5	17	P XR	YN	+
22	RM_U	08/11/82	T 2 IO	ACCEPTANCE OF PROPOSAL	0.5	17	P XR	YN	+
23	AM_A	08/16/82	T 2 IO	PROJECT ARRANGEMENTS	0.2	19	P PP	YG	0
23	CDE	08/16/82	T 2 OO	PROJECT PLANNING	0.2	17	P PP	YG	0
24	CDE	09/15/82	M 2 A	REPORTING PROCEDURES	1.5	17	P PP	YR	+
24	RM_U	09/15/82	M 2 O	REPORTING PROCEDURES	1.5	17	P PP	YE	+
25	AM_A	09/22/82	T 2 IO	PROJECT FUNDING	0.1	19	P XC	YN	-
25	CDE	09/22/82	T 2 OO	PROJECT FUNDING	0.1	17	P XC	YN	-
26	SL_A	09/29/82	T 2 IO	MEETING ARRANGEMENTS	0.1	17	P XP	YT	0
26	CDE	09/29/82	T 2 OO	MEETING ARRANGEMENTS	0.1	17	P XP	YT	0

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GTR PROJECT INTERCHANGES BY DATE AND NUMBER

INT/NO	PERSON	DATE	TYPE/L	TOPIC	HRS	£/H	P/ACT	TQ	M
27	CDE	10/06/82	W 1 O	PROJECT PLANNING	2.0	17	T XP	YR	+
28	CDE	10/08/82	W 1 O	PROJECT PLANNING	2.0	17	T XP	YL	+
29	CDE	10/11/82	W 1 T	NOTES FOR MEETING	1.0	17	T XP	YL	+
30	SL_A	10/11/82	M 3 R	GASIFIER & TEST RIG	2.0	17	T CP	YQ	+
30	R1_A	10/11/82	M 3 R	GASIFIER & TEST RIG	2.0	13	T CP	YQ	+
30	CDE	10/11/82	M 3 R	GASIFIER & TEST RIG	2.0	17	T CP	YQ	0
31	SL_A	10/11/82	M 4 R	HISTORY OF JOB + COAL	2.0	17	T CP	YQ	0
31	R1_A	10/11/82	M 4 R	HISTORY OF JOB + COAL	2.0	13	T CP	YQ	+
31	S1_A	10/11/82	M 4 R	PROJECT HISTORY & COAL	2.0	13	T CP	YQ	+
31	CDE	10/11/82	M 4 R	HISTORY & COAL	2.0	17	T CP	YQ	0
32	CDE	10/12/82	W 1 O	PROBLEM STATEMENT	3.5	17	T CP	AP	0
33	CDE	10/13/82	W 1 O	PRELIMINARY D & W LIST	2.0	17	T CP	YL	0
34	CDE	10/15/82	M 2 A	PROBLEM STATEMENT	0.5	17	T CP	AP	+
34	RM_U	10/15/82	M 2 O	PROBLEM STATEMENT	0.5	17	T CP	AP	0
35	CDE	10/17/82	W 1 H	MODIFIED D & W AND LETTER	3.0	17	T CP	YL	0
36	CDE	10/18/82	W 1 O	LETTER & INFORMATION PACKAGE	3.0	17	T CP	YR	+
37	SL_A	10/18/82	T 2 OO	MEETING DATE + GASIFIER NAME	0.2	17	T XP	YN	0
37	CDE	10/18/82	T 2 OO	MEETING DATE/ TEST RIG NAME	0.2	17	T XP	YN	0
38	CDE	10/18/82	L 1 OO	MAILED LETTERS & INFO	0.2	17	T XR	YN	0
39	SL_A	10/19/82	L 1 IO	DEMANDS & WISHES	0.3	17	T CP	SP	0
40	R1_A	10/19/82	L 1 IO	DEMANDS & WISHES	0.1	13	T CP	SP	0
41	CDE	10/25/82	W 1 O	PREPARE FOR MEETING	3.0	17	T CP	YL	+
42	SL_A	10/26/82	W 2 R	REVIEW DEMANDS & WISHES	1.5	17	T CP	YC	0
42	CDE	10/26/82	W 2 R	REVIEW P.S. AND D'S & W'S	1.5	17	T CP	YC	-
43	M_A	10/26/82	M 8 R	PROJECT PLANNING	1.5	22	T XP	YM	+
43	M_S	10/26/82	M 8 R	PROJECT PLANNING MEETING	1.5	22	T XP	YM	+
43	AM_A	10/26/82	M 8 R	PROJECT PLANNING MEETING	1.5	19	T XP	YE	+
43	SL_A	10/26/82	M 8 R	PROJECT PLANNING	1.5	17	T XP	YE	+
43	R2_A	10/26/82	M 8 R	PROJECT PLANNING	1.5	13	T XP	YM	+
43	BPO_S	10/26/82	M 8 R	PROJECT PLANNING	1.5	14	T XP	YE	+
43	SO_S	10/26/82	M 8 R	PROJECT PLANNING	1.5	14	T XP	YE	+
43	CDE	10/26/82	M 8 R	PROJECT PLANNING MEETING	1.5	17	T XP	YE	+
44	BPO_S	10/26/82	M 2 O	COST ESTIMATING	1.5	14	T XC	YC	+
44	CDE	10/26/82	M 2 O	COST ESTIMATING	1.5	17	T XC	YC	+
45	SL_A	10/27/82	W 1 O	REVIEW DEMANDS & WISHES	1.5	17	T CP	SP	0
46	CDE	10/27/82	W 1 O	MINUTES OF MEETING	1.3	17	T XR	YR	0
47	SL_A	10/28/82	T 2 OO	ADDITIONS TO DEMANDS+WISHES	0.3	17	T CP	YL	0
47	CDE	10/28/82	T 2 IO	ADDITIONS TO D'S & W'S	0.3	17	T CP	YL	0
48	AM_A	10/29/82	T 2 IO	PROJECT ORGANIZATION	0.2	19	T XP	YT	0
48	CDE	10/29/82	T 2 OO	PROJECT ORGANISATION	0.2	17	T XP	YT	0
49	SL_A	10/29/82	L 1 IO	MEETING MINUTES	0.1	17	T XR	YR	0
50	R1_A	10/29/82	L 1 IO	PROJECT MEETING MINUTES	0.1	13	T XR	YR	0
51	R2_A	10/29/82	N 1 IL	PROJECT MEETING MINUTES	0.1	13	T XR	YR	0
52	CDE	10/29/82	M 2 A	PLANNING OF BRAINSTORM	0.5	17	T XP	YT	+
52	RM_U	10/29/82	M 2 O	PLANNING/BRAINSTORM	0.5	17	T XP	YT	+
53	RM_U	10/29/82	L 1 IO	MEETING MINUTES	0.1	17	T XR	YR	+
54	SL_A	10/29/82	L 1 OO	RIG FACILITY	0.4	17	T XI	YQ	0
55	BPO_S	10/29/82	L 1 IO	RIG FACILITY	0.1	14	T XI	YQ	0
56	CDE	10/30/82	W 1 H	ORGANISATION CHARTS	4.0	17	T XP	YT	0
57	AM_A	11/02/82	T 2 OO	CONTRACT CLAUSES	0.2	19	T XP	O	0
57	CDE	11/02/82	T 2 IO	CONTRACT CLAUSES	0.2	17	T XP	YE	0
58	AM_A	11/02/82	L 1 OO	PROJECT ORGANIZATION	0.5	19	T XP	YT	0

GTR PROJECT INTERCHANGES BY DATE AND NUMBER

INT/NO	PERSON	DATE	TYPE/L		TOPIC	HRS	£/H	P/ACT	TQ	M
59	AM_A	11/03/82	L 1	OO	CONTRACT FOR CDE	2.0	19	P XC	YN	0
60	CDE	11/05/82	W 1	O	PROJECT SCHEDULE	1.0	17	T XP	YG	0
61	CDE	11/05/82	M 2	O	CDE INVOLVEMENT	0.3	17	T XP	YI	0
61	RM_U	11/05/82	M 2	O	CDE INVOLVEMENT	0.3	17	T XP	YI	+
62	CDE	11/05/82	L 1	IO	ORG. CHART FROM AM_A	0.2	17	T XP	YT	+
63	CDE	11/07/82	L 1	OH	MINUTES OF MEETING	1.0	17	T XR	YR	0
64	CDE	11/07/82	L 1	OH	MINUTES OF MEETING	0.2	17	T XR	YR	0
65	CDE	11/07/82	L 1	OH	MINUTES OF MEETING	0.2	17	T XR	YR	0
66	M_A	11/08/82	L 1	IO	PROJECT MEETING MINUTES	0.1	22	T XR	YR	0
67	M_S	11/08/82	L 1	IO	MEETING MINUTES	0.1	22	T XR	YR	0
68	AM_A	11/08/82	L 1	IO	MTG MINUTES +COPY D&W LETTER	0.2	19	T XR	YT	+
69	AM_S	11/08/82	L 1	IO	MTG MINUTES (PLANNING MTG)	0.1	19	T XR	YR	-
70	DE_S	11/08/82	L 1	ID	MTG. MINUTES (PLANNING MTG)	0.1	14	T XR	0	0
71	AM_A	11/09/82	T 2	IO	REPORTING PROCEDURES	0.2	19	T XR	YR	0
71	CDE	11/09/82	T 2	OO	REPORTING PROCEDURES	0.2	17	T XR	YR	0
72	SL_A	11/09/82	T 2	IO	VISIT TO NNC	0.1	17	T XI	0	0
72	CDE	11/09/82	T 2	OO	VISIT TO NNC BY CDE	0.1	17	T XI	0	0
73	SL_A	11/10/82	M 2	P	GREETING	0.2	17	T XS	YI	+
73	CDE	11/10/82	M 2	P	GREETING	0.2	17	T XS	YI	+
74	CDE	11/10/82	W 1	R	REVIEW CONTRACTOR INFO	1.2	17	T XI	0	0
75	SL_A	11/10/82	W 2	R	REVIEW RIG BLDG DESIGN	2.0	17	T CP	YI	-
75	CDE	11/10/82	W 2	R	REVIEW RIG BUILDING DESIGN	2.0	17	T CP	YI	0
76	SL_A	11/10/82	W 2	R	REPORT ON RIG DESIGN AT R	1.0	17	T CP	0	0
76	CDE	11/10/82	W 2	R	MARCH 82 REPORT	1.0	17	T CP	0	+
77	AM_A	11/10/82	M 2	O	UPDATE	0.1	19	T XR	YR	0
77	CDE	11/10/82	M 2	A	UPDATE	0.1	17	T XR	YR	0
78	CDE	11/11/82	W 1	O	WRITING WEEKLY REPORTS	4.0	17	T XR	YR	+
79	CDE	11/12/82	M 2	A	PROJECT PROGRESS	1.0	17	T XR	YR	0
79	RM_U	11/12/82	M 2	O	PROJECT PROGRESS	1.0	17	T XR	YQ	0
80	CDE	11/12/82	T 2	OO	CONSTRUCTING GTR	0.1	17	T XI	YE	+
80	SE_FL	11/12/82	T 2	IO	CONSTRUCTING GTR	0.1	15	T XI	0	+
81	CDE	11/15/82	T 2	OO	CDE TO VISIT NNC	0.2	17	T XI	0	+
81	SE_FL	11/15/82	T 2	IO	CDE TO VISIT NNC	0.2	15	T XI	YE	+
82	CDE	11/15/82	W 1	T	PREPARING FOR DAY	1.0	17	T XP	YL	0
83	AM_A	11/15/82	M 2	O	GENERAL INFORMATION	0.3	19	T XI	0	+
83	CDE	11/15/82	M 2	A	GENERAL INFORMATION	0.3	17	T XI	0	+
84	ASL_A	11/15/82	M 2	N	PERSONAL BACKGROUND	0.2	14	T CP	YI	+
84	CDE	11/15/82	M 2	N	ASL_A BACKGROUND	0.2	17	T CP	YI	+
85	R1_A	11/15/82	W 3	N	LIST OF D'S AND W'S	2.0	13	T CP	CK	+
85	R2_A	11/15/82	W 3	A	LIST OF DEMANDS AND WISHES	2.0	13	T CP	CK	+
85	CDE	11/15/82	W 3	A	LIST OF DEMANDS & WISHES	2.0	17	T CP	CK	+
86	AM_A	11/15/82	L 1	OO	CDE CONTRACT CLAUSES	1.5	19	P XC	YN	0
87	AM_A	11/15/82	M 2	O	PROJECT BACKGROUND	2.2	19	T CP	YE	+
87	CDE	11/15/82	M 2	O	PROJECT BACKGROUND	2.2	17	T CP	YE	+
88	SL_A	11/15/82	L 1	IO	CONTRACT FOR CDE	0.1	17	T XC	YN	0
89	RM_U	11/15/82	L 1	IO	CDE WORK CONTRACT	0.1	17	T XC	YN	0
90	CDE	11/16/82	M 2	A	VISIT BY CDE	3.5	17	T XI	YN	+
90	SE_FL	11/16/82	M 2	O	VISIT BY CDE	3.5	15	T XI	YN	+
91	CDE	11/16/82	L 1	OO	THANKS FOR TIME	0.5	17	T XI	YE	+
92	SE_FL	11/17/82	L 1	IO	THANKS FOR TIME	0.1	15	T XS	0	0
93	AM_A	11/18/82	T 2	OO	UPDATE & DATES	0.1	19	T XR	YR	+
93	CDE	11/18/82	T 2	IO	UPDATE & REVIEW	0.1	17	T XR	YR	+

GTR PROJECT INTERCHANGES BY DATE AND NUMBER

INT/NO	PERSON	DATE	TYPE/L		TOPIC	HRS	£/H	P/ACT	TQ	M
94	CDE	11/18/82	M 2	A	INTRODUCED TO LO_U	1.0	17	T XS	YE	+
94	LO_U	11/18/82	M 2	A	INTRODUCTION/ CDE	1.0	16	T XS	YE	+
95	CDE	11/18/82	M 2	A	PROJECT PROGRESS	0.9	17	T XS	YR	+
95	RM_U	11/18/82	M 2	O	PROJECT PROGRESS	0.9	17	T XS	YE	+
96	CDE	11/19/82	M 2	A	CONTRACT/VISIT OF AM_A	0.5	17	T XP	0	0
96	RM_U	11/19/82	M 2	O	CONTRACT/VISIT OF AM_A	0.5	17	T XP	YN	0
97	CDE	11/22/82	W 1	T	PREPARING FOR DAY	1.6	17	T XP	YL	0
98	AM_A	11/22/82	M 3	O	BRAINSTORM ARRANGEMENTS	1.0	19	T CP	YT	+
98	SL_A	11/22/82	M 3	A	BRAINSTORM PLAN	1.0	17	T CP	YT	+
98	CDE	11/22/82	M 3	A	PLAN FOR BRAINSTORM	1.0	17	T CP	YE	+
99	M_A	11/22/82	M 2	O	BRAINSTORM	0.1	22	T CP	YE	+
99	CDE	11/22/82	M 2	A	BRAINSTORM	0.1	17	T CP	YE	+
100	SL_A	11/22/82	M 2	C	LUNCH & WALK	1.0	17	T CP	YI	+
100	CDE	11/22/82	M 2	C	LUNCH THEN WALK	1.0	17	T CP	YI	+
101	AM_S	11/22/82	M 4	O	GTR PROJECT + QA + STDS.	1.5	19	T CP	0	-
101	SL_A	11/22/82	M 4	A	GTR PROJECT & QA & STANDARDS	1.5	17	T CP	0	-
101	DE_S	11/22/82	M 4	A	GTR PROJECT & QA & STANDARDS	1.5	14	T CP	0	-
101	CDE	11/22/82	M 4	A	GTR PROJECT & QA & STANDARDS	1.5	17	T CP	0	0
102	SL_A	11/23/82	W 2	O	ARRANGING BRAINSTORM	2.0	17	T CP	YN	+
102	CDE	11/23/82	W 2	A	ARRANGING BRAINSTORM	2.0	17	T CP	YT	+
103	CDE	11/23/82	M 2	A	BRAINSTORM TECHNIQUE	0.3	17	T CP	BS	+
103	RM_U	11/23/82	M 2	O	BRAINSTORM TECHNIQUE	0.3	17	T CP	BS	+
104	SL_A	11/24/82	M 2	O	FINAL ARRANGEMENTS	0.2	17	T CP	BS	+
104	CDE	11/24/82	M 2	A	FINAL ARRANGEMENTS	0.2	17	T CP	BS	+
105	SL_A	11/24/82	M15	R	BRAINSTORM	1.3	17	T CP	BS	+
105	ASL_A	11/24/82	M15	R	BRAINSTORM	1.3	14	T CP	BS	+
105	R1_A	11/24/82	M15	R	BRAINSTORM	1.3	13	T CP	BS	+
105	R2_A	11/24/82	M15	R	BRAINSTORM	1.3	13	T CP	BS	+
105	S1_P	11/24/82	M15	R	BRAINSTORM	1.3	13	T CP	BS	0
105	DE_S	11/24/82	M15	R	BRAINSTORM	1.3	14	T CP	BS	-
105	CDE	11/24/82	M15	R	BRAINSTORM	1.3	17	T CP	BS	+
106	SL_A	11/24/82	M 2	C	LUNCH	0.9	17	T CP	0	+
106	CDE	11/24/82	M 2	C	LUNCH	0.9	17	T CP	YI	+
107	SL_A	11/24/82	M 2	L	VISIT TO EXISTING RIGS	1.0	17	T CP	YQ	+
107	CDE	11/24/82	M 2	L	VISIT TO EXISTING RIGS	1.0	17	T CP	YQ	+
108	BPO_S	11/24/82	W 2	O	RIG FACILITY & COSTING	1.0	14	T CP	YQ	0
108	CDE	11/24/82	W 2	O	RIG FACILITY & COSTING	1.0	17	T CP	YQ	+
109	AM_A	11/24/82	M 2	O	APPROVAL OF MINUTES (12)	0.1	19	T XR	YN	0
109	CDE	11/24/82	M 2	O	APPROVAL OF MINUTES	0.1	17	T XR	YN	0
110	CDE	11/26/82	M 2	O	PROJECT MANAGEMENT	1.0	17	T XR	YR	+
110	RM_U	11/26/82	M 2	O	PROJECT MANAGEMENT	1.0	17	T XR	YR	+
111	CDE	11/29/82	W 1	O	CAT. BRAINSTORM IDEAS	1.6	17	T CP	BS	0
112	M_A	11/29/82	M 2	O	BRAINSTORM	0.1	22	T CP	BS	+
112	SL_A	11/29/82	M 2	O	PROJ ORG CHART +B'STORM LIST	0.1	17	T CP	0	-
112	CDE	11/29/82	M 2	O	ORG. CHART & BRAINSTORM LIST	0.1	17	T CP	BS	+
113	BPO_S	11/29/82	M 3	O	COMPUTER MANUAL	0.2	14	T XC	YC	+
113	SO_S	11/29/82	M 3	O	MEETING MINUTES	0.2	14	T XC	YC	0
113	CDE	11/29/82	M 3	O	COMPUTER MANUAL	0.2	17	T XC	YC	0
114	AM_S	11/29/82	M 2	O	PROJECT ORGANIZATION	0.3	19	T XR	YT	+
114	CDE	11/29/82	M 2	O	PROJECT ORGANIZATION	0.3	17	T XR	YT	+
115	CDE	11/29/82	M 2	A	BRAINSTORM RESULTS	0.1	17	T CP	BS	0
116	AM_A	11/29/82	M 2	O	BRAINSTORM RESULTS	0.2	19	T CP	BS	+

GTR PROJECT INTERCHANGES BY DATE AND NUMBER

INT/NO	PERSON	DATE	TYPE/L		TOPIC	HRS	£/H	P/ACT	TQ	M
116	CDE	11/29/82	M 2	A	BRAINSTORM RESULTS	0.2	17	T CP	BS	0
117	S1_P	11/29/82	M 2	P	BRAINSTORM RESULTS	0.1	13	T CP	BS	+
117	CDE	11/29/82	M 2	P	BRAINSTORM RESULTS	0.1	17	T CP	BS	+
118	CDE	12/03/82	M 2	A	BRAINSTORM RESULTS	0.5	17	T CP	YE	+
118	RM_U	12/03/82	M 2	O	BRAINSTORM RESULTS	0.5	17	T CP	BS	+
119	AM_A	12/06/82	T 2	10	(NOT AVAILABLE)	0.0	19	T CP	0	0
119	CDE	12/06/82	T 2	00	CONTACT AM_A	0.3	17	T XP	0	-
120	AM_S	12/06/82	T 2	10	PROJECT ORGANIZATION	0.2	19	T XP	YT	+
120	CDE	12/06/82	T 2	00	PROJECT ORGANISATION DETAILS	0.2	17	T XP	YT	0
121	CDE	12/06/82	W 1	O	FINAL LISTING OF D'S AND W'S	6.0	17	T CP	YL	0
122	CDE	12/09/82	M 2	A	REVIEW WEEKLY REPORT	0.5	17	T XR	YR	0
122	RM_U	12/09/82	M 2	O	REVIEW WEEKLY REPORT	0.5	17	T XR	YR	+
123	SL_A	12/13/82	T 2	10	TIME TO MEET	0.1	17	T XP	0	0
123	CDE	12/13/82	T 2	00	VISIT OF CDE	0.1	17	T XP	0	0
124	SL_A	12/13/82	W 2	N	DEMANDS & WISHES/ BRAINSTORM	0.5	17	T CP	YK	0
124	CDE	12/13/82	W 2	A	D'S & W'S AND BRAINSTORM	0.5	17	T CP	YK	0
125	BPO_S	12/13/82	M 2	O	RETURNED MANUAL	0.8	14	T XC	YC	+
125	CDE	12/13/82	M 2	A	RETURNED MANUAL	0.8	17	T XC	YC	0
126	S1_A	12/13/82	W 2	O	BRAINSTORM REVIEW	1.5	13	T CP	BS	+
126	CDE	12/13/82	W 2	A	BRAINSTORM REVIEW	1.5	17	T CP	BS	+
127	DE_S	12/13/82	M 2	D	CODES+STANDARDS+INFORMATION	1.0	14	T CP	Y1	+
127	CDE	12/13/82	M 2	D	CODES, STANDARDS & INFO	1.0	17	T CP	Y1	+
128	CDE	12/15/82	W 1	O	GASIFIER CALCULATIONS	6.0	17	T CP	YS	0
129	SL_A	12/17/82	T 2	10	GASIFIER	0.3	17	T CP	YQ	0
129	CDE	12/17/82	T 2	00	GASIFIER DETAILS	0.3	17	T CP	YQ	0
130	SL_A	12/20/82	T 2	10	GTR CONCEPTS	0.7	17	C SS	YQ	+
130	CDE	12/20/82	T 2	00	GTR FLOWS & CONCEPTS	0.7	17	C SS	YQ	0
131	SL_A	12/21/82	T 2	10	SPECIFICATION & MEETING	0.1	17	T SP	SP	0
131	CDE	12/21/82	T 2	00	SPECIFICATION & MEETINGS	0.1	17	T SP	SP	+
132	CDE	12/21/82	T 2	10	PROJECT PROGRESS	0.2	17	T XR	YR	+
132	SE_FL	12/21/82	T 2	00	PROJECT PROGRESS	0.2	15	T XR	YE	+
133	SE_FL	12/21/82	L 1	00	1983 CALENDAR	0.1	15	T XS	YE	+
134	CDE	12/21/82	W 1	O	PREP. OF SPEC & INSTRUCTIONS	6.0	17	T SP	SP	0
135	AM_A	12/22/82	L 1	00	GREETINGS	0.2	19	T XS	Y1	+
136	S1_A	12/22/82	W 2	O	SPECIFICATION	1.0	13	T SP	SP	+
136	CDE	12/22/82	W 2	A	SPECIFICATION	1.0	17	T SP	SP	+
137	DE_S	12/22/82	M 2	D	SPECIFICATION	0.2	14	T SP	0	+
137	CDE	12/22/82	M 2	D	SPECIFICATION	0.2	17	T SP	SP	-
138	SL_A	12/22/82	W 2	N	SPECIFICATION COPY	0.2	17	T SP	SP	+
138	CDE	12/22/82	W 2	A	SPECIFICATION	0.2	17	T SP	SP	+
139	R2_A	12/22/82	M 2	L	UPDATE/REPORTS	0.1	13	T SP	YR	0
139	BPO_S	12/22/82	M 2	O	COST ESTIMATE & SPEC. FORMS	0.1	14	T SP	YR	0
139	CDE	12/22/82	M 2	L	UPDATE/REPORTS	0.1	17	T SP	YR	0
140	ASL_A	12/22/82	M 2	N	PRESENTATION METHODS	0.2	14	T XR	YP	+
140	CDE	12/22/82	M 2	A	PRESENTATION METHODS	0.2	17	T XR	YP	+
141	R1_A	12/22/82	M 2	N	SPECIFICATION	0.3	13	T SP	SP	+
141	CDE	12/22/82	M 2	A	SPECIFICATION	0.3	17	T SP	SP	+
142	AD1_R	12/22/82	M 3	A	DESIGN/DRAFTING AT R	0.5	23	T XS	YQ	-
142	M_A	12/22/82	M 3	N	DRAWING OFFICE	0.5	22	T XS	Y1	0
142	CDE	12/22/82	M 3	A	DRAWING OFFICE	0.5	17	T XS	Y1	0
143	M_A	12/22/82	M 2	O	COST AND PROJECT CONTROL	0.5	22	T XP	YE	+
143	CDE	12/22/82	M 2	A	COST & PROJECT CONTROL	0.5	17	T XP	YC	+

GTR PROJECT INTERCHANGES BY DATE AND NUMBER

INT/NO	PERSON	DATE	TYPE/L		TOPIC	HRS	£/H	P/ACT	TQ	M
144	CDE	12/22/82	W 1	T	GTR CONCEPTS	0.9	17	C SS	11	0
145	AM_S	12/22/82	M 2	O	UPDATE ON PROJECT	0.1	19	T XR	YR	+
145	CDE	12/22/82	M 2	O	UPDATE	0.1	17	T XR	YR	+
146	CDE	12/22/82	M 2	O	COST ESTIMATE & SPEC	0.1	17	T SP	YC	0
147	S1_A	12/23/82	W 1	O	REVIEW SPECIFICATION	1.0	13	T SP	SP	+
148	SL_A	12/22/82	W 1	O	REVIEWING SPECIFICATION	2.0	17	T SP	SP	+
149	CDE	12/23/82	M 2	A	REVIEW SPECIFICATION	0.5	17	T SP	SP	+
149	RM_U	12/23/82	M 2	O	REVIEW SPECIFICATION	0.5	17	T SP	SP	+
150	CDE	12/23/82	L 1	10	1983 CALENDAR	0.2	17	T XS	0	+
151	CDE	12/23/82	L 1	10	CARD	0.1	17	T XS	0	+
152	BPO_S	12/29/82	W 1	O	REVIEWING SPECIFICATION	1.5	14	T SP	SP	+
153	CDE	01/03/83	W 1	O	PREPARING REPORT GTR-1	9.0	17	T XR	YR	0
154	CDE	01/04/83	W 1	O	PREPARING REPORT GTR-1	9.0	17	T XR	YR	0
155	AM_S	01/04/83	W 1	O	SPECIFICATION	0.5	19	T SP	SP	+
156	CDE	01/06/83	W 1	O	PREPARING REPORT GTR-1	3.0	17	T XR	YR	0
157	AM_A	01/06/83	L 1	00	PROJECT CONTRACT CDE	1.0	19	P XC	YN	0
158	R1_A	01/06/83	W 1	N	SPECIFICATION	0.8	13	T SP	SP	+
159	R2_A	01/06/83	W 1	L	SPECIFICATION	0.8	13	T SP	SP	+
160	SL_A	01/07/83	T 2	00	MEETING TO REVIEW SPEC	0.3	17	T XP	SP	+
160	CDE	01/07/83	T 2	10	MEETING TO REVIEW SPEC	0.3	17	T XP	SP	+
161	CDE	01/07/83	M 2	A	REVIEW REPORT GTR-1	0.5	17	T XR	YR	+
161	RM_U	01/07/83	M 2	O	REVIEW REPORT GTR1	0.5	17	T XR	YR	+
162	CDE	01/10/83	W 1	O	TEN BOUND COPIES GTR-1	4.0	17	T XR	YR	0
163	M_A	01/12/83	W 1	O	SPECIFICATION	0.5	22	T SP	SP	+
164	M_S	01/12/83	W 1	O	SPECIFICATION	0.5	22	T SP	SP	+
165	AM_A	01/12/83	W 1	O	SPECIFICATION	0.5	19	T SP	SP	0
166	DE_S	01/12/83	W 1	D	SPECIFICATION	0.1	14	T SP	0	+
167	RM_U	01/12/83	L 1	10	FINAL CDE CONTRACT	0.1	17	T XC	YN	0
168	AM_A	01/12/83	L 1	00	SPECIFICATION	0.2	19	T SP	SP	0
169	CDE	01/13/83	W 1	T	PREPARE FOR DAY'S WORK	0.9	17	C FS	FS	0
170	SL_A	01/13/83	W 4	N	REVIEW SPECIFICATION	1.5	17	T SP	SP	+
170	S1_A	01/13/83	W 4	A	REVIEW SPECIFICATION	1.5	13	T SP	SP	+
170	DE_S	01/13/83	W 4	A	REVIEW SPECIFICATION	1.5	14	T SP	SP	+
170	CDE	01/13/83	W 4	A	REVIEW SPECIFICATION	1.5	17	T SP	SP	+
171	S1_A	01/13/83	W 2	O	COAL BED FEATURES	1.0	13	T CP	YQ	+
171	CDE	01/13/83	W 2	A	COAL BED FEATURES	1.0	17	T CP	YQ	+
172	AM_A	01/13/83	M 2	O	REPORT GTR1 & SPECIFICATION	0.3	19	T XR	YR	+
172	CDE	01/13/83	M 2	A	REPORT GTR-1 & SPEC	0.3	17	T XR	YE	+
173	M_A	01/13/83	M 2	O	REPORT GTR-1	0.2	22	T XR	YR	+
173	CDE	01/13/83	M 2	A	REPORT GTR-1	0.2	17	T XR	YE	+
174	M_S	01/13/83	M 2	O	UPDATE, GTR-1, COST CONTROL	0.5	22	T XR	YR	+
174	CDE	01/13/83	M 2	A	REPORT GTR-1	0.5	17	T XR	YE	+
175	CDE	01/14/83	M 2	A	SPECIFICATION METHOD	1.0	17	T SP	YE	+
175	RM_U	01/14/83	M 2	O	SPECIFICATION METHOD	1.0	17	T SP	YE	+
176	CDE	01/22/83	W 1	O	REVISED SPECIFICATION	5.0	17	T SP	SP	0
177	CDE	01/23/83	W 1	O	CENTRIFUGAL CONCEPT	8.0	17	C SS	11	0
178	CDE	01/24/83	W 2	A	CENTRIFUGAL CONCEPT	0.5	17	C SS	11	+
178	RM_U	01/24/83	W 2	O	CENTRIFUGAL CONCEPT	0.5	17	C SS	11	+
179	CDE	01/24/83	W 1	T	PLAN FOR DAY	0.9	17	C XP	YL	+
180	SL_A	01/24/83	W 2	L	GTR REACTOR CONCEPTS	2.5	17	C SS	SK	+
180	CDE	01/24/83	W 2	L	GTR REACTOR CONCEPTS	2.5	17	C SS	SK	0
181	AM_A	01/24/83	M 2	O	WEEKLY REPORT & SPEC	0.1	19	C XR	SP	-

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INT/NO	PERSON	DATE	TYPE/L	TOPIC	HRS	£/H	P/ACT	TQ	M
181	CDE	01/24/83	M 2 O	WEEKLY REPORT +SPECIFICATION	0.1	17	C XR	SP	0
182	D_R	01/24/83	M 3 L	GENERAL CHAT	0.1	27	C XS	YI	+
182	SL_A	01/24/83	M 3 L	INTRODUCTION TO D_R	0.1	17	C XS	YP	+
182	CDE	01/24/83	M 3 L	INTRODUCTION TO D_R	0.1	17	C XS	YE	+
183	CDE	01/27/83	M 2 O	PROJECT PROGRESS	0.5	17	C XR	YR	0
183	RM_U	01/27/83	M 2 O	PROJECT PROGRESS	0.5	17	C XR	YR	0
184	SL_A	01/27/83	M 3 A	COAL CONDITIONS	0.3	17	C XI	YQ	-
184	R2_A	01/27/83	M 3 A	COAL CONDITIONS	0.3	13	C XI	YQ	+
184	CDE	01/27/83	M 3 A	COAL CONDITIONS	0.3	17	C XI	YQ	0
185	S1_A	01/27/83	W 2 T	CENTRIFUGAL CONCEPT	0.3	13	C SS	II	+
185	CDE	01/27/83	W 2 T	CENTRIFUGAL CONCEPT	0.3	17	C SS	II	0
186	CDE	02/03/83	T 2 IO	CONSTRUCTING GTR	0.1	17	C XR	YN	+
186	SE_FL	02/03/83	T 2 OO	PROJECT PROGRESS	0.1	15	C XR	YN	+
187	AM_A	02/14/83	M 4 A	PROJECT REVIEW MTG	6.0	19	C XR	YR	+
187	SL_A	02/14/83	M 4 A	PROJECT REVIEW MEETING	6.0	17	C XR	YR	+
187	CDE	02/14/83	M 4 A	PROJECT REVIEW MEETING	6.0	17	C XR	YR	+
187	RM_U	02/14/83	M 4 O	PROJECT REVIEW MEETING	6.0	17	C XR	YR	+
188	CDE	02/15/83	M 2 T	PROJECT PROGRESS	1.0	17	C XR	YR	+
188	LO_U	02/15/83	M 2 T	PROJECT PROGRESS	1.0	16	C XR	YR	+
189	SL_A	02/15/83	L 1 OO	REVIEW OF ICED PAPER	0.3	17	C XS	YI	0
190	RM_U	02/16/84	L 1 IO	REVIEW OF ICED PAPER	0.3	17	C XS	0	0
191	CDE	02/21/83	W 1 T	PLAN FOR DAY	0.9	17	C FS	FS	0
192	SL_A	02/21/83	W 2 N	REACTOR CONCEPTS	2.0	17	C SS	II	0
192	SL_A	02/21/83	W 2 L	FLUIDIZED BED TESTS	2.0	17	C SS	II	+
192	CDE	02/21/83	W 2 A	REACTOR CONCEPTS	2.0	17	C SS	II	0
193	SL_A	02/21/83	M 2 C	LUNCH	1.0	17	C XS	YI	0
193	CDE	02/21/83	M 2 C	LUNCH	1.0	17	C XS	YI	0
194	CDE	02/21/83	W 2 L	FLUIDIZED BED TESTS	2.0	17	C SS	ES	+
195	D_R	02/21/83	L 1 OO	DESIGN CONTRACT	0.2	27	T XC	0	0
196	AM_A	02/25/83	L 1 OO	SIGNED CDE CONTRACT	0.3	19	P XC	YN	0
197	SL_A	02/25/83	L 1 IO	CONTRACT FOR CDE	0.1	17	C XC	YN	0
198	CDE	02/25/83	W 2 A	SPECIMEN/BED INTERACTION	0.5	17	C FS	CS	0
198	RM_U	02/25/83	W 2 O	SPECIMEN/BED INTERACTION	0.5	17	C FS	CS	+
199	RM_U	02/26/83	L 1 IO	FINAL SIGNED CDE CONTRACT	0.1	17	T XC	YN	+
200	CDE	02/26/83	L 1 IO	SIGNED CDE CONTRACT	0.1	17	C XC	YN	+
201	SL_A	02/28/83	W 2 O	TEST SPECIMENS/SUBFUNCTIONS	2.7	17	C FS	CS	-
201	CDE	02/28/83	W 2 A	TEST SPECIMENS/SUBFUNCTIONS	2.7	17	C FS	CS	-
202	SL_A	03/08/83	W 3 R	GASIFIER	2.0	17	C XI	YQ	0
202	R1_A	03/08/83	W 3 N	LURGI GASIFIER	2.0	13	C XI	YQ	+
202	CDE	03/08/83	W 3 R	GASIFIER INFO	2.0	17	C XI	YQ	-
203	CDE	03/08/83	M 2 O	GTR BACKGROUND	0.9	17	C XI	YE	+
203	SE_VE	03/08/83	M 2 O	GTR BACKGROUND	0.9	15	C XI	YE	+
204	SL_A	03/14/83	W 2 O	HEATING COAL BED	2.8	17	C CP	SL	+
204	CDE	03/14/83	W 2 O	HEATING COAL BED	2.8	17	C CP	SL	+
205	AM_A	03/14/83	M 2 O	UPDATE & TECHNICAL INFO	1.2	19	C XI	YR	0
205	CDE	03/14/83	M 2 O	UPDATE & TECHNICAL INFO	1.2	17	C XI	YR	+
206	CDE	03/18/83	V 1 E	CDE VACATION	0.0	17	C XS	0	+
207	SE_FE	03/24/83	L 1 OO	COAL FEEDER INFO	0.4	15	C XI	YQ	+
208	D_R	04/05/83	L 1 OO	INVITATION TO OPEN DAY	0.1	27	C XS	YI	+
209	CDE	04/15/83	W 1 O	CONCEPT EVALUATION	4.0	17	C SC	SL	0
210	SL_A	04/18/83	W 2 N	CONCEPT EVALUATION	2.0	17	C EV	SL	0
210	CDE	04/18/83	W 2 A	CONCEPT EVALUATION	2.0	17	C EV	SL	0

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INT/NO	PERSON	DATE	TYPE/L	TOPIC	HRS	£/H	P/ACT	TQ	M
211	ASL_A	04/18/83	M 2 O	PREPARATION OF A-FORM	0.2	14	C XC	YP	+
211	CDE	04/18/83	M 2 A	PREPARATION OF A-FORMS	0.2	17	C XC	YQ	0
212	S1_A	04/18/83	W 2 O	COAL CHARACTERISTICS	0.5	13	C XI	YQ	+
212	CDE	04/18/83	W 2 A	COAL CHARACTERISTICS	0.5	17	C XI	YQ	0
213	CDE	04/20/83	T 2 OO	CONTROLS DESIGN	0.5	17	E XP	YT	+
213	CCE	04/20/83	T 2 IO	CONTROL SYSTEM DESIGN	0.5	16	E XP	YT	0
214	CDE	04/20/83	T 2 OO	ARRANGE MEETING	0.4	17	C XI	YE	+
214	SE_VE	04/20/83	T 2 IO	ARRANGE MEETING	0.4	15	C XI	YE	+
215	CDE	04/20/83	W 2 A	COST ESTIMATE FOR VESSEL	3.0	17	C XC	YC	+
215	SE_VE	04/20/83	W 2 O	COST ESTIMATE FOR VESSEL	3.0	15	C XC	YC	+
216	CDE	04/20/83	W 1 O	VESSEL DRAWING	2.0	17	E PL	SK	+
217	CDE	04/21/83	W 1 O	VESSEL WTS & COSTS	3.0	17	C XC	YC	0
218	CDE	04/21/83	T 2 OO	BUDGET QUOTE NEEDED	0.1	17	C XC	YC	+
218	SE_FE	04/21/83	T 2 IO	BUDGET QUOTE NEEDED	0.1	15	C XC	YC	+
219	CDE	04/22/83	T 2 OO	BUDGET PRICE GIVEN	0.1	17	C XC	YC	+
219	SE_FE	04/22/83	T 2 OO	BUDGET PRICE GIVEN	0.1	15	C XC	YC	+
219	SE_FL	04/22/83	T 2 IO	PRICE FOR CHAIN HOIST	0.1	15	C XC	YC	+
220	CDE	04/22/83	T 2 OO	PRICE FOR CHAIN HOIST	0.1	17	C XC	YC	+
221	CDE	04/22/83	M 2 N	COST ESTIMATE/A-FORM	0.8	17	C XC	YC	+
221	RM_U	04/22/83	M 2 O	COST ESTIMATES/A-FORM	0.8	17	C XC	YC	+
222	CDE	04/22/83	W 1 O	CONTROLS & EMBODIMENT DESIGN	3.0	17	E XP	YT	+
223	CDE	04/22/83	W 2 A	COST ESTIMATE	2.5	17	C XC	YC	+
223	DE_U	04/22/83	W 2 O	COST ESTIMATE (INT. REACTOR)	2.5	12	C XC	YC	+
224	CDE	04/22/83	W 1 O	9 COST ESTIMATE SHEETS	6.0	17	C XC	YC	+
225	DE_U	04/23/83	W 1 O	COSTS OF INCONEL	0.5	12	C XC	YC	+
226	SL_A	04/25/83	M 3 A	GREETINGS	0.1	17	C XC	0	+
226	ASL_A	04/25/83	M 3 O	PROJECT COST JUSTIFICATION	0.1	14	C XC	0	0
226	CDE	04/25/83	M 3 A	GREETINGS/COST JUSTIFICATION	0.1	17	C XC	0	+
227	ASL_A	04/25/83	M 2 O	COMPUTER PACKAGES	0.9	14	C XS	0	+
227	CDE	04/25/83	M 2 A	COMPUTER PACKAGES	0.9	17	C XS	0	+
228	SL_A	04/25/83	W 3 A	COSTS/CALCULATIONS/CONTROLS	1.5	17	C XR	YP	0
228	ASL_A	04/25/83	W 3 O	A-FORM PREPARATION	1.5	14	C XR	YP	+
228	CDE	04/25/83	W 3 A	A-FORM PREPARATION	1.5	17	C XR	YP	+
229	AM_A	04/25/83	M 2 O	A-FORM & COSTS	1.3	19	C XC	YC	+
229	CDE	04/25/83	M 2 O	A-FORM & COSTS	1.3	17	C XC	YC	+
230	CDE	04/26/83	L 1 IO	CONTROL & EMBODIMENT DESIGN	0.3	17	E XI	YE	+
231	CDE	04/26/83	W 1 O	WEEKLY REPORTS	4.0	17	C XR	YR	+
232	CDE	04/26/83	T 2 OO	THANKS FOR HELP	0.1	17	C XS	YI	+
232	DE_U	04/26/83	T 2 IO	THANKS FOR HELP (FROM CDE)	0.1	12	C XS	YE	+
233	CDE	04/26/83	T 2 OO	VAT ON A-FORMS	0.3	17	C XC	YC	0
233	LO_U	04/26/83	T 2 IO	VAT ON A-FORM	0.3	16	C XC	YC	+
234	CDE	04/27/83	W 1 O	COST JUSTIFICATION	8.0	17	C XC	YN	0
235	CDE	04/29/83	T 2 OO	COAL FEEDER PRICE	0.2	17	C XC	YC	0
235	SE_FE	04/29/83	T 2 IO	MORE DETAILS ON PRICE	0.2	15	C XC	YC	+
236	AM_A	04/29/83	T 2 IO	MEETING ARRANGEMENTS	0.1	19	C XP	0	0
236	CDE	04/29/83	T 2 OO	MEETING ARRANGEMENT	0.1	17	C XP	0	0
237	CDE	04/29/83	M 2 O	USE OF PAHL & BEITZ	0.5	17	C XP	YQ	0
237	RM_U	04/29/83	M 2 O	USE OF PAHL & BEITZ	0.5	17	C XP	0	+
238	CDE	05/02/83	W 1 O	A-FORM & DRAFT	4.0	17	C XR	YN	0
239	CDE	05/03/83	W 1 T	PLAN FOR DAY	0.9	17	C XP	YL	0
240	SL_A	05/03/83	W 2 O	HEATING/GAS REACTIONS	1.0	17	C XP	YS	0
240	CDE	05/03/83	W 2 A	HEATING/GAS REACTIONS	1.0	17	C XP	YS	0

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INT/NO	PERSON	DATE	TYPE/L		TOPIC	HRS	£/H	P/ACT	TQ	M
241	SL_A	05/03/83	M 2	A	GAS REACTION CALCULATIONS	0.3	17	C XP	YN	0
241	S1_P	05/03/83	M 2	O	GAS REACTION CALCULATIONS	0.3	13	C XP	YS	0
242	AM_A	05/03/83	M 2	O	A-FORM DRAFT	0.2	19	C XR	YN	+
242	CDE	05/03/83	M 2	A	A-FORM DRAFT	0.2	17	C XR	YN	+
243	ASL_A	05/09/83	W 3	N	COST ESTIMATE/JUSTIFICATION	2.0	14	C XC	YP	+
243	R1_A	05/09/83	W 3	N	COST ESTIMATE/JUSTIFICATION	2.0	13	C XC	YN	-
243	CDE	05/09/83	W 3	A	COST EST./JUSTIFICATION	2.0	17	C XC	YN	+
244	AM_A	05/09/83	M 2	O	COST ESTIMATE	0.3	19	C XC	YN	+
244	CDE	05/09/83	M 2	A	COST ESTIMATE	0.3	17	C XC	YN	+
245	CDE	05/10/83	W 1	O	REVISED A-FORM	2.0	17	C XR	YN	0
246	CDE	05/11/83	W 1	O	REPORT GTR-2 PREP	9.0	17	C XR	YR	0
247	CDE	05/12/83	W 1	O	REPORT GTR-2 PREP	9.0	17	C XR	YR	0
248	CDE	05/16/83	W 1	O	CORRECTIONS/COST JUSTIF.	1.4	17	C XC	YN	+
249	CDE	05/16/83	W 1	T	COST BENEFIT EXAMPLES	0.9	17	C XC	YN	+
250	S1_A	05/16/83	M 2	O	PROJECT UPDATE	0.4	13	C XR	YE	+
250	CDE	05/16/83	M 2	A	PROJECT UPDATE	0.4	17	C XR	YE	+
251	AM_A	05/16/83	M 2	O	BRAINSTORM TAPE	0.3	19	C XR	YI	+
251	CDE	05/16/83	M 2	A	BRAINSTORM TAPE	0.3	17	C XR	YE	+
252	M_A	05/16/83	M 3	O	PROJECT JUSTIFICATION	1.5	22	C XC	YM	+
252	AM_A	05/16/83	M 3	A	PROJECT COST JUSTIFICATION	1.5	19	C XC	YM	+
252	CDE	05/16/83	M 3	A	PROJECT COST JUSTIFICATION	1.5	17	C XC	YM	0
253	S1_P	05/16/83	M 2	O	GAS REACTION CALCULATIONS	0.5	13	C EV	YS	+
253	CDE	05/16/83	M 2	A	GAS REACTION CALCULATIONS	0.5	17	C EV	YS	+
254	ASL_A	05/16/83	W 3	A	DATA FOR COST JUSTIFICATION	0.6	14	C XC	YS	+
254	S2_A	05/16/83	W 3	O	DATA FOR COST JUSTIFICATION	0.6	13	C XC	YS	+
254	CDE	05/16/83	W 3	A	DATA FOR COST JUSTIFICATION	0.6	17	C XC	YS	+
255	BPO_S	05/16/83	M 3	O	PROJECT COST EST. & DESIGN	0.4	14	C XC	YC	-
255	SO_S	05/16/83	M 3	O	PROJECT COST EST. & DESIGN	0.4	14	C XC	YC	+
255	CDE	05/16/83	M 3	A	COST ESTIMATE & DESIGN	0.4	17	C XC	YC	+
256	AM_A	05/16/83	M 2	O	STATEMENT BY BPO_S	0.1	19	E XP	YR	-
256	AM_S	05/16/83	M 2	O	UPDATE	0.1	19	E XP	YR	0
256	CDE	05/16/83	M 2	A	UPDATE	0.1	17	E XP	YR	+
257	CDE	05/16/83	M 2	A	STATEMENT BY BPO_S	0.1	17	C XC	YN	0
258	ASL_A	05/23/83	M 3	O	COST JUSTIFICATION	0.3	14	C XC	YI	+
258	R1_A	05/23/83	M 3	N	GENERAL UPDATE	0.3	13	C XC	YN	-
258	CDE	05/23/83	M 3	A	COST JUSTIFICATION	0.3	17	C XC	YN	0
259	AM_A	05/23/83	M 2	O	WEEKLY REPORTS & PROMIS	0.1	19	E XP	0	0
259	BPO_S	05/23/83	M 2	O	A-FORM & COMPUTER	0.1	14	E XP	0	0
259	DE_S	05/23/83	M 2	D	ARRANGE TIME TO MEET	0.1	14	E XP	0	+
259	CDE	05/23/83	M 2	D	ARRANGE TIME TO MEET DE_S	0.1	17	E XP	0	+
260	ASL_A	05/23/83	M 2	O	SALARIES & MANAGEMENT	1.0	14	C XS	YI	-
260	CDE	05/23/83	M 2	A	SALARIES & MANAGEMENT	1.0	17	C XS	YI	0
261	DE_S	05/23/83	M 2	D	GTR CONCEPT/MAJORCA	1.5	14	C XS	YI	+
261	CDE	05/23/83	M 2	D	GTR CONCEPT/HOLIDAYS	1.5	17	C XS	YI	-
262	CDE	05/23/83	M 2	A	A-FORM & COMPUTER	0.1	17	C XC	YN	0
263	CDE	05/23/83	M 2	A	WEEKLY REPORT & PROMIS	0.1	17	C XC	YR	0
264	ASL_A	06/02/83	T 2	OO	PROCESSING A-FORM	0.2	14	C XP	YI	+
264	CDE	06/02/83	T 2	1O	PROCESSING A-FORM	0.2	17	C XP	YI	+
265	AM_A	06/03/83	M 2	O	COST JUSTIFICATION	0.1	19	C XC	YC	0
265	CDE	06/03/83	M 2	A	COST JUSTIFICATION	0.1	17	C XC	YN	0
266	M_A	06/03/83	M 2	O	COST JUSTIFICATION	0.2	22	C XC	YN	+
266	CDE	06/03/83	M 2	A	COST JUSTIFICATION	0.2	17	C XC	YN	0

GTR PROJECT INTERCHANGES BY DATE AND NUMBER

INT/NO	PERSON	DATE	TYPE/L		TOPIC	HRS	£/H	P/ACT	TQ	M
267	SL_A	06/03/83	M 2	O	COST JUSTIFICATION	0.1	17	C XC	0	0
267	CDE	06/03/83	M 2	A	COST JUSTIFICATION	0.1	17	C XC	YN	0
268	CDE	06/04/83	Z 1	H	CDE IN HOSPITAL	0.0	17	C XS	0	0
269	CDE	06/17/83	T 2	1O	VESSEL QUOTATION	0.1	17	C XC	YC	0
269	SE_VE	06/17/83	T 2	OO	DEFINITE QUOTATION	0.1	15	C XC	YC	0
270	CDE	07/14/83	W 1	O	GTR-2 REPORT	2.0	17	C XR	YR	0
271	CDE	07/18/83	W 1	O	PREPARING FOR DAY	1.9	17	C XP	YL	0
272	AM_A	07/18/83	M 2	O	UPDATE & INFORMATION	2.0	19	C XR	YR	+
272	CDE	07/18/83	M 2	A	UPDATE INFO	2.0	17	C XR	YR	+
273	SL_A	07/18/83	M 2	N	RAISE MAX TEMP/PRESSURE	0.2	17	C EV	YS	0
273	S1_P	07/18/83	M 2	O	GAS REACTION CALCULATIONS	0.2	13	C EV	YS	0
273	CDE	07/18/83	M 2	A	GAS REACTION CALCULATIONS	0.2	17	C EV	YS	0
274	CDE	07/18/83	M 2	A	RAISE MAX TEMP/PRESSURE	0.2	17	T SP	SP	0
275	S1_A	07/18/83	M 2	P	PROJECT UPDATE	0.1	13	C XR	YR	0
275	CDE	07/18/83	M 2	P	PROJECT UPDATE	0.1	17	C XR	YR	0
276	R2_A	07/18/83	M 2	L	REPORT & UPDATE	0.1	13	C XR	YR	0
276	CDE	07/18/83	M 2	L	GTR-2 REPORT/UPDATE	0.1	17	C XR	YR	0
277	ASL_A	07/18/83	M 2	O	PROGRESS ON PROJECT	0.1	14	C XR	YR	-
277	CDE	07/18/83	M 2	A	PROJECT PROGRESS	0.1	17	C XR	YR	+
278	CDE	07/19/83	W 1	O	PROJECT DESCRIPTION	7.0	17	C XR	YP	-
279	CDE	07/19/83	W 1	O	CHECK INVOICE TO M	0.5	17	C XC	YC	0
280	CDE	07/20/83	L 1	OO	OBJECTIVES SUMMARY	2.0	17	C XR	YP	0
281	AM_A	07/21/83	T 2	OO	COST ESTIMATE & JUSTIF.	0.3	19	C XC	YN	0
281	CDE	07/21/83	T 2	1O	COST ESTIMATE & JUSTIFIC.	0.3	17	C XC	YN	+
282	M_A	07/22/83	L 1	OO	GTR PROJECT	1.5	22	C XR	YE	+
283	CDE	07/22/83	W 1	O	COST ESTIMATE BREAKDOWN	1.5	17	C XC	YC	+
284	CDE	07/24/83	W 1	O	COST BENEFIT EXAMPLES	3.0	17	C XC	YC	-
285	D_G	07/25/83	L 1	1O	GTR PROJECT	0.3	27	C EV	0	0
286	AM_A	07/25/83	M 2	O	COST ESTIMATE	0.6	19	C XC	YC	+
286	CDE	07/25/83	M 2	A	COST ESTIMATE	0.6	17	C XC	YC	0
287	AM_A	07/25/83	M 2	O	REPORT GTR-2	0.8	19	C XR	YR	+
287	CDE	07/25/83	M 2	A	REPORT GTR-2	0.8	17	C XR	YR	+
288	SL_A	07/25/83	M 2	C	LUNCH	1.0	17	C XS	0	0
288	CDE	07/25/83	M 2	C	LUNCH	1.0	17	C XS	0	0
289	SL_A	07/25/83	M 2	N	GTR-2 & DESCRIPTION	1.5	17	E RC	0	-
289	CDE	07/25/83	M 2	A	GTR-2 & DESCRIPTION	1.5	17	E RC	0	0
290	SL_A	07/25/83	M 2	N	GAS CALCS/OPEN DAY	1.3	17	E RC	YS	-
290	CDE	07/25/83	M 2	A	GAS CALCULATIONS/OPEN DAY	1.3	17	E RC	YS	0
291	S1_P	07/25/83	M 2	O	GAS REACTION CALCULATIONS	0.5	13	E SC	YS	0
291	CDE	07/25/83	M 2	A	GAS REACTION CALCULATIONS	0.5	17	E SC	YS	0
292	CDE	07/25/83	W 1	T	PLAN OF WORK	0.5	17	E XP	YL	0
293	CDE	07/27/83	W 1	O	PRODUCT LITERATURE	3.0	17	E XI	YF	0
294	CDE	07/27/83	T 2	1O	DETAILS ON VESSEL PRICE	0.2	17	C XC	YC	+
294	SE_VE	07/27/83	T 2	OO	MORE DETAILS ON PRICE	0.2	15	C XC	YC	+
295	CDE	07/28/83	M 2	A	GTR CONCEPT	1.3	17	C XI	YE	+
295	LO_U	07/28/83	M 2	O	GTR CONCEPT	1.3	16	C XI	YQ	+
296	CDE	07/28/83	T 2	1O	GASIFIER FLOWS	0.2	17	C XI	YQ	+
296	LO_U	07/28/83	T 2	OO	GASIFIER FLOWS	0.2	16	C XI	YQ	+
297	CDE	07/28/83	W 1	O	BED FLOWS/SIZES	7.5	17	E SC	YS	0
298	CDE	07/29/83	M 2	A	TAR FLOWS/CONTACTS	0.5	17	E XI	YQ	+
298	LO_U	07/29/83	M 2	O	TAR FLOWS/CONTACTS	0.5	16	E XI	YQ	+
299	SL_A	07/29/83	T 2	OO	VISIT TO M	0.4	17	E XP	YN	0

GTR PROJECT INTERCHANGES BY DATE AND NUMBER

INT/NO	PERSON	DATE	TYPE/L	TOPIC	HRS	£/H	P/ACT	TQ	M
299	DEI_M	07/29/83	T 2 IO	VISIT FROM SL_A & CDE	0.4	15	E XP	0	+
300	CDE	08/02/83	W 1 T	GAS FLOW CALCULATIONS	0.9	17	E SC	YS	0
301	AM_A	08/02/83	M 2 O	A-FORM, PROJ. DESCRIPTION	0.3	19	C XC	YR	+
301	R2_A	08/02/83	M 2 L	GTR CONCEPTS	0.3	13	C XC	YR	+
301	CDE	08/02/83	M 2 A	A-FORM/ PROJ DESCRIPTION	0.3	17	C XC	YR	0
302	SL_A	08/02/83	W 2 O	GAS FLOWS/N2 FLUSH	1.0	17	E SC	YQ	0
302	CDE	08/02/83	W 2 A	GAS FLOWS/NITROGEN FLUSH	1.0	17	E SC	YQ	0
303	DE_S	08/02/83	M 2 D	PROJECT UPDATE	0.5	14	E XR	YR	+
303	CDE	08/02/83	M 2 D	PROJECT UPDATE	0.5	17	E XR	YR	+
304	CDE	08/02/83	M 2 L	GTR CONCEPTS	0.3	17	E RC	YQ	+
305	SE_VE	08/02/83	L 1 OO	WRITTEN QUOTATION	0.2	15	C XC	YC	0
306	CDE	08/03/83	L 1 IO	VESSEL QUOTE	0.1	17	E XC	YC	+
307	SL_A	08/05/83	M 3 A	GTR DESIGN	8.0	17	E RC	YE	0
307	DEI_M	08/05/83	M 3 O	VISIT FROM SL_A & CDE	8.0	15	E RC	YR	+
307	CDE	08/05/83	M 3 A	GTR DESIGN	8.0	17	E RC	YE	+
308	AM_A	08/08/83	M 2 O	M VISIT, COAL STORAGE	1.7	19	E SC	YR	0
308	CDE	08/08/83	M 2 A	VISIT TO M/ COAL STORE	1.7	17	E SC	YE	+
309	DE_S	08/08/83	M 2 D	CONCEPT, VESSEL, DRAWINGS	1.0	14	E XP	YQ	+
309	CDE	08/08/83	M 2 D	CONCEPT/VESSELS/DRAWINGS	1.0	17	E XP	YQ	+
310	ASL_A	08/08/83	M 2 O	WELD DWG - SEC. PROJ.	0.1	14	E XH	YI	0
310	CDE	08/08/83	M 2 A	WELD DRAWING (SEC. PROJ.)	0.1	17	E XH	YI	+
311	SI_A	08/08/83	W 2 O	COAL HEATING & FLOW	0.5	13	E XI	YQ	+
311	CDE	08/08/83	W 2 A	COAL HEATING & FLOW	0.5	17	E XI	YQ	+
312	D_G	08/11/83	L 1 OO	GTR PROJECT	0.5	27	C EV	0	-
313	C_G	08/11/83	L 1 IO	GTR PROJECT	0.1	22	C EV	0	0
314	M_A	08/12/83	L 1 IO	GTR PROJECT	0.3	22	C EV	YN	-
315	D_R	08/15/83	L 1 OO	GTR PROJECT DESCRIPTION	0.5	27	C EV	YR	-
316	M_A	08/15/83	L 1 IO	GTR PROJECT	0.3	22	C EV	YN	-
317	AM_A	08/15/83	L 1 IO	GTR DESCRIPTION	0.3	19	C EV	YP	0
318	AM_A	08/18/83	L 1 OO	COMMENTS BACK ON GTR	0.6	19	C EV	SC	-
319	CDE	08/18/83	L 1 OO	PROJECT UPDATE	0.4	17	E XR	YR	+
320	CDE	08/19/83	L 1 IO	COMMENTS BACK ON GTR	0.5	17	E RC	YN	-
321	AM_A	08/19/83	L 1 IO	UPDATE	0.2	19	E XR	YR	+
322	AM_A	08/19/83	T 2 IO	COMMENTS BACK ON GTR	0.6	19	E XP	YN	-
322	CDE	08/19/83	T 2 OO	COMMENTS BACK ON GTR	0.6	17	E XP	YN	-
323	CDE	08/25/83	M 2 A	CCE FLY TO UK	1.0	17	E XP	YT	+
323	CCE	08/25/83	M 2 O	FLY TO UK TO WORK	1.0	16	E XP	YT	+
324	CDE	08/25/83	M 3 A	PERMISSION FOR CCE	0.2	17	E XP	YE	+
324	CCE	08/25/83	M 3 N	PERMISSION FOR WORK	0.2	16	E XP	YN	+
325	AM_A	09/05/83	M 4 L	OPEN DAY EXHIBIT	0.4	19	E XS	YI	+
325	CDE	09/05/83	M 4 L	OPEN DAY EXHIBIT	0.4	17	E XS	YI	+
325	RM_U	09/05/83	M 4 L	OPEN DAY EXHIBIT	0.4	17	E XS	YI	+
325	LO_U	09/05/83	M 4 L	OPEN DAY EXHIBIT	0.4	16	E XS	YI	+
326	SL_A	09/05/83	M 4 L	SLAG RIG/OPEN DAY	0.3	17	E XS	YI	+
326	CDE	09/05/83	M 4 L	SLAG RIG/OPEN DAY	0.3	17	E XS	YI	+
326	RM_U	09/05/83	M 4 L	SLAG RIG/OPEN DAY	0.3	17	E XS	YI	+
326	LO_U	09/05/83	M 4 L	SLAG RIG/OPEN DAY	0.3	16	E XS	YI	+
327	DE_S	09/05/83	M 3 R	OPEN DAY DISPLAY	0.2	14	E XS	YI	+
327	CDE	09/05/83	M 3 R	OPEN DAY DISPLAY	0.2	17	E XS	YI	+
327	RM_U	09/05/83	M 3 R	OPEN DAY DISPLAY	0.2	17	E XS	YI	0
328	RI_A	09/05/83	M 3 L	OPEN DAY	0.3	13	E XS	YI	-
328	CDE	09/05/83	M 3 L	OPEN DAY VIDEO	0.3	17	E XS	YI	+

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INT/NO	PERSON	DATE	TYPE/L	TOPIC	HRS	£/H	P/ACT	TQ	M
328	RM_U	09/05/83	M 3 L	OPEN DAY	0.3	17	E XS	YI	+
329	R2_A	09/05/83	M 3 L	OPEN DAY AT R.	0.1	13	E XS	YI	+
329	CDE	09/05/83	M 3 L	OPEN DAY VISIT	0.1	17	E XS	YI	+
329	LO_U	09/05/83	M 3 L	OPEN DAY	0.1	16	E XS	YI	+
330	ASL_A	09/05/83	M 4 L	CLARET - OPEN DAY	0.2	14	E XS	YI	+
330	CDE	09/05/83	M 4 L	CLARET SOFTWARE	0.2	17	E XS	YI	+
330	RM_U	09/05/83	M 4 L	CLARET - OPEN DAY	0.2	17	E XS	YI	+
330	LO_U	09/05/83	M 4 L	CLARET PROGRAM	0.2	16	E XS	YI	+
331	CDE	09/14/83	M 2 O	PRESSURE TRANSDUCERS	1.2	17	E XI	YQ	+
331	SE_FL	09/14/83	M 2 A	PRESSURE TRANSDUCERS	1.2	15	E XI	YQ	+
332	CDE	09/14/83	W 1 O	TAR CONDENSER	2.0	17	E SS	II	0
333	CDE	09/16/83	W 1 O	VESSEL DRAWINGS & CALCS	7.0	17	E PL	YS	0
334	CDE	09/18/83	L 1 OO	THANKS FOR OPEN DAY	0.6	17	E XS	YI	+
335	D_R	09/19/83	L 1 IO	R OPEN DAY	0.1	27	E XS	0	0
336	RI_A	09/19/83	W 2 N	REACTOR CONCEPT	2.3	13	E RC	YQ	+
336	CDE	09/19/83	W 2 A	REACTOR CONCEPT	2.3	17	E RC	YE	+
337	R2_A	09/19/83	M 2 L	ADDRESSES/INFORMATION	0.3	13	E XI	YQ	+
337	CDE	09/19/83	M 2 L	CONTACTS/INFO	0.3	17	E XI	YQ	+
337	CDD	09/19/83	M 2 T	INTRODUCTION & GENERAL	0.3	15	E XI	YQ	+
338	AM_S	09/19/83	M 2 O	UPDATE	0.1	19	E XR	YR	0
338	DE_S	09/19/83	M 2 D	UPDATE	0.1	14	E XR	YR	0
338	CDE	09/19/83	M 2 D	UPDATE	0.1	17	E XR	YR	+
339	CDE	09/19/83	M 2 A	UPDATE	0.1	17	E XR	YR	+
340	CDE	09/19/83	M 2 T	INTRO & GENERAL	0.3	17	E XS	YI	+
341	CDE	09/19/83	W 1 A	WEEKLY REPORTS	0.2	17	E XR	YR	0
342	CDE	09/22/83	L 1 OO	PRODUCT INFORMATION	4.0	17	E XI	YQ	0
343	SE_FL	09/23/83	L 1 IO	TUBE INFORMATION	0.2	15	E XI	YQ	0
344	SE_FL	09/23/83	L 1 IO	PIPE INFORMATION	0.2	15	E XI	YQ	0
345	SE_FL	09/23/83	L 1 IO	SAFFIL INFORMATION	0.2	15	E XI	YQ	0
346	SE_FL	09/23/83	L 1 IO	FIBERFRAX INFORMATION	0.2	15	E XI	YQ	0
347	SE_FL	09/23/83	L 1 IO	FURNACE ELEMENTS	0.2	15	E XI	YQ	0
348	SE_FL	09/23/83	L 1 IO	HEATING ELEMENTS	0.2	15	E XI	YQ	0
349	SE_FL	09/23/83	L 1 IO	INCOLOY 800H	0.2	15	E XI	YQ	0
350	SE_FL	09/23/83	L 1 IO	SOCKET HEAD BOLTS	0.2	15	E XI	YQ	0
351	SE_FL	09/23/83	L 1 IO	CAP SCREWS	0.2	15	E XI	YQ	0
352	CDE	09/23/83	W 1 O	PRESSURE VESSEL CALCULATIONS	9.5	17	E PL	YS	0
353	CDE	09/24/83	W 1 O	CALCULATIONS AND FILING	4.0	17	E PL	YS	0
354	AM_S	09/26/83	M 4 O	CONCEPT, VESSEL & Q.A.	1.8	19	E PL	YR	0
354	SL_A	09/26/83	M 4 A	CONCEPT, VESSEL & Q.A.	1.8	17	E PL	YE	-
354	DE_S	09/26/83	M 4 A	GTR CONCEPT & Q.A.	1.8	14	E PL	0	0
354	CDE	09/26/83	M 4 A	CONCEPT, VESSEL & QA	1.8	17	E PL	YE	+
355	AM_S	09/26/83	M 4 C	GENERAL	1.0	19	E XS	YI	+
355	SL_A	09/26/83	M 4 C	LUNCH/GENERAL	1.0	17	E XS	YI	+
355	DE_S	09/26/83	M 4 C	LUNCH	1.0	14	E XS	0	+
355	CDE	09/26/83	M 4 C	LUNCH	1.0	17	E XS	YI	+
356	DE_S	09/26/83	M 3 R	SPECIFICATIONS & CODES	2.0	14	E PL	YQ	0
356	CDE	09/26/83	M 3 R	SPECIFICATION & CODES	2.0	17	E PL	YQ	0
356	CDD	09/26/83	M 3 R	SPECIFICATION & CODES	2.0	15	E PL	YQ	0
357	SL_A	09/26/83	W 2 O	PRESSURE VESSEL DESIGN	0.8	17	E PL	YQ	0
357	CDE	09/26/83	W 2 A	PRESSURE VESSEL DESIGN	0.8	17	E PL	YQ	0
358	SL_A	09/26/83	T 2 OO	APPENDIX Y ASME VIII REQUEST	0.2	17	E XI	YQ	0
358	QAO_H	09/26/83	T 2 IO	APPENDIX Y/ ASME VIII	0.2	14	E XI	0	0

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INT/NO	PERSON	DATE	TYPE/L	TOPIC	HRS	£/H	P/ACT	TQ	M
359	CDE	09/27/83	W 1 O	GTR-3 REPORT	2.0	17	E XR	YR	0
360	SE_FL	09/28/83	L 1 OO	TUBE/PIPE INFORMATION	0.3	15	E XI	YQ	0
361	SE_FL	09/28/83	L 1 OO	FURNACE ELEMENTS	0.3	15	E XI	YI	+
362	SE_FL	09/28/83	L 1 OO	INCOLOY 800H	0.3	15	E XI	YQ	0
363	SE_FL	09/28/83	L 1 OO	HEATING ELEMENTS	0.3	15	E XI	YQ	0
364	SE_FL	09/28/83	L 1 OO	FIBERFRAX INFO	0.3	15	E XI	YQ	0
365	SE_FL	09/28/83	L 1 OO	SAFFIL INFO	0.3	15	E XI	YQ	0
366	SE_FL	09/28/83	L 1 OO	TUBES	0.3	15	E XI	YQ	0
367	QAO_H	09/28/83	L 1 OO	APPENDIX Y ASME VIII	0.4	14	E XI	YI	+
368	CDE	09/29/83	L 1 IO	TUBE/PIPE INFO	0.2	17	E XI	YF	0
369	CDE	09/29/83	L 1 IO	FURNACE ELEMENTS	0.2	17	E XI	YF	+
370	CDE	09/29/83	L 1 IO	INCOLOY 800H	0.2	17	E XI	YF	0
371	CDE	09/29/83	L 1 IO	HEATING ELEMENTS	0.2	17	E XI	YF	0
372	CDE	09/29/83	L 1 IO	FIBERFRAX INFO	0.2	17	E XI	YF	0
373	CDE	09/29/83	L 1 IO	SAFFIL INFO	0.2	17	E XI	YF	0
374	CDE	09/29/83	L 1 IO	TUBES INFO	0.2	17	E XI	YF	0
375	CDE	09/29/83	L 1 IO	ASME VIII APPENDIX Y	1.0	17	E XI	YQ	+
376	CDE	10/03/83	W 1 O	SORTING PAPERS	2.0	17	E XI	YF	-
377	CDE	10/05/83	L 1 OO	THANKS TO CARBOLITE	0.1	17	E XI	YI	+
378	SE_FL	10/06/83	L 1 IO	THANKS CARBOLITE	0.1	15	E XI	0	0
379	CDE	10/10/83	W 1 O	GTR-2 REPORTS	2.0	17	C XR	YR	0
380	SL_A	10/10/83	W 2 O	VESSEL MATERIALS	2.5	17	E PL	DG	+
380	CDE	10/10/83	W 2 A	VESSEL MATERIALS	2.5	17	E PL	DG	0
381	SL_A	10/10/83	L 1 IO	C.V. FROM CCE	0.2	17	E XP	YN	-
382	AM_A	10/10/83	M 2 O	REPORTS GTR-2 DELIVERED	0.1	19	C XR	YR	0
382	CDE	10/10/83	M 2 A	REPORT GTR-2	0.1	17	C XR	YR	0
383	M_A	10/10/83	M 2 O	REPORT GTR-2	0.1	22	C XR	YE	+
383	CDE	10/10/83	M 2 A	REPORT GTR-2	0.1	17	C XR	YR	+
384	M_S	10/10/83	M 2 O	GTR-2 REPORT	0.1	22	C XR	YR	0
384	CDE	10/10/83	M 2 A	REPORT GTR-2	0.1	17	C XR	YR	0
385	CDE	10/11/83	W 1 O	PRESSURE VESSEL CALCULATIONS	2.0	17	E PL	YS	0
386	CDE	10/12/83	W 1 O	PRESSURE VESSEL DRAWINGS	3.0	17	E PL	DD	0
387	CDE	10/13/83	W 1 O	PRESSURE VESSEL DRAWINGS	6.0	17	E PL	DD	0
388	AM_A	10/17/83	L 1 OO	PROPOSED GTR	1.0	19	C XR	YP	0
389	M_A	10/17/83	L 1 IO	PROPOSED GTR	0.2	22	C EV	YP	0
390	SL_A	10/17/83	L 1 IO	GTR DESCRIPTION	0.2	17	E XR	YP	0
391	CDE	10/17/83	L 1 IA	PROPOSED GTR	0.2	17	E XR	YP	0
392	AM_A	10/17/83	M 2 O	PROJECT REVIEW	0.3	19	E XR	YR	+
392	CDE	10/17/83	M 2 A	PROJECT REVIEW	0.3	17	E XR	YR	+
393	SL_A	10/17/83	W 2 O	INNER REACTOR DETAILS	1.3	17	E ML	II	+
393	CDE	10/17/83	W 2 A	INNER REACTOR DETAILS	1.3	17	E ML	II	0
394	DE_S	10/17/83	M 3 D	WHESSOE PVE-5	0.5	14	E XI	0	+
394	CDE	10/17/83	M 3 D	WHESSOR PVE-5	0.5	17	E XI	YE	+
394	CDD	10/17/83	M 3 D	WHESSOE PVE-5	0.5	15	E XI	YE	-
395	AM_S	10/17/83	M 2 O	WHESSOE PVE-5	0.1	19	E XI	YE	+
395	CDE	10/17/83	M 2 A	WHESSOE PVE-5	0.1	17	E XI	YE	+
396	ASL_A	10/17/83	M 3 N	JOKES/STORIES	0.2	14	E XS	0	+
396	R1_A	10/17/83	M 3 N	JOKES/STORIES	0.2	13	E XS	YH	+
396	CDE	10/17/83	M 3 A	GENERAL	0.2	17	E XS	YH	+
397	AM_A	10/17/83	M 2 O	M, CONTROLS DESIGN	0.6	19	E XP	YI	+
397	CDE	10/17/83	M 2 A	D_G/CONTROLS DESIGN	0.6	17	E XP	YI	+
398	D_G	10/20/83	L 1 IO	PROPOSED GTR DESCRIPTION	0.3	27	E RC	0	0

GTR PROJECT INTERCHANGES BY DATE AND NUMBER

INT/NO	PERSON	DATE	TYPE/L	TOPIC	HRS	£/H	P/ACT	TQ	M
399	CDE	10/24/83	W 1 T	PLAN FOR DAY	0.9	17	E XP	YL	0
400	M_S	10/24/83	M 2 O	REVIEW OF GTR-2	0.2	22	C XR	YR	+
400	CDE	10/24/83	M 2 A	REVIEW OF GTR-2	0.2	17	E XR	YE	+
401	AM_A	10/24/83	M 2 O	PVE-5	0.1	19	E XI	0	-
401	CDE	10/24/83	M 2 A	PVE-5	0.1	17	E XI	0	+
402	SL_A	10/24/83	W 2 N	DETAILS OF REACTOR/SPEC	2.5	17	E ML	SC	+
402	CDE	10/24/83	W 2 A	REACTOR DETAILS	2.5	17	E ML	SC	0
403	SL_A	10/26/83	M 9 R	TEST PROGRAMS IN GTR	1.0	17	E RC	YP	-
404	AM_S	10/31/83	M 3 A	FEEDBACK ON PVE-R	0.5	19	E XI	YR	+
404	CDE	10/31/83	M 3 A	FEEDBACK ON PVE-5	0.5	17	E XI	YE	+
405	AM_A	10/31/83	M 2 O	W.P. & SUPPORT FOR GTR	0.5	19	E XR	0	+
405	CDE	10/31/83	M 2 A	W.P. & PROJECT SUPPORT	0.5	17	E XR	0	-
406	SL_A	11/06/83	W 1 H	SPECIMEN TEST PROGRAM	3.0	17	D XP	YP	+
407	SL_A	11/07/83	W 2 O	TEST PROGRAM	1.5	17	D XP	YL	+
407	CDE	11/07/83	W 2 A	TEST PROGRAM	1.5	17	D XP	YL	+
408	AM_A	11/07/83	T 2 IO	MTG. TIME IN AFTERNOON	0.1	19	E XP	0	0
408	SL_A	11/07/83	T 2 OO	MEETING TIME	0.1	17	E XP	0	+
409	SL_A	11/07/83	M 4 P	SEARCHING FOR S1_A	0.5	17	E XI	YI	-
409	CDE	11/07/83	M 4 P	SEARCHING FOR S1_A	0.5	17	E XI	YH	+
410	SL_A	11/07/83	M 3 L	H.P. PLASTOMETRY	1.1	17	E XI	YQ	+
410	CDE	11/07/83	M 3 L	H.P. PLASTOMETRY	1.1	17	E XI	YQ	+
411	S1_A	11/07/83	W 2 O	COAL TYPES	0.5	13	E XI	YQ	+
411	CDE	11/07/83	W 2 A	COAL TYPES	0.5	17	E XI	YQ	+
412	AM_A	11/07/83	M 3 O	SPECIMEN TEST PROGRAM	1.0	19	D XP	YQ	-
412	SL_A	11/07/83	M 3 A	TEST PROGRAM	1.0	17	D XP	YQ	-
412	CDE	11/07/83	M 3 A	SPECIMEN TEST PROGRAM	1.0	17	D XP	YQ	0
413	SL_A	11/13/83	W 1 H	REVISED PROGRAM DOCUMENT	3.0	17	D XP	YP	+
414	SL_A	11/14/83	M 2 P	USE OF DESIGN METHODS	0.2	17	E XR	0	0
414	CDE	11/14/83	M 2 P	USE OF DESIGN METHODS	0.2	17	E XR	YQ	0
415	SL_A	11/14/83	M 3 A	REACTOR CONCEPT	0.8	17	E RC	SC	0
415	S1_A	11/14/83	M 3 O	REACTOR CONCEPT	0.8	13	E RC	SC	+
415	CDE	11/14/83	M 3 A	REACTOR CONCEPT	0.8	17	E RC	SC	0
416	SL_A	11/14/83	M 3 A	COAL PLASTICITY	1.8	17	E DL	II	0
416	SL_P	11/14/83	M 3 O	COAL PLASTICITY	1.8	17	E DL	II	0
416	CDE	11/14/83	M 3 A	COAL PLASTICITY	1.8	17	E DL	II	0
417	SL_A	11/14/83	M 2 N	PRESENTATION TO M_A & AM_A	0.3	17	E XP	0	+
417	CDE	11/14/83	M 2 A	MEETING WITH M_A & AM_A	0.3	17	E XP	0	+
418	R1_A	11/14/83	M 2 O	GREETING ONLY	0.1	13	E XS	YI	+
418	CDE	11/14/83	M 2 A	GREETINGS ONLY	0.1	17	E XS	YI	+
419	CDE	11/14/83	W 1 T	PRESENTATION APPROACH	0.9	17	E XR	YL	+
420	CDE	11/17/83	W 1 O	PREPARING OVERHEADS	9.5	17	E XR	YP	+
421	SL_A	11/17/83	W 1 O	PREP OF TRANSPARENCIES	3.0	17	E XR	YP	0
422	CDE	11/18/83	W 1 T	PLAN FOR DAY	0.9	17	E XP	YL	+
423	SL_P	11/18/83	M 2 O	COAL CHARACTERISTICS	1.5	17	E XI	YI	+
423	CDE	11/18/83	M 2 A	COAL CHARACTERISTICS	1.5	17	E XI	YI	+
424	M_A	11/18/83	M 4 R	DRY RUN OF PRESENTATION	2.2	22	E XR	YP	+
424	AM_A	11/18/83	M 4 R	PRESENTATION DRY-RUN	2.2	19	E XR	YP	+
424	SL_A	11/18/83	M 4 R	PRESENTATION DRY RUN	2.2	17	E XR	YP	+
424	CDE	11/18/83	M 4 R	PRESENTATION DRY-RUN	2.2	17	E XR	YP	+
425	SL_A	11/18/83	M 2 R	REACTOR CONCEPT	1.0	17	E RC	SC	0
425	CDE	11/18/83	M 2 R	REACTOR CONCEPT	1.0	17	E RC	SC	0
426	SL_A	11/21/83	M 2 R	TAPES OF DRY RUN	2.0	17	E XR	0	+

GTR PROJECT INTERCHANGES BY DATE AND NUMBER

INT/NO	PERSON	DATE	TYPE/L	TOPIC	HRS	£/H	P/ACT	TQ	M
426	CDE	11/21/83	M 2	R TAPES OF DRY RUN	2.0	17	E XR	0	-
427	CDE	11/22/83	L 1	OO UPDATE & THANKS	2.0	17	E XR	YR	+
428	DE1_M	11/23/83	L 1	IO LETTER OF THANKS	0.1	15	E XR	0	0
429	AM_A	11/23/83	L 1	IO M MTG REVIEW	0.1	19	E XR	YR	+
430	SL_A	11/28/83	L 1	IO GAS/TAR SEPARATION	0.1	17	E RC	SC	0
431	SL_A	11/28/83	W 2	L HASKEL PUMP	2.0	17	E AL	SP	0
431	CDE	11/28/83	W 2	L HASKEL PUMP	2.0	17	E AL	SP	0
432	AM_A	12/05/83	M 2	O DATES & ARRANGEMENT	1.0	19	E XP	0	0
432	CDE	12/05/83	M 2	A DATES/ARRANGEMENTS	1.0	17	E XP	0	0
433	SL_A	12/05/83	M 2	C PRESENTATION DATES	0.5	17	E XP	0	-
433	CDE	12/05/83	M 2	C LUNCH/PRESENTATION DATES	0.5	17	E XP	0	+
434	R2_A	12/05/83	M 3	E VISIT TO TEST RIG BLDG	1.5	13	E XI	YQ	+
434	BPO_S	12/05/83	M 3	E VISIT TO TEST RIG BLDG	1.5	14	E XI	YQ	+
434	CDE	12/05/83	M 3	E VISIT TO TEST RIG BLDG	1.5	17	E XI	YQ	+
435	AM_A	12/05/83	M 2	O DAY'S EFFORTS	0.1	19	E XR	YI	0
435	CDE	12/05/83	M 2	A REPORT ON DAY'S WORK	0.1	17	E XR	YR	0
436	M_A	12/05/83	M 2	O GAS STORAGE-RIG BUILDING	0.1	22	E SC	0	0
436	CDE	12/05/83	M 2	A GAS STORAGE/ RIG BLDG	0.1	17	E SC	YS	+
437	SL_A	12/08/83	T 2	OO PRESENTATION DATE	0.5	17	E XP	0	-
437	CDE	12/08/83	T 2	IO PRESENTATION DATE	0.5	17	E XP	YE	+
438	ASL_A	12/09/83	T 2	OO GTR PRESENTATION & REVIEW	0.1	14	E XP	0	+
438	CDE	12/09/83	T 2	IO GTR PRESENTATION	0.1	17	E XP	YE	+
439	AM_A	12/12/83	T 2	IO MEETING ARRANGEMENTS	0.3	19	E XR	YP	+
439	CDE	12/12/83	T 2	OO MEETING ARRANGEMENTS	0.3	17	E XR	YP	+
440	CCE	12/12/83	L 1	OO CONTROL SYSTEM DESIGN	1.0	16	E XP	YI	-
441	CDE	12/16/83	W 1	O PREPARING TRANSPARENCIES	7.0	17	E XR	YP	+
442	AM_A	12/16/83	T 2	OO FINAL ARRANGEMENTS	0.2	19	E XP	0	+
442	CDE	12/16/83	T 2	OO FINAL ARRANGEMENTS	0.2	17	E XP	YE	+
443	SL_A	12/16/83	T 2	IO PREPARATION FOR PRESENTATION	0.4	17	E XR	YP	+
443	CDE	12/16/83	T 2	OO PREPARING FOR PRESENTATION	0.4	17	E XR	YP	+
444	SL_A	12/19/83	T 2	OO TAPE TRANSCRIPTION	0.4	17	E XP	0	-
444	CDE	12/19/83	T 2	IO TAPE TRANSCRIPTION	0.4	17	E XP	YH	+
445	SL_A	12/20/83	W 1	O PREPARATION FOR MEETING	2.5	17	E XP	YP	0
446	CDE	12/20/83	W 2	L GTR PRESENTATION DRY RUN	1.0	17	E XR	YP	-
446	RM_U	12/20/83	W 2	L GTR PRESENTATION DRY RUN	1.0	17	E XR	YP	-
447	CDE	12/20/83	W 2	L SECOND DRY RUN	1.2	17	E XR	YP	0
447	RM_U	12/20/83	W 2	L SECOND DRY RUN	1.2	17	E XR	YP	0
448	M_A	12/21/83	M 4	O MTG BEFORE PRESENTATION	1.0	22	E XR	YP	+
448	AM_A	12/21/83	M 4	R FINAL BRIEFING/DRY RUN	1.0	19	E XR	YP	+
448	SL_A	12/21/83	M 4	R PRELIMINARY MEETING	1.0	17	E XR	YP	+
448	CDE	12/21/83	M 4	R MEETING BEFORE PRESENTATION	1.0	17	E XR	YP	+
449	CDE	12/21/83	L 1	IO CONTROL SYSTEM DESIGN	0.2	17	E XP	YE	+
450	D_G	12/21/83	M 9	A GTR CONCEPT	2.6	27	E RC	YQ	0
450	D_R	12/21/83	M 9	N GTR CONCEPT	2.6	27	E RC	YR	+
450	AD2_R	12/21/83	M 9	A GTR CONCEPT	2.6	23	E RC	YE	+
450	M_A	12/21/83	M 9	A GTR PROJECT & CONCEPT	2.6	22	E XR	YP	+
450	AM_A	12/21/83	M 9	A GTR PRESENTATION	2.6	19	E XR	YP	+
450	SL_A	12/21/83	M 9	A GTR PROJECT & CONCEPT	2.6	17	E XR	YP	+
450	C_G	12/21/83	M 9	A GTR PRESENTATION	2.6	22	E XR	YQ	0
450	CDE	12/21/83	M 9	A GTR CONCEPT REVIEW	2.6	17	E RC	YE	+
450	RM_U	12/21/83	M 9	A GTR PRESENTATION	2.6	17	E XR	YE	+
451	CDE	12/21/83	L 1	OH CONTROL SYSTEM DESIGN	0.3	17	E XP	YE	+

GTR PROJECT INTERCHANGES BY DATE AND NUMBER

INT/NO	PERSON	DATE	TYPE/L	TOPIC	HRS	£/H	P/ACT	TQ	M
452	CCE	12/24/83	L 1	IH CONTROL SYSTEM DESIGN	0.2	16	E XP	YI	0
453	AM_A	01/02/84	L 1	OO PRESENTATION & SECONDMENT	0.5	19	E XP	YI	+
454	D_G	01/03/84	L 1	OO GTR PROJECT	1.5	27	E RC	YR	-
455	AD2_R	01/03/84	L 1	IO GTR PROJECT -LETTER FROM D_G	0.2	23	E RC	0	0
456	M_A	01/03/84	L 1	IO GTR PROJECT & CONCEPT	0.5	22	E RC	0	-
457	C_G	01/03/84	L 1	IO GTR PROJECT	0.1	22	E RC	0	0
458	CDE	01/04/84	L 1	IO THANKS FROM AM_A	0.2	17	E XS	0	+
459	SL_A	01/04/84	T 2	IO PROJECT FUTURE	0.0	17	D XP	0	0
459	CDE	01/04/84	T 2	OO PROJECT FUTURE	0.1	17	D XP	0	+
460	SL_A	01/06/84	T 2	IO PROJECT FUTURE	0.0	17	D XP	0	0
460	CDE	01/06/84	T 2	OO PROJECT FUTURE	0.2	17	D XP	0	+
461	SL_A	01/09/84	T 2	IO PROJECT FUTURE	0.0	17	D XP	0	0
461	CDE	01/09/84	T 2	IO PROJECT FUTURE	0.1	17	D XP	0	0
462	SL_A	01/09/84	T 2	OO FEEDBACK FROM D_G	0.5	17	E EL	YN	-
462	CDE	01/09/84	T 2	IO FEEDBACK FROM D_G	0.5	17	E EL	YN	-
463	SL_A	01/11/84	T 2	IO NEXT VISIT OF CDE	0.1	17	E XP	YN	-
463	CDE	01/11/84	T 2	IO NEXT VISIT OF CDE	0.1	17	E XP	YN	-
464	CDE	01/16/84	W 1	T PLAN FOR DAY	0.9	17	E XP	YL	0
465	SL_A	01/16/84	M 2	O CASE FOR PROJECT	2.0	17	E EL	YN	0
465	CDE	01/16/84	M 2	A CASE FOR PROJECT	2.0	17	E EL	YN	0
466	BPO_S	01/16/84	M 2	P PROJECT STATUS	0.1	14	E EL	YN	+
466	CDE	01/16/84	M 2	P PROJECT STATUS	0.1	17	E EL	YN	+
467	SL_P	01/16/84	M 2	A DESIGN REVIEW	0.5	17	E RD	YR	+
467	CDE	01/16/84	M 2	A DESIGN REVIEW	0.5	17	E RD	YN	+
468	S1_P	01/16/84	M 2	P GAS REACTION CALCULATIONS	0.3	13	E XR	YS	+
468	CDE	01/16/84	M 2	P GAS REACTION CALCULATIONS	0.3	17	E XR	YS	+
469	SL_A	01/16/84	M 2	A FUTURE OPTIONS	1.0	17	D XP	YN	0
470	CDE	01/18/84	L 1	OO GTR PROJECT	4.0	17	E RD	YN	0
471	SL_A	01/18/84	L 1	OO GASIFIER TEST RIG	1.0	17	E RC	YN	+
472	M_A	01/18/84	L 1	IO GTR PROJECT	0.5	22	E RC	0	-
473	M_A	01/19/84	L 1	IO GTR PROJECT & CONCEPT	0.5	22	E RC	0	+
474	CDE	01/19/84	L 1	OO UPDATE ON PROJECT	1.5	17	E XR	YE	+
475	AM_A	01/19/84	L 1	IO UPDATE	0.1	19	E XR	YR	0
476	AM_A	01/19/84	L 1	IO MEMO FROM D_G	0.1	19	E RC	SC	0
477	AM_A	01/19/84	L 1	IO MEMO FROM D_G	0.1	19	E RC	SC	+
478	RM_U	01/19/84	L 1	IO COPIES OF LETTERS	0.1	17	E XR	YR	+
479	CDE	01/20/84	L 1	OO DRAWING TO D_G	0.6	17	E XS	DD	+
480	SL_A	01/20/84	L 1	IO ANSWER TO D_G LETTER	0.2	17	E RC	YN	+
481	D_G	01/21/84	L 1	IO PROJECT MEETING	0.1	27	E RC	0	+
482	SL_A	01/23/84	T 2	IA VISIT OF CDE	0.1	17	E XP	0	0
482	CDE	01/23/84	T 2	OO VISIT OF CDE	0.1	17	E XP	0	0
483	CDE	01/23/84	W 1	O REPORT GTR-3	9.5	17	E XR	YR	0
484	SL_A	01/30/84	T 2	IO SUPPORT FOR GTR	0.1	17	D XP	YN	+
484	CDE	01/30/84	T 2	OO SUPPORT FOR GTR	0.1	17	D XP	YN	+
485	SL_A	01/30/84	T 2	OO SUPPORT FOR GTR	0.2	17	D XP	YN	+
485	CDE	01/30/84	T 2	IO SUPPORT FOR GTR	0.2	17	D XP	YN	+
486	CDE	01/30/84	W 1	T PLAN FOR DAY	0.9	17	E XP	YL	+
487	SL_A	01/30/84	M 2	C REVIEW OF CONCEPT	1.0	17	E RD	SC	+
487	CDE	01/30/84	M 2	C REVIEW OF CONCEPT	1.0	17	E RD	SC	+
488	D_R	01/30/84	M 2	P GREETING ONLY	0.1	27	E XS	YI	+
488	CDE	01/30/84	M 2	P GREETING ONLY	0.1	17	E XS	YI	+
489	AD2_R	01/30/84	M 3	P GTR PROJECT	0.5	23	D XP	YE	+

GTR PROJECT INTERCHANGES BY DATE AND NUMBER

INT/NO	PERSON	DATE	TYPE/L		TOPIC	HRS	£/H	P/ACT	TQ	M
489	SL_A	01/30/84	M 3	P	PROJECT DIRECTION/FUNDS	0.5	17	D XP	YN	+
489	CDE	01/30/84	M 3	P	GTR PROJECT	0.5	17	D XP	YE	+
490	SL_A	01/30/84	M 2	R	PAHL & BEITZ AND MANAGEMENT	2.0	17	E XS	YI	0
490	CDE	01/30/84	M 2	R	PAHL & BEITZ/MANAGEMENT	2.0	17	E XS	YI	0
491	SL_P	01/30/84	M 2	P	ARRANGE MEETING	0.1	17	E XH	YQ	+
491	CDE	01/30/84	M 2	P	ARRANGE MEETING	0.1	17	E XH	YI	+
492	SI_P	01/30/84	M 2	O	GAS REACTION CALCULATIONS	0.1	13	E PL	YS	-
492	CDE	01/30/84	M 2	A	GAS REACTION CALCULATIONS	0.1	17	E PL	YQ	0
493	M_A	01/30/84	M 2	O	FUNDING FOR RIG	0.1	22	D XC	YN	-
493	CDE	01/30/84	M 2	A	FUNDING FOR RIG	0.1	17	E XC	YN	+
494	SL_A	01/30/84	M 2	O	REVIEW DAY'S WORK	0.2	17	E XR	YR	0
494	CDE	01/30/84	M 2	A	REVIEW DAY'S WORK	0.2	17	E XR	YR	0
495	SI_P	01/30/84	M 2	P	CDE INTRODUCED TO SUPERVISOR	0.2	13	E XS	YI	+
495	CDE	01/30/84	M 2	P	INTRO TO SI_P BOSS	0.2	17	E XS	YI	+
496	CDE	02/02/84	M 2	C	PROJECT STATUS	0.3	17	E XR	YE	+
496	LO_U	02/02/84	M 2	C	PROJECT STATUS	0.3	16	E XR	YE	+
497	SL_A	02/02/84	T 2	OO	GTR PROJECT	0.8	17	T SP	SP	+
497	CDE	02/02/84	T 2	IO	GTR PROJECT	0.8	17	T SP	SP	+
498	CDE	02/02/84	M 2	A	CALL FROM SL_A	0.1	17	D XP	YE	+
498	RM_U	02/02/84	M 2	O	CALL FROM SL_A	0.1	17	D XP	YE	+
499	SL_A	02/03/84	T 2	IO	MTG BETWEEN D'S AND M'S	0.1	17	D XP	YN	+
499	CDE	02/03/84	T 2	OO	MEETING BETWEEN DIRS & MGRS	0.1	17	D XP	YN	+
500	CDE	02/03/84	M 2	C	GTR DESCRIPTION	0.5	17	E XS	YT	+
500	LO_U	02/03/84	M 2	C	GTR DESCRIPTION	0.5	16	E XS	YT	+
501	SL_A	02/03/84	T 2	IO	MEETING WITH M_A	0.2	17	D XP	YN	+
501	CDE	02/03/84	T 2	IO	ARRANGE MEETING WITH M_A	0.2	17	D XP	YN	+
502	CDE	02/07/84	W 1	T	PLAN FOR DAY	0.9	17	E XP	YL	0
503	SL_A	02/07/84	M 2	O	REVIEW OF STATUS	0.5	17	D XP	YR	+
503	CDE	02/07/84	M 2	A	REVIEW STATUS	0.5	17	D XP	YR	0
504	M_A	02/07/84	M 3	O	DETAIL DESIGN	2.0	22	D XP	YN	+
504	SL_A	02/07/84	M 3	A	DECISION TO GO AHEAD	2.0	17	D XP	YN	+
504	CDE	02/07/84	M 3	A	DECISION TO GO AHEAD	2.0	17	D XP	YN	+
505	SI_P	02/07/84	W 1	O	FULL GAS REACTION CALCS.	4.0	13	E OD	YS	0
506	SI_P	02/07/84	M 2	L	REVISED CALCULATION RESULTS	0.3	13	E XR	YS	0
506	CDE	02/07/84	M 2	L	REVISED CALCULATION RESULTS	0.3	17	E XR	YS	+
507	SL_P	02/07/84	M 2	O	HEAT TRANSFER IN COAL	1.5	17	E XI	YQ	+
507	CDE	02/07/84	M 2	A	HEAT TRANSFER IN COAL	1.5	17	E XI	YQ	0
508	RI_A	02/08/84	T 2	IO	REVIEW OF PROJECT	0.2	13	E XR	YR	+
508	CDE	02/08/84	T 2	OO	REVIEW OF PROJECT	0.2	17	E XR	YR	+
509	SL_A	02/08/84	T 2	IO	IDEAS FOR REACTOR	0.5	17	E OD	II	0
509	CDE	02/08/84	T 2	OO	IDEAS FOR REACTOR	0.5	17	E OD	II	0
510	SL_A	02/09/84	M 2	C	PREPARE FOR PRESENTATION	1.5	17	E XR	YP	0
510	CDE	02/09/84	M 2	C	PREPARING FOR PRESENTATION	1.5	17	E XR	YP	+
511	M_A	02/09/84	M20	R	GTR PROJECT & CONCEPT	1.5	22	E XR	YP	0
511	M_S	02/09/84	M20	R	CONCEPT PRESENTATION	1.5	22	E XR	YP	0
511	AM_A	02/09/84	M20	R	CONCEPT PRESENTATION	1.5	19	E XR	YP	+
511	AM_S	02/09/84	M20	R	CONCEPT PRESENTATION	1.5	19	E XR	YP	+
511	SL_A	02/09/84	M20	R	PRESENTATION ON GTR	1.5	17	E XR	YE	0
511	SL_P	02/09/84	M20	R	PRESENTATION ON GTR	1.5	17	E XR	YP	+
511	ASL_A	02/09/84	M20	R	PRESENTATION ON GTR	1.5	14	E XR	YP	+
511	SI_A	02/09/84	M20	R	PRESENTATION ON GTR	1.5	13	E XR	YP	0
511	SI_P	02/09/84	M20	R	PRESENTATION ON GTR	1.5	13	E XR	YP	0

GTR PROJECT INTERCHANGES BY DATE AND NUMBER

INT/NO	PERSON	DATE	TYPE/L		TOPIC	HRS	£/H	P/ACT	TQ	M
511	DE_S	02/09/84	M20	R	CONCEPT PRESENTATION	1.5	14	E XR	0	0
511	CDE	02/09/84	M20	R	PRESENTATION ON GTR	1.5	17	E XR	YE	+
512	CDE	02/13/84	W 1	T	PLAN FOR DAY	0.9	17	D XP	YL	+
513	M_A	02/13/84	M 3	A	DETAIL DESIGN PLANNED	0.8	22	D XP	YL	0
513	AM_S	02/13/84	M 3	O	PLANNING DETAIL DESIGN	0.8	19	D XP	YL	0
513	CDE	02/13/84	M 3	A	DETAIL DESIGN PLANNING	0.8	17	D XP	YL	+
514	RI_A	02/13/84	W 2	O	REVIEW OF CONCEPT	0.3	13	E RC	SC	+
514	CDE	02/13/84	W 2	A	REVIEW OF CONCEPT	0.3	17	E RC	SC	+
515	R2_A	02/13/84	M 2	L	DRAWING OF CONCEPT	0.3	13	E DL	YT	+
515	CDE	02/13/84	M 2	L	DRAWING OF CONCEPT	0.3	17	E DL	YE	+
516	SL_A	02/13/84	M 2	A	DETAIL DESIGN	0.1	17	D XS	0	-
516	CDE	02/13/84	M 2	A	DETAIL DESIGN	0.1	17	D XS	YE	+
517	RI_A	02/13/84	M 2	L	VISIT TO SLAG RIG	0.2	13	E SS	ES	+
517	CDE	02/13/84	M 2	L	VISIT TO SLAG RIG	0.2	17	E SS	ES	+
518	SL_A	02/13/84	M 2	A	REACTOR AND FUNDING	1.3	17	E OD	SP	+
518	CDE	02/13/84	M 2	A	REACTOR & FUNDING	1.3	17	E OD	SP	+
519	CDE	02/19/84	W 1	O	PLANNING DETAIL DESIGN	2.0	17	D XP	YL	0
520	CDE	02/20/84	W 1	T	REVISED D.D. SCHEDULE	0.9	17	D XP	YG	+
521	AM_S	02/20/84	M 3	O	DETAIL DESIGN SCHEDULE	1.0	19	D XP	YG	-
521	DE_S	02/20/84	M 3	A	DETAIL DESIGN SCHEDULE	0.0	14	D XP	0	0
521	CDE	02/20/84	M 3	A	DETAIL DESIGN SCHEDULE	1.0	17	D XP	YG	+
522	CDE	02/20/84	W 1	B	AGREED SCHEDULE	1.0	17	D XP	YN	+
523	SI_A	02/20/84	M 2	B	AUGER IN REACTOR	0.2	13	E OD	II	0
523	CDE	02/20/84	M 2	B	AUGER IN REACTOR	0.2	17	E OD	II	0
524	RI_A	02/20/84	M 2	E	GENERAL UPDATE	0.1	13	D XR	YR	+
524	CDE	02/20/84	M 2	E	GENERAL UPDATE	0.1	17	D XR	YE	+
525	AM_A	02/20/84	M 2	O	PROJECT UPDATE FOR AM_AI	0.7	19	D XR	0	-
525	CDE	02/20/84	M 2	A	PROJECT UPDATE	0.7	17	D XR	YE	+
526	M_A	02/20/84	M 2	A	DETAIL DESIGN PROGRESS	0.1	22	D XR	YI	-
526	CDE	02/20/84	M 2	A	DETAIL DESIGN PROGRESS	0.1	17	D XR	YE	+
527	AM_S	02/24/84	T 2	IO	CALL BACK LATER	0.1	19	D XP	0	0
527	CDE	02/24/84	T 2	OO	CALL TO AM_S	0.1	17	D XP	0	0
528	AM_S	02/24/84	T 2	IO	DESIGN DRAFTSMAN	0.2	19	D XP	0	+
528	CDE	02/24/84	T 2	OO	DESIGN DRAFTSMAN	0.2	17	D XP	0	+
529	CDE	02/25/84	W 1	O	REPORT GTR-3	9.5	17	E XR	YR	+
530	CDE	02/27/84	W 1	O	REPORT GTR-3	9.5	17	E XR	YR	+
531	DR_S	02/27/84	T 2	ID	DETAIL DESIGN DRAWINGS	0.1	9	D XP	YQ	+
531	CDE	02/27/84	T 2	OO	CALL TO DE_S	0.1	17	D XP	YQ	0
532	DR_S	02/28/84	T 2	OD	USE OF DR_S SERVICES	0.1	9	D XP	YE	+
532	CDE	02/28/84	T 2	IO	ARRANGE MEETING DE_S	0.1	17	D XP	YE	+
533	CDE	02/28/84	W 1	E	COAL FEED/TOP PISTON	1.5	17	E DL	OG	0
534	SL_A	03/01/84	T 2	OO	D.O. & CHANGED SPECIFICATION	0.4	17	D XP	SP	0
534	CDE	03/01/84	T 2	IO	D.O. & CHANGED SPEC	0.4	17	D XP	SP	+
535	CDE	03/05/84	W 1	T	PLAN FOR DAY	0.9	17	D XP	YL	+
536	DR_S	03/05/84	M 2	D	CURRENT WORK OF DR_S	0.5	9	D XP	YE	+
536	CDE	03/05/84	M 2	D	CURRENT WORK OF DR_S	0.5	17	D XP	YI	+
537	DE_S	03/05/84	M 3	D	D.O. PERSONNEL/DRAWINGS	1.0	14	D XS	YI	-
537	DR_S	03/05/84	M 3	D	D.O. PERSONNEL/RIG DRAWINGS	1.0	9	D XS	YI	+
537	CDE	03/05/84	M 3	D	D.O. PERSONNEL/DRAWINGS	1.0	17	D XS	YI	0
538	DE_S	03/05/84	M 2	C	LUNCH/DESIGN SITUATION	0.6	14	D XS	YH	-
538	CDE	03/05/84	M 2	C	LUNCH/DESIGN SITUATION	0.6	17	D XS	YI	+
539	DE_S	03/05/84	M 3	D	DETAILS OF GTR	3.3	14	D XP	YN	+

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539	DR_S	03/05/84	M 3	D DETAILS OF GTR	3.3	9	D XP	YN	-
539	CDE	03/05/84	M 3	D DETAILS OF GTR	3.3	17	D XP	YN	+
540	AM_S	03/05/84	M 3	O DETAIL DESIGN PROGRAM	0.3	19	D XP	YN	+
540	DE_S	03/05/84	M 3	A GTR SYSTEMS	0.3	14	D XP	YN	+
540	CDE	03/05/84	M 3	A GTR SYSTEMS	0.3	17	D XP	YN	+
541	M_A	03/05/84	M 2	O REPORT GTR-3	0.3	22	E XR	YR	0
541	CDE	03/05/84	M 2	A REPORT GTR-3	0.3	17	E XR	YR	0
542	CDE	03/06/84	T 2	OO ENGINEER TO CALL	0.1	17	E AL	YN	+
542	SE_FE	03/06/84	T 2	IO ENGINEER TO CALL	0.1	15	E AL	YQ	+
543	CDE	03/06/84	T 2	IO SE_FE TO VISIT	0.1	17	E AL	YN	+
543	SE_FE	03/06/84	T 2	OO DATE OF VISIT FIXED	0.1	15	E AL	YE	+
544	CDE	03/06/84	T 2	OO CREEP DRAWINGS/CONTROLS	0.4	17	E AL	YG	+
544	CCE	03/06/84	T 2	IO VESSEL DWGS/CONTROL DESIGN	0.4	16	E AL	YG	+
545	CDE	03/06/84	W 1	O WEEKLY REPORTS	4.4	17	D XR	YR	0
546	CDE	03/07/84	W 1	T PLAN FOR DAY	0.9	17	E XP	YL	+
547	DE_S	03/07/84	M 2	D REVIEW COAL FEEDER	0.3	14	E AL	YR	+
547	CDE	03/07/84	M 2	D REVIEW COAL FEEDER	0.3	17	E AL	YR	+
548	SL_A	03/07/84	T 2	IO PRESSURE & TEMP. LIMITS	0.4	17	T SP	SP	0
548	CDE	03/07/84	T 2	OD PRESSURE & TEMP LIMITS	0.4	17	T SP	SP	+
549	ASL_A	03/07/84	M 2	O PROJECT SCHEDULE (R1_A+R2_A)	0.4	14	D XP	YG	+
549	CDE	03/07/84	M 2	A PROJECT SCHEDULE	0.4	17	D XP	YG	+
550	AM_S	03/07/84	M 2	O COAL STORAGE SPACE	0.2	19	E SC	YQ	+
550	CDE	03/07/84	M 2	A COAL STORAGE SPACE	0.2	17	E SC	YN	+
551	DE_S	03/07/84	M 2	D LAYOUT REQUIREMENTS	0.2	14	E AL	O	0
551	CDE	03/07/84	M 2	D LAYOUT REQUIREMENTS	0.2	17	E AL	YT	+
552	CDE	03/07/84	W 1	D COAL FEED SPECIFICATION	0.7	17	E AL	SP	+
553	AM_S	03/07/84	M 2	O JOB APPLICANTS	0.5	19	D XP	YT	-
553	DE_S	03/07/84	M 2	A DESIGN JOB APPLICANTS	0.5	14	D XP	YT	-
554	SL_A	03/07/84	M 2	A RETURN OF OVERHEADS	0.1	17	E XR	O	0
554	CDE	03/07/84	M 2	A RETURN OF OVERHEADS	0.1	17	E XR	O	0
555	CDE	03/07/84	W 1	D PREPARING FOR AFTERNOON	0.4	17	E XP	CK	+
556	AM_S	03/07/84	M 3	C GENERAL	0.5	19	E XS	YI	+
556	DE_S	03/07/84	M 3	C LUNCH/ COAL VESSEL	0.5	14	E XS	YI	-
556	CDE	03/07/84	M 3	C LUNCH	0.5	17	E XS	YI	+
557	AM_S	03/07/84	M 2	C COAL STORAGE SPACE	0.1	19	E SC	YN	0
557	BPO_S	03/07/84	M 2	C COAL STORAGE SPACE	0.1	14	E SC	YN	+
558	AM_S	03/07/84	M 4	C COAL FEED SYSTEM	0.3	19	E CL	OG	+
558	DE_S	03/07/84	M 4	C GENERAL INTRODUCTIONS	0.3	14	E CL	OG	+
558	CDE	03/07/84	M 4	C COAL FEED SYSTEM	0.3	17	E CL	OG	+
558	SE_FE	03/07/84	M 4	C INTRODUCTIONS - COAL FEED	0.3	15	E CL	OG	+
559	BPO_S	03/07/84	M 4	E VISIT TO TEST RIG BLDG.	0.5	14	E CL	SC	+
559	DE_S	03/07/84	M 4	E VISIT TO TEST RIG BUILDING	0.5	14	E CL	SC	+
559	CDE	03/07/84	M 4	E VISIT TO TEST RIG BLDG	0.5	17	E CL	SC	+
559	SE_FE	03/07/84	M 4	E VISIT TO TEST RIG BLDG	0.5	15	E CL	SC	+
560	DE_S	03/07/84	W 3	D DESIGN OF COAL FEEDER	1.5	14	E EL	YQ	+
560	CDE	03/07/84	W 3	D DESIGN OF COAL FEEDER	1.5	17	E EL	OG	+
560	SE_FE	03/07/84	W 3	D DESIGN OF COAL FEEDER	1.5	15	E EL	OG	0
561	M_A	03/07/84	M 2	O JOB NUMBER & REFERENCE	0.2	22	D XP	YI	+
561	CDE	03/07/84	M 2	A JOB NUMBER & DAY'S WORK	0.2	17	D XP	YE	+
562	M_A	03/07/84	M 2	O CONTRACT CONTROLS ENGINEER	0.1	22	E XC	YN	+
562	CDE	03/07/84	M 2	A CCE OFFER & COSTS	0.1	17	E XC	YN	+
563	SL_A	03/07/84	M 2	A D.O. AND DAY'S WORK	0.5	17	D XR	YI	+

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INT/NO	PERSON	DATE	TYPE/L	TOPIC	HRS	£/H	P/ACT	TQ	M
563	CDE	03/07/84	M 2	A D.O. & DAY'S WORK	0.5	17	D XR	YR	-
564	CCE	03/10/84	W 1	O PRINTS OF CREEP VESSEL DWGS	2.0	16	D XI	YI	0
565	CDE	03/12/84	W 1	T PLAN FOR DAY	0.9	17	D XP	YL	0
566	ASL_A	03/12/84	M 3	O PROJECT SCHEDULE	0.4	14	D XP	YG	+
566	R1_A	03/12/84	M 3	O PROJECT SCHEDULE	0.4	13	D XP	YG	+
566	CDE	03/12/84	M 3	O PROJECT SCHEDULE	0.4	17	D XP	YG	+
567	DE_S	03/12/84	M 2	C PERSONAL BACKGROUND OF DE_S	0.5	14	D XS	YI	-
567	CDE	03/12/84	M 2	C DE_S BACKGROUND/LUNCH	0.5	17	D XS	YI	+
568	R2_A	03/12/84	M 2	L PROJECT UPDATE	0.5	13	E AL	YR	+
568	CDE	03/12/84	M 2	L PROJECT UPDATE	0.5	17	E AL	YE	+
569	ASL_A	03/12/84	M 4	L STORIES/JOKES	0.2	14	D XS	YI	+
569	R1_A	03/12/84	M 4	L STORIES/JOKES	0.2	13	D XS	YH	+
569	R2_A	03/12/84	M 4	L STORIES/JOKES	0.2	13	E XS	YH	+
569	CDE	03/12/84	M 4	L STORIES/JOKES	0.2	17	D XS	YH	+
570	M_S	03/12/84	M 2	O UPDATE & D.O. STAFF	0.5	22	D XR	YR	+
570	CDE	03/12/84	M 2	O UPDATE & D.O. STAFF	0.5	17	D XR	YE	+
571	DR_S	03/12/84	W 3	D CDE PREP. TO WORK ON D.O.	2.0	9	D FD	YE	+
571	GI_S	03/12/84	W 3	D CDE PREP TO WORK IN D.O.	2.0	8	D FD	YE	+
571	CDE	03/12/84	W 3	D PREPARE FOR WORK IN D.O.	2.0	17	D FD	YE	+
572	CDE	03/12/84	W 1	D REACTOR DRAWING	0.5	17	D FD	DD	+
573	CDE	03/13/84	W 1	O WEEKLY REPORTS	2.4	17	D XR	YR	0
574	CDE	03/14/84	W 1	T PLAN FOR DAY	0.9	17	D XP	YL	-
575	DR_S	03/14/84	M 3	D GENERAL DISCUSSIONS	0.3	9	D XR	YI	0
575	GI_S	03/14/84	M 3	D GENERAL DISCUSSIONS	0.3	8	D XR	O	+
575	CDE	03/14/84	M 3	D GENERAL DISCUSSIONS	0.3	17	D XR	YI	+
576	CDE	03/14/84	W 1	D REACTOR VESSEL DRAWING	0.8	17	D FD	DD	+
577	DE_S	03/14/84	W 1	D GTR VESSEL BOLTS	0.2	14	D FD	YQ	-
578	SL_A	03/14/84	M 3	A PROJECTS IN USA	2.0	17	D XS	YI	+
578	CDE	03/14/84	M 3	A PROJECTS IN USA	2.0	17	D XS	YI	+
579	DE_S	03/14/84	M 5	D MET VISITOR	0.1	14	D XS	YI	+
579	DR_S	03/14/84	M 5	D VISITOR TO D.O.	0.1	9	D XS	YE	+
579	GI_S	03/14/84	M 5	D VISITOR TO D.O.	0.1	8	D XS	YI	+
579	CDE	03/14/84	M 5	D MAH VISIT TO D.O.	0.1	17	D XS	YI	+
580	R1_A	03/14/84	M 3	O VISITOR	0.1	13	D XS	YI	+
580	CDE	03/14/84	M 3	A INTRODUCED MAH	0.1	17	D XS	YE	+
581	CDE	03/19/84	W 1	T PLAN FOR DAY	0.9	17	D XP	YL	-
582	DR_S	03/19/84	W 2	D REACTOR SUPPORT BEARINGS	1.3	9	D FD	DD	-
582	CDE	03/19/84	W 2	D REACTOR SUPPORT BEARINGS	1.3	17	D FD	DD	+
583	S1_P	03/19/84	M 3	D H.PRESS. H.TEMP. VESSELS	0.5	13	D XH	O	0
583	DR_S	03/19/84	M 3	D H.PRESS, H.TEMP. VESSELS	0.5	9	D XH	O	-
583	CDE	03/19/84	M 3	D HIGH PRESS HIGH TEMP VESSELS	0.5	17	D XH	YI	+
584	SL_P	03/19/84	M 3	D SOCIAL CALL ON D.E.	0.5	17	D XS	YH	-
584	DR_S	03/19/84	M 3	D SL_P WANTED DE_S	0.5	9	D XS	O	+
584	CDE	03/19/84	M 3	D SL_P WANTED DE_S	0.5	17	D XS	YI	+
585	CDE	03/19/84	W 1	D BEARING CATALOGUES	1.0	17	D XI	DD	0
586	GI_S	03/19/84	M 2	D GI_S BACKGROUND	1.2	8	D XS	YI	-
586	CDE	03/19/84	M 2	C GI_S BACKGROUND	1.2	17	D XS	YI	+
587	BPO_S	03/19/84	M 2	P NITROGEN SYSTEM	0.2	14	E AL	YQ	+
587	CDE	03/19/84	M 2	P NITROGEN SYSTEM	0.2	17	E AL	YQ	+
588	R1_A	03/19/84	W 3	N GAS BOTTLES + SPACE	1.2	13	E AL	YQ	+
588	R2_A	03/19/84	W 3	A GAS SUPPLY/RIG SPACE	1.2	13	E AL	YQ	+
588	CDE	03/19/84	W 3	A GAS BOTTLES & SPACE	1.2	17	E AL	YQ	0

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589	SL_A	03/19/84	M 2 O	D.O. STAFF & GTR-3	1.2	17	E XR	YR	0
589	CDE	03/19/84	M 2 A	D.O. STAFF & GTR-3	1.2	17	E XR	YE	+
590	CDE	03/19/84	W 1 D	CUBICLE DRAWINGS	0.5	17	D FD	0	-
591	CDE	03/19/84	N 1 OD	PLAN & ELEVATION FO CUBICLE	0.1	17	D FD	SK	-
592	DR_S	03/19/84	L 1 ID	PLAN & ELEVATION OF CUBICLE	0.1	9	D FD	0	0
593	SL_A	03/20/84	T 2 IO	CREEP STRESS	0.5	17	D XS	DG	0
593	CDE	03/20/84	T 2 OO	CREEP STRESS	0.5	17	D XS	DG	0
594	CDE	03/21/84	W 1 O	VESSEL LAYOUT	0.9	17	D FD	DD	-
595	DE_S	03/21/84	M 2 D	GREETINGS	0.1	14	D XS	YI	+
595	CDE	03/21/84	M 2 D	GREETINGS ONLY	0.1	17	D XS	YE	+
596	SL_A	03/21/84	M 2 O	PROJECT PROGRESS	1.0	17	D XR	YI	+
596	CDE	03/21/84	M 2 A	PROJECT PROGRESS	1.0	17	D XR	YI	-
597	R1_A	03/21/84	W 2 N	GAS BOTTLES/CRADLES	0.1	13	E AL	YN	+
597	CDE	03/21/84	W 2 A	GAS BOTTLES/CRADLES	0.1	17	E AL	YN	0
598	DE_S	03/21/84	W 2 D	TECH INFO/DWG REQUIREMENTS	1.0	14	D ID	YF	+
598	CDE	03/21/84	W 2 D	TECH INFO/DRAWING REGISTER	1.0	17	D ID	YF	+
599	DR_S	03/21/84	W 1 D	CUBICLE LAYOUT	2.0	9	D FD	0	-
600	M_S	03/21/84	M 2 O	GTR-3 REPORT	0.1	22	E XR	YR	0
600	CDE	03/21/84	M 2 A	GTR-3 REPORT	0.1	17	E XR	YR	0
601	SL_P	03/21/84	M 2 D	SOCIAL CALL	0.3	17	D XS	YH	+
601	DE_S	03/21/84	M 2 D	SUN NEWSPAPER	0.3	14	D XS	YH	+
602	R2_A	03/21/84	W 2 D	CRADLES/GAS BOTTLES	0.1	13	E AL	YN	+
602	CDE	03/21/84	W 2 D	CRADLES/GAS BOTTLES	0.1	17	E AL	YN	+
603	CDE	03/21/84	T 2 OD	CDE CONTACTING SE_FE	0.1	17	E AL	YN	0
603	SE_FE	03/21/84	T 2 IO	CDE CALLING	0.1	15	E AL	YN	0
604	AM_S	03/21/84	M 3 O	DESIGN DRAFTSMAN	0.5	19	E CL	YN	-
604	DE_S	03/21/84	M 3 A	DESIGNERS/RIG SPACE	0.5	14	E CL	YN	+
604	CDE	03/21/84	M 3 A	DESIGNERS/RIG SPACE	0.5	17	E CL	YN	+
605	SL_A	03/21/84	M 4 D	PROGRESS UPDATE	0.5	17	D XR	YR	0
605	DE_S	03/21/84	M 4 D	PROGRESS UPDATE	0.5	14	D XR	YR	-
605	DR_S	03/21/84	M 4 D	PROGRESS UPDATE	0.5	9	D XR	YR	-
605	CDE	03/21/84	M 4 D	PROGRESS UPDATE	0.5	17	D XR	YR	+
606	DR_S	03/21/84	W 2 D	CDE HELPING ON LAYOUT	0.5	9	D FD	YE	+
606	CDE	03/21/84	W 2 D	CDE HELPING DR_S	0.5	17	D FD	YE	+
607	DR_S	03/21/84	W 1 E	DIMENSIONS OF CUBICLE	1.5	9	D FD	YE	+
608	CDE	03/21/84	W 1 D	DRAWING REGISTER	1.0	17	D ID	YF	+
609	SL_A	03/21/84	M 2 O	GAS UTILIZATION & CRADLES	0.4	17	E AL	YL	0
609	CDE	03/21/84	M 2 A	GAS UTILIZATION/CRADLES	0.4	17	E AL	YL	+
610	CDE	03/23/84	T 2 IO	CLARIFICATION ON SPEC	0.3	17	E AL	SP	+
610	SE_FE	03/23/84	T 2 OO	CLARIFICATION OF SPEC.	0.3	15	E AL	SP	0
611	CDE	03/23/84	T 2 OO	NITROGEN SYSTEM	0.1	17	E AL	YN	+
611	SE_FE	03/23/84	T 2 IO	NITROGEN SYSTEM	0.1	15	E AL	YN	0
612	CDE	03/28/84	M 2 A	INFO ON GTR PROJECT	0.5	17	E XI	YE	+
612	CCE	03/28/84	M 2 O	INFO ON GTR PROJECT	0.5	16	E XI	YR	+
613	CCE	03/28/84	W 1 O	QUESTIONS/ARRANGEMENT	2.0	16	T CP	YQ	+
614	CDE	03/29/84	M 2 A	LISTING OF QUESTIONS	1.5	17	T SP	YL	+
614	CCE	03/29/84	M 2 O	LISTING OF QUESTIONS	1.5	16	T SP	YL	+
615	CCE	04/04/84	W 1 O	PREPARE PROPOSAL	2.0	16	T CP	YC	+
616	SE_FE	04/04/84	W 1 O	DRAWING & ITEMIZED PRICE	4.0	15	E XC	YC	0
617	CDE	04/05/84	M 2 H	FINALIZE WORK & SCHEDULE	1.0	17	T SP	YG	+
617	CCE	04/05/84	M 2 H	FINALIZE WORK & SCHEDULE	1.0	16	T SP	YG	+
618	CCE	04/05/84	W 1 H	LISTING OF INFO REQUIRED	1.0	16	T XI	YL	0

GTR PROJECT INTERCHANGES BY DATE AND NUMBER

INT/NO	PERSON	DATE	TYPE/L	TOPIC	HRS	£/H	P/ACT	TQ	M
619	CCE	04/06/84	W 1 H	DESIGN PROCEDURE	2.0	16	T CP	YK	0
620	CDE	04/09/84	T 2 IO	ARRANGE MEETING	0.1	17	E AL	YN	+
620	SE_FE	04/09/84	T 2 OO	ARRANGE MEETING	0.1	15	E AL	YN	+
621	DE_S	04/09/84	T 2 ID	PROGRESS UPDATE	0.2	14	D XR	YR	0
621	CDE	04/09/84	T 2 OO	DETAIL DESIGN PROGRESS	0.2	17	D XR	YR	-
622	SL_A	04/09/84	T 2 IO	POOR DETAIL DESIGN PROGRESS	0.5	17	D XR	YI	0
622	CDE	04/09/84	T 2 OO	POOR DETAIL DESIGN PROGRESS	0.5	17	D XR	YI	-
623	CDE	04/09/84	W 1 T	PLAN FOR DAY	1.2	17	D XP	YL	-
624	DR_S	04/09/84	M 3 D	GENERAL ON DRAWINGS	0.2	9	D XI	YN	+
624	GI_S	04/09/84	M 3 D	GENERAL CHAT	0.2	8	D XI	YI	+
624	CDE	04/09/84	M 3 D	GENERAL ON DRAWINGS	0.2	17	D XI	YQ	0
625	DR_S	04/09/84	W 2 D	STEEL VESSEL FRAME	0.9	9	D CD	DD	+
625	CDE	04/09/84	W 2 D	STEEL VESSEL FRAME	0.9	17	D CD	DD	+
626	CDE	04/09/84	W 1 D	GRAPHICAL SYMBOLS	0.5	17	D XI	CK	+
627	SL_A	04/09/84	M 3 D	REVIEW L/O DRAWINGS	0.4	17	D CD	YR	0
627	DR_S	04/09/84	M 3 D	REVIEW L/O DRAWINGS	0.4	9	D CD	YR	+
627	CDE	04/09/84	M 3 D	REVIEW LAYOUT DRAWINGS	0.4	17	D CD	YR	-
628	SL_A	04/09/84	M 2 A	DETAIL DESIGN/CONTROL DESIGN	1.8	17	E XP	YN	0
628	CDE	04/09/84	M 2 O	DETAIL DESIGN & CONTROLS DES	1.8	17	E XP	YN	+
629	CDE	04/10/84	T 2 IO	VISITOR FROM M	0.1	17	D XS	YI	-
629	LO_U	04/10/84	T 2 OO	VISITOR FROM M	0.1	16	D XS	YE	+
630	CDE	04/10/84	L 1 OO	3-MONTH PROJECT SUMMARY	2.0	17	D XR	YR	+
631	CDE	04/10/84	W 1 O	INFO FOR CCE	6.5	17	E XI	YE	+
632	M_A	04/11/84	L 1 IO	3-MONTH SUMMARY	0.2	22	D XR	0	0
633	AM_A	04/11/84	L 1 IO	3-MONTH SUMMARY & GTR-3	0.6	19	E XR	0	0
634	SL_A	04/11/84	L 1 IO	PROGRESS SUMMARY	0.1	17	D XR	YR	0
635	RM_U	04/11/84	L 1 IO	PROGRESS SUMMARY	0.1	17	D XR	YR	0
636	CDE	04/11/84	W 1 T	PLAN FOR DAY	0.9	17	D XP	YL	+
637	SL_A	04/11/84	M 2 O	CUBICLE LAYOUT	0.2	17	E CL	DD	0
637	CDE	04/11/84	M 2 A	CUBICLE LAYOUT	0.2	17	E CL	DD	0
638	DE_S	04/11/84	M 3 D	BEARINGS - WRONG CATALOGUE	0.3	14	D XI	DD	0
638	DR_S	04/11/84	M 3 D	BEARINGS - WRONG CATALOGUE	0.3	9	D XI	DD	+
638	CDE	04/11/84	M 3 D	BEARINGS/WRONG CATALOG	0.3	17	D XI	DD	-
639	DE_S	04/11/84	W 3 D	COAL FEEDING SYSTEM	2.0	14	E SL	0	+
639	CDE	04/11/84	W 3 D	COAL FEEDING SYSTEM	2.0	17	E SL	II	+
639	SE_FE	04/11/84	W 3 D	COAL FEED SYSTEM	2.0	15	E SL	II	+
640	DE_S	04/11/84	M 3 C	LUNCH	0.6	14	E EL	0	-
640	CDE	04/11/84	M 3 C	LUNCH & COAL SYSTEMS	0.6	17	E EL	YN	+
640	SE_FE	04/11/84	M 3 C	LUNCH	0.6	15	E EL	YN	+
641	DE_S	04/11/84	W 3 D	COAL STORAGE DRUMS	1.5	14	E SS	0	+
641	CDE	04/11/84	W 3 D	COAL STORAGE DRUMS	1.5	17	E SS	YN	+
641	SE_FE	04/11/84	W 3 D	COAL STORAGE SYSTEM	1.5	15	E SS	YN	+
642	R2_A	04/11/84	W 2 P	COAL HOPPERS	0.1	13	E EL	YN	+
642	CDE	04/11/84	W 2 P	COAL HOPPERS	0.1	17	E EL	YN	+
643	DE_S	04/11/84	M 3 D	SELF PERCEPTION INVENTORY	0.1	14	D XS	0	-
643	DR_S	04/11/84	M 3 D	SELF PERCEPTION INVENTORIES	0.1	9	D XS	YE	+
643	CDE	04/11/84	M 3 D	SELF PERCEPTION INVENTORY	0.1	17	D XS	0	-
644	BPO_S	04/11/84	M 2 O	COAL STORE & CUBICLE	0.4	14	E AL	YN	+
644	CDE	04/11/84	M 2 A	COAL STORE & CUBICLE	0.4	17	E AL	YN	+
645	R2_A	04/11/84	W 2 L	LAYOUT & CONTROLS	1.2	13	E AL	YN	+
645	CDE	04/11/84	W 2 L	LAYOUT & CONTROLS	1.2	17	E AL	YN	0
646	AM_A	04/11/84	M 2 O	PROGRESS ON GTR	1.3	19	D XR	YE	+

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646	CDE	04/11/84	M 2	A	PROGRESS ON GTR	1.3	17	D XR	YR +
647	CDE	04/12/84	T 2	OO	REQUEST FOR INFO	0.1	17	D XI	YQ +
647	SE_FL	04/12/84	T 2	IO	REQUEST FOR INFO	0.1	15	D XI	YQ +
648	CDE	04/12/84	W 1	O	CUBICLE WALLS	1.0	17	E OD	YN 0
649	CDE	04/12/84	W 1	O	CONTROL SYSTEM INFO	8.5	17	E XI	YI 0
650	CCE	04/12/84	W 1	H	SYSTEM DESCRIPTION	3.0	16	E RC	DS 0
651	CDE	04/13/84	W 1	T	PLAN FOR DAY	0.9	17	D XP	YL +
652	R2_A	04/13/84	M 2	P	CONTROLS DESIGN INFORMATION	0.1	13	E XI	YI +
652	CDE	04/13/84	M 2	P	CONTROLS DESIGN INFO	0.1	17	E XI	YI +
653	DR_S	04/13/84	M 2	D	PIVOT PIN DRAWING	0.2	9	D FD	DD -
653	CDE	04/13/84	M 2	D	PIVOT PIN DRAWING	0.2	17	D FD	DD -
654	DE_S	04/13/84	M 2	D	STANDARDS/Q.A.	0.5	14	D XR	YI -
654	CDE	04/13/84	M 2	D	STANDARDS/QA	0.5	17	D XR	YI 0
655	DR_S	04/13/84	W 1	D	PIVOT PIN DRAWINGS	3.0	9	D FD	DD +
656	CDE	04/13/84	W 1	D	CHECKING DRAWINGS	1.3	17	D CD	YL -
657	SL_P	04/13/84	M 3	C	HOLIDAYS	0.9	17	D XS	YI +
657	DE_S	04/13/84	M 3	C	HOLIDAYS	0.9	14	D XS	YH +
657	CDE	04/13/84	M 3	C	LUNCH/HOLIDAYS	0.9	17	D XS	YI +
658	DE_S	04/13/84	M 2	D	POOR OUTPUT FROM D.O.	1.0	14	D XR	YI -
658	CDE	04/13/84	M 2	D	POOR OUTPUT FROM D.O.	1.0	17	D XR	YQ 0
659	R2_A	04/13/84	W 2	O	GAS SYSTEM	1.8	13	E AL	DD +
659	CDE	04/13/84	W 2	A	GAS SYSTEM	1.8	17	E AL	DD 0
660	SL_A	04/13/84	M 2	O	CCE FUNDS & COAL STORAGE	0.8	17	E AL	YN +
660	CDE	04/13/84	M 2	A	CCE FUNDS & COAL STORAGE	0.8	17	E AL	YN +
661	CDE	04/15/84	W 1	H	PACKAGE FOR CCE	2.0	17	E AL	YI +
662	CCE	04/15/85	W 1	H	GAS DELIVERY SCHEMATIC	2.0	16	E PL	FS 0
663	CCE	04/15/84	W 1	H	GAS/TAR/ASH SYSTEMS	2.0	16	E PL	FS 0
664	DR_S	04/16/84	T 2	ID	CDE VISIT	0.1	9	D XP	0 +
664	CDE	04/16/84	T 2	OO	CDE VISIT TODAY	0.1	17	D XP	YE +
665	CDE	04/16/84	W 1	T	PLAN FOR DAY	0.9	17	D XP	YL +
666	DR_S	04/16/84	W 2	D	PIVOT PIN DRAWING	0.3	9	D FD	YL +
666	CDE	04/16/84	W 2	D	PIVOT PIN DRAWING	0.3	17	D FD	YL -
667	DR_S	04/16/84	W 1	D	PIVOT PIN DRAWING	6.0	9	D FD	DD +
668	CDE	04/16/84	L 1	OD	PACKAGE FOR CCE	1.5	17	E XI	YE +
669	AM_A	04/16/84	M 2	O	ORDER FOR CCE	0.1	19	E XC	YN -
669	AM_A	04/16/84	M 2	O	PROGRESS ON ORDER	0.1	19	E XC	YN -
669	CDE	04/16/84	M 2	A	ORDER FOR CCE	0.1	17	E XC	YN +
670	CDE	04/16/84	W 1	C	LUNCH	0.3	17	E AL	YE -
671	CDE	04/16/84	W 1	D	GAS SYSTEM SCHEMATIC	3.8	17	E AL	DD -
672	CDE	04/16/84	M 2	O	PROGRESS ON ORDER	0.1	17	E XC	YN +
673	R2_A	04/16/84	T 2	OO	VALVE REQUIREMENTS	0.2	13	E AL	YN 0
673	SE1_VA	04/16/84	T 2	IO	VALVES NEEDED	0.2	15	E AL	YQ +
674	R2_A	04/16/84	W 2	L	TAR SEPARATION	0.2	13	E OD	YL +
674	CDE	04/16/84	W 2	L	TAR SEPARATION	0.2	17	E OD	YL +
675	AM_A	04/16/84	W 1	A	ORDER SIGNED	1.1	19	E XC	YN +
676	CDE	04/16/84	T 2	ID	ORDER FOR CCE	0.1	17	E XC	YN +
677	CDE	04/16/84	T 2	OA	CONTRACT & PACKAGE	0.2	17	E XP	YN +
677	CCE	04/16/84	T 2	IO	CONTRACT & PACKAGE	0.2	16	E XP	YN 0
678	CDE	04/16/84	L 1	OA	LETTER TO CCE	0.1	17	E XR	YN 0
679	CDE	04/16/84	L 1	OA	LETTER TO CCE	0.2	17	E XR	YN 0
680	AM_A	04/16/84	L 1	IO	LETTER TO CCE	0.1	19	E XP	YN 0
681	SL_A	04/16/84	L 1	IO	CCE WORK	0.2	17	E XR	YN 0

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682	LO_U	04/16/84	L 1	OO	VISIT TO M	1.4	16	D XP	YE +
683	CDE	04/16/84	L 1	IO	VISIT TO M	0.1	17	D XP	YE +
684	CDE	04/18/84	W 1	O	PREPARING FOR VISIT TO M	1.1	17	D XR	YP +
685	CDE	04/18/84	M 2	E	GENERAL DISCUSSION	1.7	17	D XS	YT +
685	LO_U	04/18/84	M 2	E	GENERAL DISCUSSION	1.7	16	D XS	YT +
686	CDE	04/18/84	W 1	E	COAL FEEDING TESTS	2.0	17	E EL	ES +
687	D_G	04/18/84	M 2	C	PROJECT PROGRESS	0.2	27	D XR	YQ +
687	CDE	04/18/84	M 2	C	PROJECT PROGRESS	0.2	17	E XR	YE +
688	D_G	04/18/84	M 3	C	PROJECT FUNDING	0.1	27	D XC	YN 0
688	AD2_R	04/18/84	M 3	E	PROJECT FUNDING	0.1	23	D XC	YN -
688	CDE	04/18/84	M 3	C	PROJECT FUNDING	0.1	17	D XC	YN -
689	DE2_M	04/18/84	M 2	O	D.O. PROCEDURES	1.0	15	D XI	YR +
689	CDE	04/18/84	M 2	O	D.O. PROCEDURES	1.0	17	D XI	YQ +
690	CCE	04/18/84	W 1	H	COAL DELIVERY & PV SYSTEMS	2.0	16	E PL	FS 0
691	CCE	04/19/84	W 1	H	DATA & CONTROL SYSTEM	1.0	16	E FC	SC 0
692	CCE	04/20/84	W 1	H	OPERATOR CONTROLS	1.0	16	E PL	SC 0
693	CCE	04/20/84	L 1	IO	PROJECT INFORMATION	2.0	16	E XI	YR 0
694	CDE	04/24/84	T 2	OO	REVIEW VISIT TO M	0.3	17	D XS	YI +
694	LO_U	04/24/84	T 2	IO	REVIEW VISIT TO M	0.3	16	D XS	YE +
695	CDE	04/24/84	W 1	O	WRITING REPORTS	3.0	17	D XR	YR 0
696	CDE	04/25/84	W 1	O	WEEKLY REPORTS	5.0	17	D XR	YR 0
697	CDE	04/25/84	T 2	IO	SALES ENGINEER TO VISIT	0.1	17	D XP	YN +
697	SE_FL	04/25/84	T 2	OO	SALES ENGINEER TO VISIT	0.1	15	D XP	YE +
698	DR_S	04/25/84	T 2	ID	PIVOT PIN BEARINGS	0.2	9	D FD	DD +
698	CDE	04/25/84	T 2	OO	PIVOT PIN BEARINGS	0.2	17	D FD	DD -
699	SE_FE	04/25/84	L 1	OO	REVISED QUOTATION	2.0	15	E XC	YC 0
700	SE_FE	04/25/84	L 1	OO	REVISED QUOTATION	0.1	15	E XC	YC 0
701	DR_S	04/26/84	T 2	ID	PIVOT PIN DRAWINGS	0.2	9	D FD	DD +
701	CDE	04/26/84	T 2	OO	PIVOT PIN BEARINGS	0.2	17	D FD	DD 0
702	CDE	04/27/84	W 1	T	PLAN FOR DAY	0.9	17	D XP	YL +
703	AM_S	04/27/84	M 2	O	MRS DESIGN GROUP	0.1	19	D XR	YR +
703	CDE	04/27/84	M 2	A	M DESIGN GROUP	0.1	17	D XR	YE +
704	CDE	04/27/84	W 1	D	CHECKING DRAWINGS	3.1	17	D CD	YL -
705	DR_S	04/27/84	W 1	D	CUBICLE LAYOUT	3.0	9	D FD	DD -
706	AM_S	04/27/84	M 3	C	MRS D.C. & METRIC/IMPERIAL	0.8	19	D XS	YI +
706	DR_S	04/27/84	M 3	C	LUNCH./ D.O. & UNITS	0.8	9	D XS	YE +
706	CDE	04/27/84	M 3	C	LUNCH/D.O./UNITS	0.8	17	D XS	YQ 0
707	DR_S	04/27/84	W 2	D	CHECKING 3 DRAWINGS	0.5	9	D CD	YL +
707	CDE	04/27/84	W 2	D	CHECKING 3 DRAWINGS	0.5	17	D CD	YL -
708	DR_S	04/27/84	W 1	D	WORKING ON CORRECTIONS	2.0	9	D FD	DD +
709	AM_A	04/27/84	M 2	O	REPORT ON M VISIT	1.3	19	D XR	YT +
709	CDE	04/27/84	M 2	O	REPORT ON M VISIT	1.3	17	D XR	YT +
710	DE_S	04/27/84	L 1	ID	COAL SUPPLY SYSTEM	0.2	14	E XC	YN 0
711	CDE	04/27/84	L 1	ID	COAL FEEDER QUOTE	0.2	17	E XC	YN +
712	CDE	04/30/84	W 1	T	PLAN FOR DAY	0.9	17	D XP	YL 0
713	R1_A	04/30/84	W 3	N	SOLIDS REMOVAL	1.5	13	E AL	YS +
713	R2_A	04/30/84	W 3	A	SOLIDS REMOVAL	1.5	13	E AL	YS +
713	CDE	04/30/84	W 3	A	SOLIDS REMOVAL	1.5	17	E AL	YS 0
714	SL_A	04/30/84	M 2	O	POOR DETAIL DESIGN PROGRESS	1.8	17	D XR	YR -
714	CDE	04/30/84	M 2	A	POOR D.O. PROGRESS	1.8	17	D XR	YR -
715	M_A	04/30/84	M 2	O	PERSONAL REFERENCE	0.1	22	D XS	0 +
715	CDE	04/30/84	M 2	A	PERSONAL REFERENCE	0.1	17	D XS	0 +

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716	CCE	04/30/84	W 1	L	PREVIOUS EXPERIENCE	1.0	16	E XI	0	0
717	CDE	05/01/84	W 2	O	FLOW CONTROLLERS	1.5	17	D XC	YN	+
717	SE_FL	05/01/84	W 2	A	FLOW CONTROLLERS	1.5	15	D XC	YN	+
718	CDE	05/01/84	T 2	IH	TECH DETAILS/TRAVEL	0.6	17	E AL	YE	+
718	CCE	05/01/84	T 2	OO	TECH DETAILS/TRAVEL	0.6	16	E AL	YI	+
719	CDE	05/01/84	W 1	H	REPORT ON DETAIL DESIGN	2.3	17	D XR	YN	+
720	CDE	05/02/84	W 1	T	PLAN FOR DAY	0.9	17	D XP	YL	+
721	CDE	05/02/84	W 1	A	UPDATED GAS SCHEMATIC	2.5	17	E AL	DD	+
722	DE_S	05/02/84	T 2	OD	MEETING WITH QAO_H	0.2	14	D XI	YI	0
722	QAO_H	05/02/84	T 2	OO	GTR PROJECT	0.2	14	D XI	0	+
723	DR_S	05/02/84	W 1	D	CORRECTING DRAWINGS	2.5	9	D FD	DD	+
724	DE_S	05/02/84	M 2	C	HEALTH/Q.A.MEETING	0.7	14	D ID	YI	0
724	CDE	05/02/84	M 2	C	HEALTH/QA MEETING	0.7	17	D ID	YI	0
725	CDE	05/02/84	W 1	P	PRODUCTION CAPABILITY	0.5	17	D FD	YH	+
726	CDE	05/02/84	W 1	R	WORKER PRODUCTIVITY	1.2	17	D XS	YH	+
727	ASL_A	05/02/84	M 2	O	REVIEW CHIEF DIRECTOR'S TALK	0.2	14	D XS	YI	-
727	CDE	05/02/84	M 2	A	REVIEW OF TALK BY DIRECTOR	0.2	17	D XS	YE	+
728	M_S	05/02/84	M 3	P	TALK BY SENIOR MANAGEMENT	0.1	22	D XS	YI	0
728	BPO_S	05/02/84	M 3	P	DIRECTOR TALK	0.1	14	D XS	YI	+
728	CDE	05/02/84	M 3	P	TOP MANAGEMENT TALK TO STAFF	0.1	17	D XS	YI	0
729	DE_S	05/02/84	M 4	D	PAPER/PIPE/EARPHONES	0.5	14	D XS	YH	+
729	DR_S	05/02/84	M 4	D	PAPER/PIPE/EARPHONES	0.5	9	D XS	YH	+
729	GI_S	05/02/84	M 4	D	PAPER/PIPE/EARPHONES	0.5	8	D XS	YH	+
729	CDE	05/02/84	M 4	D	PAPER/PIPE/EARPHONES GI_S	0.5	17	D XS	YH	+
730	CDE	05/02/84	W 1	D	CHECKING DRAWINGS	0.8	17	D CD	YL	+
731	SL_A	05/03/84	T 2	IO	POOR DETAIL DESIGN PROGRESS	0.7	17	D XR	YI	0
731	CDE	05/03/84	T 2	OO	POOR D.D. PROGRESS	0.7	17	D XR	YI	0
732	CDE	05/03/84	W 1	O	MODIFIED ORGANIZATION PLAN	3.0	17	D XP	YN	+
733	SL_A	05/03/84	T 2	IO	ORG. FOR DETAIL DESIGN	0.2	17	D XP	YN	0
733	CDE	05/03/84	T 2	OO	MODIFIED ORGANIZATION PLAN	0.2	17	D XP	YN	+
734	CDE	05/03/84	L 1	OO	ORG. FOR DETAIL DESIGN	1.3	17	D XP	YN	+
735	CDE	05/03/84	W 1	A	GEOMETRIC TOLERANCING	0.3	17	D XI	DG	+
736	CCE	05/03/84	W 1	H	REVIEWED ALL MATERIAL	4.0	16	T CP	YR	0
737	CDE	05/04/84	W 1	T	PLAN FOR DAY	0.9	17	D XP	YL	+
738	R2_A	05/04/84	M 2	L	MESSAGE FROM AM_A	0.1	13	E XI	0	0
738	CDE	05/04/84	M 2	L	MESSAGE FOR CDE	0.1	17	D XI	0	0
739	AM_A	05/04/84	L 1	IO	DETAIL DESIGN WORK	0.5	19	D XP	YN	0
740	AM_A	05/04/84	M 2	O	DETAIL DESIGN ORGANIZATION	0.2	19	D XP	YT	+
740	CDE	05/04/84	M 2	A	DETAIL DESIGN ORGANIZATION	0.2	17	D XP	YT	+
741	R1_A	05/04/84	W 5	R	VALVES/GAS SYSTEMS	5.0	13	E AL	YL	+
741	R2_A	05/04/84	W 5	R	VALVES/GAS SYSTEM	5.0	13	E AL	YL	+
741	CDE	05/04/84	W 5	R	VALVES/GAS SYSTEM	5.0	17	E AL	YL	+
741	SE1_VA	05/04/84	W 5	R	VALVES/GAS SYSTEM	5.0	15	E AL	YL	+
741	SE2_VA	05/04/84	W 5	R	VALVES/GAS SYSTEM	5.0	15	E AL	YL	+
742	DE_S	05/04/84	M 4	D	UPDATE-SCHEMATICS/TOL.CHART	0.5	14	D XR	DG	+
742	DR_S	05/04/84	M 4	D	GEOMETRIC TOL. WALLCHART	0.5	9	D XR	DG	+
742	GI_S	05/04/84	M 4	D	GEOM. TOLERANCE WALLCHART	0.5	8	D XR	YH	+
742	CDE	05/04/84	M 4	D	GEOM. TOLERANCES & UPDATE	0.5	17	D XR	DG	+
743	DR_S	05/04/84	M 2	D	DRAWING PRINTS+CO. STANDARDS	0.5	9	D FD	DG	+
743	CDE	05/04/84	M 2	D	DRAWING PRINTS/CO. STANDARDS	0.5	17	D FD	DG	+
744	AM_S	05/04/84	M 3	O	VISIT TO MRS	0.1	19	D XP	0	+
744	BPO_S	05/04/84	M 3	A	VISIT TO STATION M	0.1	14	D XP	0	+

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744	DE_S	05/04/84	M 3	A	VISIT TO M	0.1	14	D XP	0	+
745	AM_A	05/04/84	M 2	O	GENERAL/MANAGEMENT	1.0	19	D XS	YT	+
745	CDE	05/04/84	M 2	A	GENERAL/MANAGEMENT	1.0	17	D XS	YT	+
746	R2_A	05/04/84	M 2	E	CUBICLE SPACE	0.2	13	E EL	YN	+
746	CDE	05/04/84	M 2	E	CUBICLE SPACE	0.2	17	E EL	YN	+
747	RM_U	05/04/84	L 1	IO	REPORT ON DETAIL DESIGN	0.1	17	D XR	YR	+
748	CCE	05/07/84	W 1	H	STATEMENT OF PROBLEM	2.0	16	T CP	AP	0
749	CCE	05/07/84	W 1	H	DEMANDS & WISHES SHEETS	8.0	16	T CP	SP	0
750	CCE	05/08/84	W 1	H	SCHEMATICS & DEMANDS/WISHES	9.9	16	T SP	SP	0
751	AM_A	05/08/84	L 1	OO	DETAIL DESIGN PROGRESS	0.5	19	D XR	YR	0
752	M_S	05/08/84	L 1	IO	PROJECT PROGRESS	0.2	22	D XR	YQ	0
753	AM_S	05/08/84	L 1	IO	DETAIL DESIGN PROGRESS	0.2	19	D XR	YR	0
754	M_A	05/08/84	L 1	IO	DETAIL DESIGN UPDATE	0.2	22	D XR	YI	+
755	SL_A	05/08/84	L 1	IO	DETAIL DESIGN PROBLEMS/PLAN	0.1	17	D XP	YN	0
756	CDE	05/08/84	M 2	O	ORG. FOR DETAIL DESIGN	0.2	17	D XP	YT	+
756	LO_U	05/08/84	M 2	O	ORG.FOR DETAIL DESIGN	0.2	16	D XP	YT	+
757	CCE	05/09/84	W 1	H	CONTINUED & OVERALL FUNCTION	8.0	16	E RC	FS	0
758	DR_S	05/10/84	T 2	ID	MEETING ON Q.A. ON 11TH	0.1	9	D XP	0	+
758	CDE	05/10/84	T 2	OO	MTG ON QUALITY ASSUR ON 11TH	0.1	17	D XP	0	+
759	CDE	05/10/84	T 2	OH	TRAVEL ARRANGEMENTS	0.6	17	E XP	YE	+
759	CCE	05/10/84	T 2	IH	TRAVEL ARRANGEMENTS	0.6	16	E XP	YI	+
760	CDE	05/11/84	W 1	T	PLAN FOR DAY	0.9	17	D XP	YL	+
761	DE_S	05/11/84	M 5	D	PROSPECTIVE DRAFTSMAN	0.5	14	D XP	YI	+
761	DR_S	05/11/84	M 5	D	PROSPECTIVE DRAFTSMAN	0.5	9	D XP	YE	+
761	GI_S	05/11/84	M 5	D	PROSPECTIVE DRAFTSMAN	0.5	8	D XP	YI	+
761	CDE	05/11/84	M 5	D	PROSPECTIVE DRAFTSMAN	0.5	17	D XP	YI	+
762	CDE	05/11/84	W 1	D	DRAWINGS & PREP FOR MEETING	0.5	17	D XR	YP	+
763	GI_S	05/11/84	M 2	D	D.O. WALL CLOCK FOUND BY CDE	0.1	8	D XS	YH	+
763	CDE	05/11/84	M 2	D	WALL CLOCK IN D.O.	0.1	17	D XS	YH	+
764	AM_S	05/11/84	M 4	A	PRESSURE VESSEL Q.A.	1.5	19	D XR	YP	0
764	DE_S	05/11/84	M 4	A	QUALITY ASSURANCE	1.5	14	D XR	YP	+
764	QAO_H	05/11/84	M 4	A	P.V. QUALITY ASSURANCE	1.5	14	D XR	YI	+
764	CDE	05/11/84	M 4	A	QUALITY ASSURANCE	1.5	17	D XR	YE	+
765	AM_S	05/11/84	M 4	C	COMPANY IN GENERAL	0.8	19	D XI	YI	+
765	DE_S	05/11/84	M 4	C	LUNCH	0.8	14	D XI	YI	+
765	QAO_H	05/11/84	M 4	C	LUNCH	0.8	14	D XI	YI	+
765	CDE	05/11/84	M 4	C	LUNCH	0.8	17	D XI	YI	+
766	AM_S	05/11/84	M 4	A	GTR PROJECT/UNITS	1.6	19	D XI	YQ	0
766	DE_S	05/11/84	M 4	A	CONTRACTORS/Q.A.	1.6	14	D XI	YQ	+
766	QAO_H	05/11/84	M 4	A	CONTRACTORS/QA/IMP-SI UNITS	1.6	14	D XI	YQ	+
766	CDE	05/11/84	M 4	A	GTR PROJECT/UNITS	1.6	17	D XI	YQ	0
767	DR_S	05/11/84	M 2	D	GOOD WISHES-DR_S VACATION	0.1	9	D XS	YE	+
767	CDE	05/11/84	M 2	D	GOOD WISHES FOR VACATION	0.1	17	D XS	YI	+
768	QAO_H	05/11/84	M 2	T	QA IN COMPANY	2.0	14	D XI	YI	+
768	CDE	05/11/84	M 2	T	QUALITY ASSURANCE IN COMPANY	2.0	17	D XI	YE	+
769	CCE	05/11/84	W 1	T	AIRCRAFT FLIGHT	9.9	16	E XI	0	+
770	CDE	05/12/84	M 2	T	PROJECT BRIEFING	4.0	17	E XP	YE	+
770	CCE	05/12/84	M 2	T	PROJECT BRIEFING/SIGHTSEEING	4.0	16	E XP	YR	+
771	CDE	05/13/84	W 2	H	CONTROLS DESIGN WORK SCHED.	2.0	17	E XP	YG	+
771	CCE	05/13/84	W 2	H	SCHEDULE FOR WORK	2.0	16	E XP	YG	+
772	CDE	05/14/84	W 2	T	REVIEW ALL SUBSYSTEMS	2.0	17	E RD	YR	+
772	CCE	05/14/84	W 2	T	REVIEW OF EACH SUBSYSTEM	2.0	16	E RD	YR	+

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773	SL_A	05/14/84	M 3	C VISIT TO RIG ROOM	0.6	17	E XI	YQ	-
773	CDE	05/14/84	M 3	C VISIT TO RIG ROOM	0.6	17	E XI	YQ	+
773	CCE	05/14/84	M 3	C ESTABLISH WORK PROGRAM	0.6	16	E XI	YQ	+
774	S2_A	05/14/84	M 3	L VISIT TO RIG ROOM	1.0	13	E XI	YQ	+
774	CDE	05/14/84	M 3	E VISIT TO RIG ROOM	1.0	17	E XI	YQ	0
774	CCE	05/14/84	M 3	E VISIT TO RIG ROOM	1.0	16	E XI	YQ	+
775	R1_A	05/14/84	W 2	O GAS SYSTEM	2.0	13	E PL	YQ	+
775	CCE	05/14/84	W 2	A GAS SUBSYSTEM	2.0	16	E PL	YQ	+
776	SL_A	05/14/84	W 1	A GAS SYSTEM	1.0	17	E RC	SC	0
777	DE_S	05/14/84	M 3	D ARRANGED TO MEET	0.3	14	E XP	YI	0
777	GI_S	05/14/84	M 3	D ARRANGED TO MEET	0.3	8	E XP	YI	0
777	CDE	05/14/84	M 3	D ARRANGED TO MEET	0.3	17	E XP	YE	+
778	M_S	05/14/84	M 3	N REPORT ON DETAIL DESIGN	0.1	22	D XR	YR	+
778	AM_S	05/14/84	M 3	O DETAIL DESIGN PROGRESS	0.1	19	D XR	YQ	0
778	CDE	05/14/84	M 3	A DETAIL DESIGN PROGRESS	0.1	17	D XR	YR	+
779	AM_A	05/14/84	M 2	O ARRANGE MEETING WITH CCE	0.1	19	E XP	YQ	-
779	CDE	05/14/84	M 2	A ARRANGE MTG WITH CCE	0.1	17	E XP	YQ	+
780	AM_S	05/14/84	M 2	O D.O. & DETAIL DESIGN	0.3	19	D XP	YT	+
780	CDE	05/14/84	M 2	A D.O. & DETAIL DESIGN	0.3	17	D XP	YT	+
781	AM_S	05/14/84	M 3	O REVIEW QUALITY ASSURANCE MTG	0.1	19	D XR	YR	+
781	DE_S	05/14/84	M 3	A REVIEW Q.A. MEETING	0.1	14	D XR	0	0
781	CDE	05/14/84	M 3	A REVIEW QUALITY ASSURANCE MTG	0.1	17	D XR	YR	+
782	AM_S	05/14/84	M 4	D INTRODUCTION OF CCE	0.2	19	E XS	YI	+
782	DE_S	05/14/84	M 4	A CCE MET OTHERS	0.2	14	E XS	YI	+
782	CDE	05/14/84	M 4	D INTRODUCTION OF CCE	0.2	17	E XS	YE	+
782	CCE	05/14/84	M 4	A INTRODUCTION TO DE_S & AM_S	0.2	16	E XS	YI	+
783	SL_P	05/14/84	M 3	D INTRODUCTION TO CCE	0.1	17	E XS	YH	+
783	CDE	05/14/84	M 3	D INTRODUCTION TO SL_P	0.1	17	E XS	YE	+
783	CCE	05/14/84	M 3	D INTRODUCTION TO SL_P	0.1	16	E XS	YI	+
784	AM_A	05/14/84	M 3	O UPDATE ON CONTROLS WORK	0.5	19	E XR	YR	+
784	CDE	05/14/84	M 3	A UPDATE ON CONTROLS WORK	0.5	17	E XR	YE	+
784	CCE	05/14/84	M 3	A INTRODUCTION TO AM_A	0.5	16	E XR	YR	+
785	CDE	05/14/84	W 2	B ORDERED PS/DIV 5	0.3	17	E XI	CK	0
785	CCE	05/14/84	W 2	B ORDERED PS/DIV 5 STANDARD	0.3	16	E XI	CK	0
786	CDE	05/14/84	W 2	H REVIEW OF SYSTEMS	3.5	17	E RD	SC	0
786	CCE	05/14/84	W 2	H REVIEW OF SYSTEMS ETC	3.5	16	E RD	SC	-
787	CDE	05/15/84	W 1	H PLAN FOR DAY	0.9	17	E XP	YL	+
788	R2_A	05/15/84	M 2	P PLAN FOR DAY	0.1	13	E XP	YL	+
788	CCE	05/15/84	M 2	P PLAN FOR DAY	0.1	16	E XP	YL	+
789	AM_A	05/15/84	M 2	O PAYMENT FOR CCE	0.2	19	E XC	YN	+
789	CCE	05/15/84	M 2	A PAYMENT FOR WORK	0.2	16	E XC	YC	+
790	R2_A	05/15/84	W 2	L CONTROL SYSTEM	2.0	13	E RC	YQ	+
790	CCE	05/15/84	W 2	L GAS & CONTROL SYSTEMS	2.0	16	E RC	YQ	+
791	R2_A	05/15/84	M 2	C LUNCH	1.5	13	E XS	YI	+
791	CCE	05/15/84	M 2	C LUNCH	1.5	16	E XS	YH	+
792	R2_A	05/15/84	W 2	L GAS/TAR EXIT CONTROLS	2.3	13	E AL	YQ	+
792	CCE	05/15/84	W 2	L GAS/TAR EXIT SYSTEM	2.3	16	E AL	YQ	+
793	DE_S	05/15/84	W 3	D GENERAL CHAT	1.0	14	E PL	0	+
793	GI_S	05/15/84	W 3	D GENERAL CHAT	1.0	8	E PL	0	+
793	CCE	05/15/84	W 3	D P & I DIAGRAM	1.0	16	E PL	DD	+
794	CCE	05/15/84	W 1	D P & I DIAGRAM	3.3	16	E PL	DD	+
795	CDE	05/16/84	M 2	H PLAN FOR DAY	0.5	17	E XP	YL	+

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795	CCE	05/16/84	M 2	H PLAN FOR DAY	0.5	16	E XP	YL	+
796	R2_A	05/16/84	M 2	P PLAN FOR DAY	0.2	13	E XP	YL	+
796	CCE	05/16/84	M 2	P PLAN FOR DAY	0.2	16	E XP	YL	+
797	DE_S	05/16/84	W 2	D P & I DIAGRAM	2.0	14	E PL	0	-
797	CCE	05/16/84	W 2	D P & I DIAGRAM	2.0	16	E PL	DD	+
798	R1_A	05/16/84	W 3	O COAL/ASH REMOVAL	1.3	13	E AL	YQ	+
798	R2_A	05/16/84	W 3	A COAL/ASH REMOVAL	1.3	13	E AL	YQ	+
798	CCE	05/16/84	W 3	A COAL/ASH REMOVAL	1.3	16	E AL	YQ	+
799	DE_S	05/16/84	M 2	C HOLIDAY FLATS ETC	1.0	14	E XS	YH	+
799	CCE	05/16/84	M 2	C HOLIDAY FLATS OF DE_S	1.0	16	E XS	YI	0
800	R1_A	05/16/84	M 3	C LUNCHTIME DRINK	1.0	13	E XS	YH	+
800	R2_A	05/16/84	M 3	E LUNCHTIME DRINK	1.0	13	E XS	YH	+
800	CCE	05/16/84	M 3	E LUNCHTIME DRINK	1.0	16	E XS	YI	+
801	R1_A	05/16/84	W 3	O PRESSURE VESSEL SYSTEM	1.0	13	E PL	YQ	+
801	R2_A	05/16/84	W 3	A PRESSURE VESSEL SYSTEM	1.0	13	E PL	YQ	+
801	CCE	05/16/84	W 3	A PRESSURE VESSEL SYSTEM	1.0	16	E PL	YQ	+
802	R1_A	05/16/84	W 4	O REVIEW OF CONTROLS	0.3	13	E CL	SC	+
802	R2_A	05/16/84	W 4	D REVIEW OF CONTROLS	0.3	13	E CL	SC	+
802	DE_S	05/16/84	W 4	D P & I DIAGRAM	0.3	14	E CL	YQ	+
802	CCE	05/16/84	W 4	D REVIEW P & I DIAGRAM	0.3	16	E CL	YR	+
803	CCE	05/16/84	W 1	D FINISHED P & I BASIC	2.0	16	E DL	DD	+
804	SL_P	05/16/84	M 2	D HOLIDAY FLATS ETC	1.0	17	E XS	YH	+
804	DE_S	05/16/84	M 2	D HOLIDAY FLATS ETC	1.0	14	E XS	0	+
805	GI_S	05/16/84	W 1	D TEA	0.2	8	D XS	YI	+
806	CDE	05/17/84	W 2	O SUPPLIERS OF PC'S	1.0	17	E XI	YE	+
806	CCE	05/17/84	W 2	A SUPPLIERS OF P.C.S	1.0	16	E XI	YN	+
807	CDE	05/17/84	W 2	O STATUS OF CONTROLS DESIGN	0.5	17	E XR	YR	0
807	CCE	05/17/84	W 2	A STATUS OF CONTROL DESIGN	0.5	16	E XR	YR	-
808	DE_S	05/17/84	T 2	ID NBR OF PRINTS TO BE MADE	0.1	14	E AL	DD	0
808	CDE	05/17/84	T 2	OO NUMBER OF PRINTS NEEDED	0.1	17	E AL	DD	+
809	SL_A	05/17/84	T 2	IA CONTROL SYSTEM DESIGN	0.1	17	E AL	DD	-
809	CDE	05/17/84	T 2	OO CONTROL SYSTEM DESIGN	0.1	17	E XR	0	+
810	CDE	05/17/84	T 2	OO ARRANGE VISIT TO ERA	0.5	17	E XI	0	+
811	CDE	05/17/84	W 2	O CAREFUL PLAN FOR WEEK	1.5	17	E XP	YG	+
811	CCE	05/17/84	W 2	A CAREFUL PLAN FOR WEEK	1.5	16	E XP	YG	+
812	CCE	05/17/84	W 1	A SPECIFICATION/LISTINGS	2.5	16	E RC	SP	0
813	DE_S	05/17/84	T 2	ID INVITATION TO MEETING	0.3	14	E XP	YI	0
813	CDE	05/17/84	T 2	OO INVITE DE-S TO MEETING	0.3	17	E XP	YI	+
814	CDE	05/17/84	M 3	A CONTROL SYSTEM DESIGN	0.5	17	E XS	YE	+
814	CCE	05/17/84	M 3	A REVIEW OF PROJECT	0.5	16	E XS	0	+
814	RM_U	05/17/84	M 3	O CONTROL SYSTEM DESIGN	0.5	17	E XS	YE	+
815	CDE	05/17/84	W 1	O REPORTS/CORRESPONDENCE	1.4	17	E XR	YR	+
816	CCE	05/17/84	W 1	A CONTROL PANELS & L.O.	1.5	16	E SC	OG	+
817	CDE	05/18/84	W 2	T CONTROL PANELS	1.5	17	E AL	DG	+
817	CCE	05/18/84	W 2	T CONTROL PANELS	1.5	16	E AL	DG	+
818	DE_S	05/18/84	M 3	D DRAWING PRINTS	0.2	14	E AL	DD	0
818	CDE	05/18/84	M 3	D DRAWING PRINTS	0.2	17	E AL	DD	+
818	CCE	05/18/84	M 3	D DRAWING PRINTS	0.2	16	E AL	DD	0
819	AM_S	05/18/84	M 3	O INVITATION TO SAFETY OFFICER	0.1	19	E XP	0	0
819	DE_S	05/18/84	M 3	A SAFETY OFFICER	0.1	14	E XP	0	0
819	CDE	05/18/84	M 3	A SO_H TO MEETING	0.1	17	E XP	YN	+
820	AM_S	05/18/84	T 2	OO SO_H TO ATTEND MEETING	0.2	19	E XP	0	0

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820	SO_H	05/18/84	T 2 IO	GTR CONTROL SYSTEM	0.2	14	E XP	0	0
821	BPO_S	05/18/84	M 3 P	INTRO TO CCE	0.1	14	E AL	YI	+
821	CDE	05/18/84	M 3 P	INTRO TO CCE	0.1	17	E AL	YN	+
821	CCE	05/18/84	M 3 P	INTRODUCTION TO BPO_S	0.1	16	E AL	YN	+
822	R1_A	05/18/84	W 6 R	VALVES/GAS SYSTEM	2.5	13	E AL	YL	+
822	R2_A	05/18/84	W 6 R	VALVES/GAS SYSTEM	2.5	13	E AL	YL	+
822	CDE	05/18/84	W 6 R	VALVES/GAS SYSTEM	2.5	17	E AL	YL	+
822	CCE	05/18/84	W 6 R	VALVES/GAS SYSTEM	2.5	16	E AL	YL	+
822	SE1_VA	05/18/84	W 6 R	VALVES/GAS SYSTEM	2.5	15	E AL	YL	+
822	SE2_VA	05/18/84	W 6 R	VALVES/GAS SYSTEM	2.5	15	E AL	YL	+
823	AM_A	05/18/84	M 2 O	GTR PROGRESS	0.1	19	E AL	YN	+
823	CDE	05/18/84	M 2 A	GTR PROGRESS	0.1	17	E AL	YN	+
824	R1_A	05/18/84	M 6 C	LUNCH	1.0	13	E XS	YH	+
824	R2_A	05/18/84	M 6 C	LUNCH	1.0	13	E XS	YE	+
824	CDE	05/18/84	M 6 C	LUNCH	1.0	17	E XS	YI	+
824	CCE	05/18/84	M 6 C	LUNCH	1.0	16	E XS	YI	+
824	SE1_VA	05/18/84	M 6 C	LUNCH	1.0	15	E XS	YE	+
824	SE2_VA	05/18/84	M 6 C	LUNCH	1.0	15	E XS	YE	+
825	R1_A	05/18/84	W 6 L	VALVES/GAS SYSTEM	1.2	13	E AL	YN	+
825	R2_A	05/18/84	W 6 L	VALVES/GAS SYSTEM	1.2	13	E AL	YN	+
825	CDE	05/18/84	W 6 L	VALVES/GAS SYSTEM	1.2	17	E AL	YN	+
825	CCE	05/18/84	W 6 L	VALVES/GAS SYSTEM	1.2	16	E AL	YN	+
825	SE1_VA	05/18/84	W 6 L	VALVES/GAS SYSTEM	1.2	15	E AL	YE	+
825	SE2_VA	05/18/84	W 6 L	VALVES/GAS SYSTEM	1.2	15	E AL	YE	+
826	SL_A	05/18/84	W 7 R	SOLIDS SYSTEM & CONTROLS	1.5	17	E AL	0	+
826	R1_A	05/18/84	W 7 R	SOLIDS SYSTEM	1.5	13	E AL	0	0
826	R2_A	05/18/84	W 7 R	SOLIDS SYSTEM	1.5	13	E AL	0	0
826	CDE	05/18/84	W 7 R	SOLIDS SYSTEM	1.5	17	E AL	0	+
826	CCE	05/18/84	W 7 R	SOLIDS SYSTEM	1.5	16	E AL	YE	0
826	SE1_VA	05/18/84	W 7 R	SOLIDS SYSTEM	1.5	15	E AL	YE	-
826	SE2_VA	05/18/84	W 7 R	SOLIDS SYSTEM	1.5	15	E AL	YQ	-
827	CDE	05/18/84	M 2 T	REVIEW OF PROGRESS	2.5	17	E XR	YR	+
827	CCE	05/18/84	M 2 T	REVIEW OF PROGRESS (ON TRAIN	2.5	16	E XR	YR	-
828	CDE	05/19/84	M 2 H	DECISION ON PRESENTATION	0.5	17	E XR	YL	+
828	CCE	05/19/84	M 2 H	DECISION ON PRESENTATION	0.5	16	E XR	YL	+
829	CCE	05/19/84	W 1 T	PROGRAMMABLE CONTROLLERS	4.0	16	E FC	YQ	+
830	CCE	05/20/84	W 1 T	T.I. CONTROLLERS	3.0	16	E FC	YQ	+
831	CCE	05/20/84	W 1 H	BLOCK DIAGRAM & PANELS	8.0	16	E PL	DS	-
832	CDE	05/21/84	W 2 T	REVIEW & PLAN	2.0	17	E XR	YP	+
832	CCE	05/21/84	W 2 T	REVIEW & PLAN (ON TRAIN)	2.0	16	E XR	YR	+
833	CDE	05/21/84	W 2 D	CONTROL PANELS/P & I DIAGRAM	2.0	17	E AL	DD	+
833	CCE	05/21/84	W 2 D	CONTROL PANELS/BLOCK DIAGRAM	2.0	16	E AL	DD	+
834	DE_S	05/21/84	M 3 C	LUNCH	0.5	14	E AL	0	0
834	CDE	05/21/84	M 3 C	LUNCH	0.5	17	E AL	0	+
834	CCE	05/21/84	M 3 C	LUNCH	0.5	16	E AL	YE	0
835	SL_A	05/21/84	M 2 R	PROJECT ORGANIZATION & D.D.	0.5	17	D XP	YR	0
835	CDE	05/21/84	M 2 R	PROJECT ORG. & DETAIL DESIGN	0.5	17	D XP	YR	+
836	CCE	05/21/84	W 1 D	CONTROL PANELS	1.0	16	E AL	DD	0
837	CDE	05/21/84	M 2 T	EXHAUSTED	1.0	17	E AL	0	-
837	CCE	05/21/84	M 2 T	EXHAUSTED	1.0	16	E AL	0	-
838	CDE	05/21/84	M 3 E	ERA TECHNOLOGY	2.0	17	E XI	0	+
838	CCE	05/21/84	M 3 E	ERA TECHNOLOGY	2.0	16	E XI	0	+

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INT/NO	PERSON	DATE	TYPE/L	TOPIC	HRS	£/H	P/ACT	TQ	M
839	CDE	05/21/84	W 2 T	REVIEW P & I DIAGRAM	3.0	17	E CL	FT	-
839	CCE	05/21/84	W 2 T	REVIEWING P & I DIAGRAM	3.0	16	E CL	FT	-
840	DE_S	05/22/84	T 2 ID	SAFETY OFFICER	0.2	14	E XR	0	0
840	CDE	05/22/84	T 2 OO	SAFETY OFFICER	0.2	17	E XR	0	-
841	R1_A	05/22/84	T 2 IO	UPDATE/ELEMENTS	0.1	13	E XI	DG	+
841	CDE	05/22/84	T 2 OO	UPDATE/ERA FURNACE ELEMENTS	0.1	17	E XI	DG	+
842	CCE	05/22/84	T 2 OA	PROGRAMMABLE CONTROLLER	0.5	16	E XI	YQ	+
842	SE_FL	05/22/84	T 2 IO	PROGRAMMABLE CONTROLLER	0.5	15	E XI	YQ	+
843	DE_S	05/22/84	T 2 OD	SAFETY OFFICER TO ATTEND MTG	0.2	14	E XP	0	+
843	SO_H	05/22/84	T 2 IO	MEETING ON GTR	0.2	14	E XP	0	+
844	DE_S	05/22/84	T 2 ID	SAFETY OFFICER	0.1	14	E XP	0	+
844	CDE	05/22/84	T 2 OO	SAFETY OFFICER	0.1	17	E XP	0	-
845	SL_A	05/22/84	T 2 IO	NOTICE ON PRESENTATION	0.2	17	E XP	YE	+
845	CDE	05/22/84	T 2 OO	NOTICE ON PRESENTATION	0.2	17	E XP	0	0
846	CDE	05/22/84	W 1 O	BLOCK DIAGRAM/CONTROL PANELS	6.5	17	E AL	DS	+
847	CCE	05/22/84	W 1 D	P & I DIAGRAM	7.5	16	E AL	DD	+
848	CDE	05/22/84	W 1 H	CONTROL CABINETS	3.5	17	E AL	SK	0
849	CCE	05/22/84	W 1 H	WRITING REPORT	5.0	16	E PD	YR	+
850	SL_A	05/23/84	L 1 OO	PRESENTATION MEETING	1.0	17	D XP	YE	+
851	CDE	05/23/84	W 2 O	GTR-4 REPORT/DRAWINGS	6.0	17	E PD	RR	+
851	CCE	05/23/84	W 2 D	REPORT & DRAWINGS	6.0	16	E PD	YR	+
852	CDE	05/23/84	W 2 O	GTR-4 REPORT/DRAWINGS	6.0	17	E PD	FT	+
852	CCE	05/23/84	W 2 D	REPORT & DWGS-SAME DAY AS 89	6.0	16	E PD	DD	+
853	M_A	05/23/84	L 1 IO	NOTICE OF PRESENTATION	0.1	22	E RD	0	0
854	AM_A	05/23/84	L 1 IO	NOTICE OF MEETING	0.1	19	E RD	0	0
855	R1_A	05/23/84	L 1 IO	NOTICE OF PRESENTATION	0.1	13	E RD	YR	0
856	R2_A	05/23/84	L 1 IL	NOTICE OF PRESENTATION MTG.	0.1	13	E RD	YR	0
857	ASL_A	05/23/84	L 1 IO	NOTICE OF PRESENTATION	0.2	14	E RD	0	0
858	S2_A	05/23/84	L 1 IO	NOTICE OF PRESENTATION	0.1	13	E RD	0	0
859	M_S	05/23/84	L 1 IO	NOTICE OF PRESENTATION	0.1	22	E RD	0	0
860	AM_S	05/23/84	L 1 IO	NOTICE OF MEETING	0.1	19	E RD	0	0
861	BPO_S	05/23/84	L 1 IO	NOTICE OF PRESENTATION	0.1	14	E RD	0	0
862	DE_S	05/23/84	L 1 ID	NOTICE OF MEETING	0.1	14	E RD	0	0
863	RM_U	05/23/84	L 1 IO	NOTICE OF MEETING	0.1	17	E RD	0	0
864	CDE	05/24/84	W 1 O	REPORT GTR-4	2.0	17	E PD	YR	+
865	CDE	05/24/84	W 2 D	FINISHED DRAWINGS	1.0	17	E PD	DD	-
865	CCE	05/24/84	W 2 D	FINISHED ALL DRAWINGS	1.0	16	E PD	DD	+
866	CDE	05/24/84	W 2 O	GTR-4 FINISHED	8.5	17	E XR	YR	+
866	CCE	05/24/84	W 2 A	FINISHED REPORT & COPYING	8.5	16	E XR	YR	+
867	CCE	05/25/84	W 1 T	COST ESTIMATE	1.0	16	E XC	YC	-
868	CDE	05/25/84	W 1 O	10 COPIES GTR-4	1.2	17	E XR	YR	+
869	CDE	05/25/84	W 1 T	OVERHEAD TRANSPARENCIES	1.4	17	E XR	YP	+
870	SL_A	05/25/84	W 2 R	PREPARE FOR PRESENTATION	0.6	17	E XR	YP	-
870	CDE	05/25/84	W 2 R	PREPARING FOR MEETING	0.6	17	E XR	YP	-
871	AD2_R	05/25/84	M10 R	CONTROL SYSTEM DESIGN	2.5	23	E XR	YE	+
871	AM_A	05/25/84	M10 R	CONTROL SYSTEM DESIGN	2.5	19	E XR	YE	+
871	SL_A	05/25/84	M10 R	CONTROL SYSTEM DESIGN	2.5	17	E XR	YE	+
871	R1_A	05/25/84	M10 R	CONTROL SYSTEM DESIGN	2.5	13	E XR	YP	+
871	S2_A	05/25/84	M10 R	CONTROL SYSTEM DESIGN	2.5	13	E XR	YR	+
871	DE_S	05/25/84	M10 R	CONTROL SYSTEM DESIGN	2.5	14	E XR	YP	0
871	SO_H	05/25/84	M10 R	CONTROL SYSTEM DESIGN	2.5	14	E XR	YQ	+
871	CDE	05/25/84	M10 R	CONTROL SYSTEM DESIGN	2.5	17	E XR	YP	+

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871	CCE	05/25/84	M10 R	CONTROL SYSTEM DESIGN	2.5	16	E XR	YP	+
872	SO_H	05/25/84	M 2 O	GTR-4 REPORT	0.1	14	E XR	YR	0
872	CDE	05/25/84	M 2 R	GTR-4 REPORT	0.1	17	E XR	YR	0
873	AD2_R	05/25/84	M 5 R	PROJECT FUNDING	0.5	23	D XC	YC	+
873	AM_A	05/25/84	M 5 R	PROJECT FUNDING	0.5	19	D XC	YC	+
873	SL_A	05/25/84	M 5 R	CONCLUDING REMARKS	0.5	17	D XC	YC	+
873	CDE	05/25/84	M 5 R	PROJECT FUNDING	0.5	17	D XC	YE	+
873	CCE	05/25/84	M 5 R	CONCLUDING REMARKS	0.5	16	E XC	YC	+
874	CDE	05/25/84	M 2 T	REVIEW OF CONTROL SYSTEM	1.5	17	E RD	YC	+
874	CCE	05/25/84	M 2 T	REVIEW OF WHOLE SYSTEM	1.5	16	E RD	YC	+
875	CCE	05/25/84	L 1 OA	INVOICE FOR DESIGN WORK	0.2	16	E XC	YC	-
876	AM_A	05/25/84	N 1 IO	CONTROL SYSTEM DESIGN	0.2	19	E XR	0	0
877	CDE	05/27/84	W 1 H	ORG. FOR DETAIL DESIGN	2.0	17	D XP	YP	+
878	DE1_M	05/28/84	T 2 OO	REQUEST FOR GTR INFORMATION	0.1	15	D XI	YQ	+
878	LO_U	05/28/84	T 2 IO	INTEREST IN GTR AT M	0.1	16	D XI	YE	+
879	CDE	05/28/84	T 2 IO	CDE TO CONTACT M	0.1	17	D XP	0	+
879	LO_U	05/28/84	T 2 OO	CDE TO CONTACT M	0.1	16	D XP	YE	+
880	DE1_M	05/29/84	T 2 IO	DISCUSSION ON VISIT	0.2	15	D XS	YQ	+
880	CDE	05/29/84	T 2 OO	DISCUSSION ON VISIT	0.2	17	D XS	0	+
881	AM_A	05/29/84	T 2 IO	CONTROLS/M REQUEST	0.2	19	D XS	0	+
881	CDE	05/29/84	T 2 OO	CONTROLS/M REQUEST	0.2	17	D XS	YE	+
882	AM_A	05/29/84	T 2 OO	D.O.	0.1	19	D XP	YN	+
882	CDE	05/29/84	T 2 IO	D.O. - MEETING ON PROBLEMS	0.1	17	D XP	YN	+
883	AM_A	05/29/84	L 1 OO	CONTROLS	0.5	19	E XR	YE	+
884	AM_A	05/29/84	L 1 OO	CONTROLS	0.5	19	E XR	YE	+
885	AM_A	05/29/84	L 1 OO	CONTROLS	0.5	19	E XR	YE	+
886	DE1_M	05/30/84	T 2 OO	DISCUSSION ON VISIT	0.2	15	D XP	0	+
886	LO_U	05/30/84	T 2 IO	INTEREST FROM OTHERS AT M	0.2	16	D XP	YE	+
887	CDE	05/30/84	T 2 IO	MEETING AT M	0.2	17	D XP	0	+
887	LO_U	05/30/84	T 2 OO	LO_U WILL ARRANGE	0.2	16	D XP	YE	+
888	CDE	05/31/84	L 2 OO	THANKS TO CCE	0.2	17	E XS	YE	+
888	RM_U	05/31/84	L 2 OO	THANKS TO CCE	0.2	17	E XS	YE	+
889	CDE	05/31/84	L 1 IO	THANKS TO CDE	0.3	17	E XS	YE	+
890	CDE	06/04/84	W 1 O	5 MORE GTR-4 COPIES	2.5	17	E XR	YR	+
891	CDE	06/04/84	W 1 T	PLAN FOR DAY	0.9	17	D XP	YL	+
892	DE_S	06/04/84	M 4 D	GREETINGS	0.1	14	D XS	YI	+
892	DR_S	06/04/84	M 4 D	GREETINGS	0.1	9	D XS	YI	+
892	GI_S	06/04/84	M 4 D	GREETINGS	0.1	8	D XS	YI	+
892	CDE	06/04/84	M 4 D	GREETINGS	0.1	17	D XS	YI	+
893	M_S	06/04/84	M 2 O	GTR-4 REPORT	0.1	22	E XR	YR	0
893	CDE	06/04/84	M 2 A	GTR-4 REPORT	0.1	17	E XR	YR	+
894	M_A	06/04/84	M 2 O	REPORT GTR-4	0.1	22	E XR	YR	+
894	CDE	06/04/84	M 2 A	GTR-4 REPORT	0.1	17	E XR	YR	+
895	AM_A	06/04/84	M 2 O	REPORT GTR-4	0.1	19	E XR	YR	0
895	CDE	06/04/84	M 2 A	GTR-4 REPORT	0.1	17	E XR	YR	+
896	ASL_A	06/04/84	M 2 O	GTR PROJECT & FUTURE	0.2	14	D XP	0	-
896	CDE	06/04/84	M 2 A	GTR PROJECT & FUTURE	0.2	17	D XP	YE	+
897	S2_A	06/04/84	M 2 A	COMPUTER CONTROL OF RIG	0.2	13	D XP	YI	+
897	CDE	06/04/84	M 2 A	COMPUTER CONTROL OF RIG	0.2	17	D XP	YT	+
898	AM_A	06/04/84	M 2 O	D.O.	0.5	19	D XP	YN	+
898	CDE	06/04/84	M 2 A	DRAWING OFFICE	0.5	17	D XP	YN	+
899	DE_S	06/04/84	W 2 D	VESSEL DRAWING	0.3	14	D FD	0	-

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899	CDE	06/04/84	W 2 D	VESSEL DRAWING	0.3	17	D FD	DD	-
900	AM_A	06/05/84	T 2 OO	D.O.	0.2	19	D XS	0	0
900	CDE	06/05/84	T 2 IO	DRAWING OFFICE	0.2	17	D XS	0	0
901	CDE	06/07/84	W 1 O	PREPARING FOR MTG ON D.O.	9.5	17	D XR	YP	+
902	CDE	06/08/84	W 1 T	PLAN FOR DAY	0.9	17	D XP	YL	+
903	AM_A	06/08/84	M 2 O	ORGANIZATION CHART	0.1	19	D XI	YT	0
903	CDE	06/08/84	M 2 O	ORGANIZATION CHART	0.1	17	D XI	0	0
904	M_A	06/08/84	M 5 R	PRESENTATION ON D.O.	1.5	22	D XR	YP	+
904	M_S	06/08/84	M 5 R	DESIGN/DRAFTING AT R	1.5	22	D XR	YP	-
904	AM_A	06/08/84	M 5 R	DRAWING & DESIGN	1.5	19	D XR	YP	+
904	AM_S	06/08/84	M 5 R	DESIGN & DRAFTING - R	1.5	19	D XR	YP	-
904	CDE	06/08/84	M 5 R	DRAWING & DESIGN	1.5	17	D XR	YP	+
905	AM_A	06/08/84	M 3 R	GENERAL/FUNDING	0.2	19	D XC	0	0
905	AM_S	06/08/84	M 3 O	DESIGN PROGRESS	0.2	19	D XC	0	+
905	CDE	06/08/84	M 3 R	GENERAL/FUNDING	0.2	17	D XC	0	+
906	R1_A	06/08/84	T 2 IO	VALVES & CONTROLS	0.2	13	E XC	OG	0
906	SE1_VA	06/08/84	T 2 OO	VALVES & CONTROLS	0.2	15	E XC	YQ	0
907	R1_A	06/08/84	L 1 OO	REPORT & DRAWINGS	0.3	13	E XC	YR	0
908	AM_A	06/08/84	M 2 O	FEEDBACK FROM M-5	0.1	19	D XR	0	+
908	CDE	06/08/84	M 2 A	FEEDBACK FROM M-5	0.1	17	D XR	0	+
909	AM_S	06/08/84	M 2 C	DESIGN PERSONNEL	0.5	19	D XS	YP	+
909	CDE	06/08/84	M 2 C	LUNCH/D.O. SITUATION	0.5	17	D XS	YP	+
910	R1_A	06/08/84	W 2 O	SCREW FEEDING	1.5	13	E OD	DG	+
910	CDE	06/08/84	W 2 A	SCREW FEEDING	1.5	17	E OD	DG	0
911	R1_A	06/08/84	W 3 O	REVIEW OF PROJECT	1.0	13	D XR	YE	+
911	R2_A	06/08/84	W 3 A	REVIEW OF PROJECT	1.0	13	D XR	YE	+
911	CDE	06/08/84	W 3 A	REVIEW OF PROJECT	1.0	17	D XR	YE	+
912	AM_A	06/08/84	T 2 IO	M VISIT TO COME	0.2	19	D XP	0	+
913	AM_A	06/08/84	M 2 O	D.O. & CONTROLS	0.2	19	D XS	0	+
913	CDE	06/08/84	M 2 A	D.O. & CONTROLS	0.2	17	D XS	0	+
914	CDE	06/08/84	M 2 T	SECONDARY PROJECT	0.3	17	D XH	YI	+
915	CDE	06/11/84	T 2 IO	SMALL VALVES CATALOGUE	0.1	17	D XI	DG	+
915	SE_FL	06/11/84	T 2 OO	SMALL VALVES CATALOGUE	0.1	15	D XI	DG	+
916	CDE	06/11/84	W 1 T	PLAN FOR DAY	0.9	17	D XP	YL	-
917	ASL_A	06/11/84	M 2 O	CDE TO VISIT R1_A	0.1	14	D XI	0	+
917	CDE	06/11/84	M 2 A	CDE TO SEE R1-A	0.1	17	D XI	0	+
918	DE_S	06/11/84	W 2 D	VESSEL PENETRATIONS	1.0	14	D FD	0	-
918	CDE	06/11/84	W 2 D	VESSEL PENETRATIONS	1.0	17	D FD	DG	-
919	R2_A	06/11/84	W 2 L	VESSEL PENETRATIONS	1.3	13	D FD	DG	0
919	CDE	06/11/84	W 2 L	VESSEL PENETRATIONS	1.3	17	D FD	DG	+
920	R1_A	06/11/84	M 2 O	UNITS	0.2	13	D ID	DG	+
920	CDE	06/11/84	M 2 A	METRIC VERSUS IMPERIAL UNITS	0.2	17	D ID	DG	0
921	SE1_VA	06/11/84	L 1 IO	REPORT & DRAWINGS	1.3	15	E XI	YE	0
922	CDE	06/13/84	W 1 O	5 MORE GTR-4 REPORTS	1.2	17	E XR	YR	0
923	CDE	06/13/84	W 1 T	PLAN FOR DAY	0.4	17	D XP	YL	0
924	R1_A	06/13/84	W 2 O	P & I DIAGRAM	2.5	13	D FD	DG	+
924	CDE	06/13/84	W 2 A	P & I DIAGRAM	2.5	17	D FD	DG	+
925	AM_A	06/13/84	M 2 O	DESIGN PERSONNEL	0.5	19	D XP	YN	0
925	CDE	06/13/84	M 2 A	DESIGN PERSONNEL	0.5	17	D XP	YN	-
926	AM_S	06/13/84	M 2 T	DESIGN PERSONNEL	0.3	19	D XP	YN	+
926	CDE	06/13/84	M 2 T	DESIGN PERSONNEL	0.3	17	D XP	YN	0
927	R1_A	06/14/84	T 2 OO	FLOWS & PRESSURES	0.5	13	D FD	YQ	0

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927	SE1_VA	06/14/84	T 2 IO	FLOWS & PRESSURES	0.5	15	D FD	YQ	0
928	CDE	06/15/84	T 1 OO	DESIGN DRAFTSMAN	0.3	17	D XP	YN	0
929	AM_A	06/19/84	T 2 OO	UPDATE/M/FUNDING	0.3	19	D XC	YN	0
929	CDE	06/19/84	T 2 IO	UPDATE/M/FUNDING	0.3	17	D XC	YN	0
930	M_A	06/19/84	M 2 O	FUNDING FOR CONSTRUCTION	0.1	22	D XP	YN	-
930	AM_A	06/19/84	M 2 A	FUNDING	0.1	19	D XP	YN	0
931	AD2_R	06/19/84	M 2 O	PROJECT FUNDING	0.2	23	D XC	YN	-
931	AM_A	06/19/84	M 2 A	FUNDING	0.2	19	D XC	YN	0
932	CDE	06/19/84	T 1 OO	DESIGN HELP	0.2	17	D XP	YN	0
933	CDE	06/22/84	W 1 O	LIST WORK TO BE DONE	0.8	17	D XP	YL	-
934	CDE	06/25/84	W 1 T	PLAN FOR DAY	0.9	17	D XP	YL	-
935	AM_A	06/25/84	M 2 O	A-FORM & D.O.	0.7	19	D XC	YN	0
935	CDE	06/25/84	M 2 A	A-FORM & D.O.	0.7	17	D XC	YN	-
936	AD2_R	06/25/84	M 3 O	PROJECT FUNDING	0.5	23	D XC	YN	-
936	M_A	06/25/84	M 3 A	FUNDING FOR CONSTRUCTION	0.5	22	D XC	YN	-
936	AM_A	06/25/84	M 3 A	FUNDING FOR GTR	0.5	19	D XC	YN	0
937	CDE	06/25/84	W 1 P	DESIGN HELP	0.5	17	D XP	YN	-
938	DE_S	06/25/84	M 2 D	LACK OF PROGRESS ON DRAWINGS	0.5	14	D XR	YN	-
938	CDE	06/25/84	M 2 D	LACK OF PROGRESS ON DRAWINGS	0.5	17	D XR	YN	-
939	SE_FE	06/25/84	T 2 OO	NEWS ON PROJECT	0.1	15	D XR	YR	0
940	R1_A	06/25/84	W 2 O	PIPING & VALVES	1.5	13	D ID	DG	0
940	CDE	06/25/84	W 2 A	PIPING & VALVES	1.5	17	D ID	DG	0
941	R1_A	06/25/84	T 2 IO	VALVES & CONTROLS	0.1	13	D XC	YQ	0
941	SE1_VA	06/25/84	T 2 OO	VALVES & CONTROLS	0.1	15	D XC	YQ	0
942	AM_A	06/25/84	M 2 O	SCHEDULE & GENERAL	1.0	19	D XP	YG	0
942	CDE	06/25/84	M 2 A	SCHEDULE & GENERAL	1.0	17	D XP	YG	0
943	AM_S	06/25/84	M 3 O	DESIGN PERSONNEL	0.5	19	D XP	YT	+
943	DE_S	06/25/84	M 3 A	DESIGN DRAFTING	0.5	14	D XP	YN	-
943	CDE	06/25/84	M 3 A	DESIGN PERSONNEL	0.5	17	D XP	YN	+
944	AM_A	06/26/84	T 2 OO	MESSAGE	0.1	19	D XC	0	0
944	CDE	06/26/84	T 2 IO	MESSAGE - CDE TO CALL	0.1	17	D XC	YC	0
945	SL_A	06/26/84	T 2 OO	PROJECT UPDATE	0.1	17	D XP	YR	0
945	CDE	06/26/84	T 2 IO	MESSAGE-CDE TO CALL	0.1	17	D XP	0	0
946	AM_A	06/27/84	T 2 IO	EXPENDITURE PLAN & M	0.4	19	D XC	YC	0
946	CDE	06/27/84	T 2 OO	EXPENDITURE PLAN/M	0.4	17	D XC	YC	0
947	SL_A	06/27/84	T 2 OO	VISIT TO M & PROJECT ORG.	0.3	17	D XP	YI	-
947	CDE	06/27/84	T 2 IO	VISIT TO M & PROJECT ORG	0.3	17	D XP	0	-
948	DE1_M	06/27/84	T 2 OO	FINAL M VISIT DETAILS	0.3	15	D XP	0	+
948	CDE	06/27/84	T 2 IO	FINAL M VISIT DETAILS	0.3	17	D XP	0	+
949	CDE	06/27/84	W 1 O	EXPENDITURE SCHEDULE	1.5	17	D XC	YC	+
950	AM_A	06/27/84	T 2 IO	BUDGET	0.1	19	D XC	YC	0
950	CDE	06/27/84	T 2 OO	BUDGET	0.1	17	D XC	YC	+
951	AM_A	06/27/84	T 2 OO	BUDGET	0.2	19	D XC	YC	0
951	CDE	06/27/84	T 2 IO	BUDGET	0.2	17	D XC	YC	0
952	AM_S	06/27/84	M 2 O	LRS HELP WITH DESIGN	0.2	19	D XP	YN	+
952	SL_A	06/27/84	M 2 A	D.O. HELP WITH DESIGN	0.2	17	D XP	YN	+
953	SL_A	06/27/84	T 2 OO	D.O. HELP WITH DESIGN	0.2	17	D XP	YN	-
953	CDE	06/27/84	T 2 IO	D.O. HELP WITH DESIGN	0.2	17	D XP	YN	0
954	AM_A	06/27/84	W 1 O	MANPOWER REQUIREMENTS	1.5	19	D XP	YC	0
955	SL_A	06/28/84	M 3 R	EXCHANGE IDEAS WITH M	3.0	17	D XI	YP	+
955	DE1_M	06/28/84	M 3 R	EXCHANGE IDEAS WITH M STAFF	3.0	15	D XI	YP	+
955	CDE	06/28/84	M 3 R	EXCHANGE IDEAS WITH M	3.0	17	D XI	YP	+

GTR PROJECT INTERCHANGES BY DATE AND NUMBER

INT/NO	PERSON	DATE	TYPE/L	TOPIC	HRS	£/H	P/ACT	TQ	M
956	DE1_M	06/28/84	M 2 O	COMPANY DESIGN MANAGEMENT	1.0	15	D XI	YR	+
956	CDE	06/28/84	M 2 A	DESIGN MANAGEMENT	1.0	17	D XI	YI	+
957	SL_A	06/28/84	M 2 T	DETAIL DESIGN OF GTR	1.0	17	D XC	YR	+
957	CDE	06/28/84	M 2 T	GTR DETAIL DESIGN	1.0	17	D XC	YN	0
958	CDE	06/28/84	L 1 OH	THANKS TO CCE	1.5	17	D XR	YR	+
959	CDE	07/02/84	T 2 OH	COAL FEED SYSTEM	0.1	17	D XR	0	0
959	SE_FE	07/02/84	T 2 IO	CDE CALLING	0.1	15	D XR	0	0
960	CDE	07/02/84	T 2 OH	PRESSURE VESSEL	0.1	17	D XI	0	0
960	SE_VE	07/02/84	T 2 IO	CDE CALLING	0.1	15	D XI	0	0
961	CDE	07/02/84	T 2 IO	FLOW CONTROLLERS	0.1	17	D XI	YN	0
961	SE_FL	07/02/84	T 2 OO	ARRANGE MEETING	0.1	15	D XI	YE	+
962	CDE	07/04/84	L 1 OO	COAL STORAGE/CUBICLES	2.0	17	E SC	YN	0
963	CCE	07/04/84	L 1 IO	THANKS & FINAL REPORT GTR-4	1.0	16	D XR	YR	+
964	BPO_S	07/05/84	L 1 IO	COAL STORE & CUBICLES	1.0	14	E SC	YN	0
965	CDE	07/05/84	T 2 OO	PROJECT UPDATE	0.2	17	D XR	YR	0
965	SE_FE	07/05/84	T 2 IO	PROJECT UPDATE	0.2	15	D XR	YR	-
966	CDE	07/05/84	W 2 O	FLOW CONTROL SYSTEM	2.0	17	D ID	YN	+
966	SE_FL	07/05/84	W 2 A	FLOW CONTROL SYSTEM	2.0	15	D ID	YN	+
967	SL_A	07/06/84	L 1 OO	REPORT ON VISIT TO M	1.0	17	D XR	YE	-
968	M_A	07/06/84	M 2 O	D.O. & MRS	0.5	22	D XR	YQ	+
968	SL_A	07/06/84	M 2 A	D.O. & VISIT TO M	0.5	17	D XR	YN	+
969	SL_A	07/06/84	T 2 OO	PROJECT ORGANIZATION	0.3	17	D XR	YN	0
969	CDE	07/06/84	T 2 IO	PROJECT ORG/D.O.	0.3	17	D XR	YN	+
970	SL_A	07/06/84	T 2 IO	MEETING WITH AD1_R	0.6	17	D XR	YT	+
970	CDE	07/06/84	T 2 OO	MTG WITH AD1_R	0.6	17	D XR	YT	+
971	CDE	07/06/84	W 1 O	TASK TEAM ORGANIZATION	7.0	17	D XP	YT	+
972	CDE	07/06/84	L 1 OO	TASK TEAM FOR PROJECT	1.0	17	D XP	YT	+
973	M_A	07/09/84	L 1 IO	TASK TEAMS	0.1	22	D XP	0	0
974	M_S	07/09/84	L 1 IO	TASK TEAMS & PROGRESS	0.1	22	D XP	0	0
975	AM_A	07/09/84	L 1 IO	TASK TEAMS	0.5	19	D XP	YT	0
976	AM_S	07/09/84	L 1 IO	TASK TEAMS	0.1	19	D XP	YT	0
977	SL_A	07/09/84	L 1 IO	TASK TEAMS	0.1	17	D XP	YT	0
978	RM_U	07/09/84	L 1 IO	TASK TEAMS	0.1	17	D XP	YT	0
979	AM_A	07/09/84	N 1 IO	BUILDING SPACE	0.1	19	D ID	YR	0
980	AM_S	07/09/84	L 1 IO	L BUILDING SPACE	0.1	19	D ID	0	0
981	SL_A	07/09/84	L 1 IO	WEEKLY REPORTS ETC	0.1	17	D XR	YR	0
982	R1_A	07/09/84	L 1 IO	BUILDING SPACE	0.1	13	D XR	YN	0
983	R2_A	07/09/84	N 1 IL	BUILDING SPACE	0.1	13	D XR	YN	0
984	DE_S	07/09/84	N 1 ID	BUILDING SPACE	0.1	14	E SC	0	0
985	RM_U	07/09/84	L 1 IO	CUBICLE SPACE	0.1	17	E SC	YR	0
986	BPO_S	07/09/84	L 1 OO	COAL+ELECTRICS+CUBICLE SPACE	1.5	14	E SC	YN	0
987	CDE	07/10/84	W 1 O	PRESSURE VESSEL CALCS	5.0	17	D FD	YS	0
988	CDE	07/10/84	T 2 OO	VESSEL BOLT MATERIAL	0.2	17	D FD	DG	+
988	SE_VE	07/10/84	T 2 IO	VESSEL BOLT MATERIAL	0.2	15	D FD	DG	0
989	M_A	07/11/84	T 2 OO	DESIGN MANAGEMENT	0.5	22	D XR	YT	+
989	CDE	07/11/84	T 2 IO	DESIGN MANAGEMENT	0.5	17	D XR	YT	0
990	CDE	07/11/84	W 1 O	PRESSURE VESSEL CALCS	9.0	17	D FD	YS	+
991	CDE	07/11/84	W 1 H	PRESSURE VESSEL CALCS	3.5	17	D FD	YS	+
992	CDE	07/12/84	W 1 O	PRESSURE VESSEL CALCS	7.5	17	D FD	YS	0
993	CDE	07/12/84	W 1 H	VESSEL HEAD DRAWINGS	4.5	17	D FD	DD	-
994	SL_A	07/13/84	T 2 IO	MEETING WITH AD1_R + CUBICLE	0.2	17	D ID	YN	+
994	CDE	07/13/84	T 2 OO	AD1_R MTG/CUBICLES	0.2	17	D ID	YQ	0

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995	CDE	07/13/84	W 1	H	PRESSURE VESSEL CALCS	5.0	17	D FD	YS	0
996	CDE	07/14/84	W 1	H	PRESSURE VESSEL CALCS	7.0	17	D FD	YS	-
997	CDE	07/14/84	W 1	H	PRESSURE VESSEL CALCS	8.0	17	D FD	YS	-
998	CDE	07/16/84	L 1	IO	COAL/ELECTRICITY/CUBICLES	0.3	17	E SC	YN	0
999	CDE	07/16/84	W 1	H	PRESSURE VESSEL CALCS	9.1	17	D FD	YS	-
1000	CDE	07/17/84	W 1	H	PRESSURE VESSEL CALCS	6.5	17	D FD	YS	0
1001	BPO_S	07/19/84	T 2	IO	ISSUES IN LETTER FROM BPO_S	0.2	14	D ID	YN	+
1001	CDE	07/19/84	T 2	OO	ISSUES IN BPO_S LETTER	0.2	17	E SC	YN	+
1002	AM_A	07/19/84	T 2	IO	MESSAGE TO SL_A ON AD1_R MTG	0.1	19	D XR	0	0
1002	CDE	07/19/84	T 2	OO	MTG WITH AD1_R	0.1	17	D XR	0	0
1003	CDE	07/19/84	L 1	OO	CONFIRM BPO_S MTG	0.7	17	E SC	YN	0
1004	BPO_S	07/20/84	L 1	IO	CONFIRMATION OF MTG	0.2	14	E SC	0	0
1005	CDE	07/20/84	W 1	O	WEEKLY REPORTS	4.0	17	D XR	YR	0
1006	CDE	07/21/84	W 1	H	VESSEL HEAD DRAWINGS	6.0	17	D FD	DD	0
1007	CDE	07/22/84	W 1	H	VESSEL HEAD DRAWINGS	6.5	17	D FD	DD	0
1008	DE_S	07/23/84	T 2	OD	CONTACT CDE	0.1	14	D XP	YI	0
1008	CDE	07/23/84	T 2	IO	CALL FROM DE_S	0.1	17	D XP	0	0
1009	DR_S	07/23/84	T 2	ID	CDE CALLING BACK DE_S	0.1	9	D XP	0	0
1009	CDE	07/23/84	T 2	OO	CDE CALLING DE_S	0.1	17	D XP	0	0
1010	DE_S	07/23/84	T 2	OD	NEW DESIGN DRAFTSMAN	0.2	14	D XP	YE	+
1010	CDE	07/23/84	T 2	IO	NEW DESIGN DRAFTSMAN	0.2	17	D XP	YE	+
1011	AM_A	07/23/84	L 1	IO	WEEKLY REPORTS	1.0	19	D XR	YR	0
1012	AM_A	10/12/84	N 1	OO	ORGANIZATION CHART	0.3	19	D XP	YT	0
1013	R1_A	07/23/84	M 4	R	QUOTE FOR VALVES	1.0	13	D XC	YN	0
1013	R2_A	07/23/84	M 4	R	QUOTE FOR VALVES	1.0	13	D XC	YN	0
1013	SE1_VA	07/23/84	M 4	R	VERBAL QUOTATION	1.0	15	D XC	YC	0
1013	SE2_VA	07/23/84	M 4	R	VERBAL QUOTATION	1.0	15	D XC	YC	0
1014	CDE	07/23/84	W 1	O	PREPARING FOR MTG WITH CDD	4.0	17	D XP	YL	+
1015	BPO_S	07/24/84	M 2	O	NEW OFFICES FOR SERVICES DIV	0.1	14	D XP	0	+
1015	CDE	07/24/84	M 2	O	NEW DRAWING OFFICE PLANNED	0.1	17	D XP	YE	+
1016	CDE	07/24/84	T 2	OD	CALL TO SL_A	0.1	17	D XI	0	0
1017	R2_A	07/24/84	T 2	IL	QUOTE FOR VALVES	0.1	13	D XC	YN	0
1017	CDE	07/24/84	T 2	OD	QUOTE FOR VALVES	0.1	17	D XC	YN	-
1018	CDE	07/24/84	T 2	OD	CALL TO AM_A	0.1	17	D XS	0	0
1019	DE_S	07/24/84	M 5	D	INTRODUCTIONS ALL ROUND	0.3	14	D XS	YI	+
1019	DR_S	07/24/84	M 5	D	INTRO OF CDD TO CDE	0.3	9	D XS	YE	+
1019	GI_S	07/24/84	M 5	D	INTRO CDD TO CDE	0.3	8	D XS	YI	+
1019	CDE	07/24/84	M 5	D	INTRO CDD TO CDE	0.3	17	D XS	YE	+
1019	CDD	07/24/84	M 5	D	INTRODUCTION TO CDD	0.3	15	D XS	YI	+
1020	CDE	07/24/84	M 2	D	BACKGROUND OF CDD	0.8	17	D XS	YE	+
1020	CDD	07/24/84	M 2	D	BACKGROUND OF CDD	0.8	15	D XS	YI	+
1021	DE_S	07/24/84	M 4	R	REVIEW OF WHOLE PROJECT	2.0	14	D XR	YR	+
1021	DR_S	07/24/84	M 4	R	REVIEW OF WHOLE PROJECT	2.0	9	D XR	YE	+
1021	CDE	07/24/84	M 4	R	REVIEW OF WHOLE PROJECT	2.0	17	D XR	YE	+
1021	CDD	07/24/84	M 4	R	REVIEW OF WHOLE PROJECT	2.0	15	D XR	YR	+
1022	CDE	07/24/84	W 1	H	PREPARING FOR AD1-R MEETING	3.0	17	D XP	YP	+
1023	CDE	07/25/84	W 1	H	CUBICLE PLAN/ELEVATION	2.0	17	D ID	YN	+
1024	CDE	07/25/84	W 1	O	HAND-OUT FOR AD1-R MTG	9.0	17	D XR	YP	+
1025	R1_A	07/25/84	T 2	OO	VALVE COST ESTIMATE	0.3	13	D XC	YN	+
1025	CDE	07/25/84	T 2	IO	VALVE QUOTE/CUBICLE	0.3	17	D XC	YN	+
1026	CDE	07/25/84	W 1	H	FLOOR SPACE MODELS	1.5	17	D ID	YN	+
1027	CDE	07/26/84	W 1	T	FINAL PREP FOR MEETINGS	0.9	17	D XR	YP	-

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1028	SL_A	07/26/84	M 3	A	D.DESIGN PROGRESS & ORG.	0.4	17	D XR	YR	+
1028	ASL_A	07/26/84	M 3	O	PROJECT STATUS & ORG.	0.4	14	D XR	YR	+
1028	CDE	07/26/84	M 3	A	PROJECT STATUS & ORG.	0.4	17	D XR	YR	0
1029	AM_S	07/26/84	M 2	O	CONTRACT DESIGN DRAFTSMAN	0.3	19	D XS	YI	+
1029	CDE	07/26/84	M 2	A	ARRIVAL OF CDD	0.3	17	D XS	YE	+
1030	SL_A	07/26/84	M 5	R	CUBICLE & ELECTRICAL NEEDS	1.5	17	D ID	YN	+
1030	R2_A	07/26/84	M 5	R	RIG SPACE & ELECTRICAL NEEDS	1.5	13	D ID	YN	+
1030	BPO_S	07/26/84	M 5	R	RIG SPACE & ELECTRICS	1.5	14	D ID	YN	-
1030	DE_S	07/26/84	M 5	R	RIG SPACE & ELECTRICAL	1.5	14	D ID	YN	+
1030	CDE	07/26/84	M 5	R	CUBICLE & ELECTRICAL NEEDS	1.5	17	D ID	YN	+
1031	AM_S	07/26/84	M 3	O	CRANES	0.2	19	D ID	YN	0
1031	DE_S	07/26/84	M 3	A	CRANES & RIG SPACE	0.2	14	D ID	YN	+
1031	CDE	07/26/84	M 3	A	CRANES & RIG SPACE	0.2	17	D ID	YN	0
1032	SL_A	07/26/84	M 4	C	MORNING MEETING	0.4	17	D XS	YI	+
1032	DE_S	07/26/84	M 4	C	LUNCH	0.4	14	D XS	YI	0
1032	CDE	07/26/84	M 4	C	LUNCH	0.4	17	D XS	YE	+
1032	CDD	07/26/84	M 4	C	LUNCH	0.4	15	D XS	YI	0
1033	AD1_R	07/26/84	M 5	O	DESIGN/DRAFTING AT R	2.0	23	D XP	YQ	-
1033	M_A	07/26/84	M 5	A	DESIGN & DRAFTING	2.0	22	D XR	YI	+
1033	AM_A	07/26/84	M 5	A	D.O. MANAGEMENT	2.0	19	D XR	YI	-
1033	SL_A	07/26/84	M 5	A	DESIGN & DRAFTING AT R	2.0	17	D XR	YI	-
1033	CDE	07/26/84	M 5	A	DESIGN & DRAFTING	2.0	17	D XR	YI	-
1034	AM_S	07/26/84	M 2	O	DESIGN & DRAFTING AT L	0.1	19	D XR	YI	0
1034	CDE	07/26/84	M 2	A	DESIGN & DRAFTING	0.1	17	D XR	YI	0
1035	R2_A	07/26/84	M 3	L	SCRUBBER	0.5	13	D XI	YQ	-
1035	DE_S	07/26/84	M 3	E	SCRUBBER IN RIG ROOM	0.5	14	D XI	YQ	-
1035	CDD	07/26/84	M 3	E	SCRUBBER IN RIG ROOM	0.5	15	D XI	YQ	+
1036	DE_S	07/26/84	M 3	D	SCRUBBER	0.5	14	D XI	YQ	0
1036	CDE	07/26/84	M 3	D	SCRUBBER	0.5	17	D XI	DG	+
1036	CDD	07/26/84	M 3	D	SCRUBBER (& GTR-3)	0.5	15	D XI	DG	+
1037	CDE	07/26/84	M 2	T	WORK SITUATION	1.0	17	D XR	YH	+
1037	CDD	07/26/84	M 2	T	WORK SITUATION	1.0	15	D XR	YH	0
1038	SL_A	07/27/84	T 2	IO	VISIT TO CRE & AD1_R MEETING	0.4	17	D XS	0	0
1038	CDE	07/27/84	T 2	OO	CRE VISIT/AD1_R MTG	0.4	17	D XS	0	0
1039	CDE	07/31/84	W 1	R	MEETINGS ON PROJECT	4.5	17	D XI	YP	0
1040	CDE	07/31/84	W 1	E	COAL FEED DEMONSTRATION	1.0	17	D XI	ES	+
1041	CDE	08/01/84	W 1	T	PLAN FOR DAY	0.9	17	D XP	YL	0
1042	DR_S	08/01/84	M 4	D	MISTAKES & ILLNESS	0.3	9	D CD	YH	+
1042	GI_S	08/01/84	M 4	D	SPELLING MISTAKES & ILLNESS	0.3	8	D CD	YH	+
1042	CDE	08/01/84	M 4	D	MISTAKES/ILLNESS	0.3	17	D CD	YH	+
1042	CDD	08/01/84	M 4	D	MISTAKES & ILLNESS	0.3	15	D CD	YH	+
1043	R1_A	08/01/84	W 2	N	SCRUBBER/LAYOUT	1.0	13	D ID	KS	+
1043	CDE	08/01/84	W 2	A	SCRUBBER/LAYOUT	1.0	17	D ID	KS	0
1044	R1_A	08/01/84	W 3	D	RIG LAYOUT & SCRUBBER	1.5	13	D ID	OG	0
1044	CDE	08/01/84	W 3	D	RIG LAYOUT & SCRUBBER	1.5	17	D ID	OG	+
1044	CDD	08/01/84	W 3	L	RIG & SCRUBBER LAYOUT	1.5	15	D ID	OG	-
1045	CDE	08/01/84	M 2	C	LUNCH/CRICKET	1.0	17	D XS	YI	+
1045	CDD	08/01/84	M 2	C	LUNCH/CRICKET	1.0	15	D XS	YI	0
1046	DR_S	08/01/84	W 3	D	MISTAKES IN LAYOUT	1.5	9	D CD	DD	-
1046	CDE	08/01/84	W 3	D	DR_S MISTAKES IN LAYOUT	1.5	17	D CD	DD	0
1046	CDD	08/01/84	W 3	D	DR_S MISTAKES IN LAYOUT	1.5	15	D CD	DD	+
1047	SL_A	08/01/84	W 3	A	HEATING ELEMENTS & MATERIALS	2.2	17	D ID	DG	0

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1047	R1_A	08/01/84	W 3	O HEATING ELEMENTS & MATERIALS	2.2	13	D ID	DG	0
1047	CDE	08/01/84	W 3	A HEATING ELEMENTS/MATERIALS	2.2	17	D ID	DG	0
1048	DR_S	08/01/84	M 3	D PLAN FOR WEEK	0.3	9	D XP	YN	0
1048	CDE	08/01/84	M 3	D PLAN FOR WEEK	0.3	17	D XP	YN	+
1048	CDD	08/01/84	M 3	D PLAN FOR WEEK	0.3	15	D XP	YN	+
1049	S1_A	08/01/84	M 2	P PROJECT PROGRESS	0.1	13	D XR	YR	+
1049	CDE	08/01/84	M 2	P PROJECT PROGRESS	0.1	17	D XR	YR	+
1050	CDE	08/02/84	W 1	O WEEKLY REPORTS	4.0	17	D XR	YR	0
1051	SL_A	08/02/84	T 2	IO CDE VISIT TO R	0.1	17	D XP	0	0
1051	CDE	08/02/84	T 2	OO CDE VISIT TO R	0.1	17	D XP	0	0
1052	CDE	08/04/84	T 2	OO SCRUBBER REACTION	0.3	17	D FD	YS	+
1052	DE_U	08/04/84	T 2	IO SCRUBBER REACTION CALCS.	0.3	12	D FD	YS	+
1053	DE_U	08/06/84	W 1	O SCRUBBER REACTION CALCS (ZNO	2.3	12	D OD	YS	0
1054	CDE	08/06/84	W 1	T PLAN FOR DAY	0.9	17	D XP	YL	0
1055	R1_A	08/06/84	M 2	L GREETING ONLY	0.1	13	D XS	YI	+
1055	CDE	08/06/84	M 2	L GREETING ONLY	0.1	17	D XS	YI	+
1056	ASL_A	08/06/84	M 2	O GREETING ONLY	0.1	14	D XS	YI	+
1056	CDE	08/06/84	M 2	O GREETING ONLY	0.1	17	D XS	YI	+
1057	DE1_M	08/06/84	M 2	P VISIT TO STATION R	0.1	15	D XS	YI	+
1057	CDE	08/06/84	M 2	P VISIT TO R	0.1	17	D XS	YI	+
1058	AM_S	08/06/84	M 2	O VISITOR FROM M	0.1	19	D XS	0	+
1058	DE1_M	08/06/84	M 2	A VISIT TO SEE AM_S	0.1	15	D XS	YI	+
1059	DR_S	08/06/84	W 3	D SCRUBBER CALCULATIONS	1.0	9	D FD	YS	-
1059	CDE	08/06/84	W 3	D SCRUBBER CALCS	1.0	17	D FD	YS	-
1059	CDD	08/06/84	W 3	D ON PHONE/SCRUBBER	1.0	15	D FD	YS	+
1060	R1_A	08/06/84	T 2	IO GASKET MATERIAL	0.1	13	D FD	DG	+
1060	CDE	08/06/84	T 2	OD GASKET MATERIAL	0.1	17	D FD	DG	0
1061	BPO_S	08/06/84	M 2	P RESULT OF MTG	0.2	14	D XR	YR	+
1061	CDE	08/06/84	M 2	P RESULT OF BPO_S MTG	0.2	17	D XR	YR	+
1062	AM_A	08/06/84	M 2	O UPDATE - GENERAL	1.2	19	D XR	YR	+
1062	CDE	08/06/84	M 2	A UPDATE/GENERAL	1.2	17	D XR	YE	+
1063	AD1_R	08/06/84	M 2	O DESIGN & DRAFTING	0.5	23	D XP	0	-
1063	AM_A	08/06/84	M 2	A D.O. MANAGEMENT	0.5	19	D XP	YI	0
1064	CDD	08/06/84	W 1	D SCRUBBER CALCULATIONS	4.0	15	D FD	YS	0
1065	DR_S	08/06/84	M 2	D CHEERIO FOR DAY	0.1	9	D XS	0	+
1065	CDE	08/06/84	M 2	D CHEERIO FOR DAY	0.1	17	D XS	YI	+
1066	AM_A	08/06/84	M 2	O COMPUTER LINKS	0.1	19	D ID	0	0
1066	CDE	08/06/84	M 2	O COMPUTER LINKS	0.1	17	D ID	DG	0
1067	CDE	08/07/84	T 2	IO REACTION CALCS	0.3	17	D FD	YE	+
1067	DE_U	08/07/84	T 2	OO REACTION CALCULATIONS (ZNO)	0.3	12	D FD	YS	+
1068	CDD	08/07/84	W 1	D SCRUBBER DRAWINGS	8.0	15	D FD	DD	0
1069	CDE	08/07/84	W 1	O BPO_S MTG SUMMARY	2.5	17	D XR	YR	0
1070	CDE	08/08/84	W 1	O BPO_S LETTER & SUMMARY	1.0	17	D XR	YR	0
1071	CDE	08/08/84	W 1	T PLAN FOR DAY	0.9	17	D XP	YL	0
1072	CDD	08/08/84	W 1	D SCRUBBER DRAWINGS	3.5	15	D FD	DD	0
1073	CDE	08/08/84	W 2	D REVIEWED SCRUBBER DWGS	0.3	17	D CD	CD	+
1073	CDD	08/08/84	W 2	D REVIEWED SCRUBBER DRAWINGS	0.3	15	D CD	CD	+
1074	BPO_S	08/08/84	M 2	O FLOOR LOADS & MTG SUMMARY	0.7	14	D ID	YN	0
1074	CDE	08/08/84	M 2	A FLOOR LOADS/MTG SUMMARY	0.7	17	D ID	YN	+
1075	CDE	08/08/84	W 2	D VESSEL HEIGHTS & FRAME	1.2	17	D FD	YS	+
1075	CDD	08/08/84	W 2	D VESSEL HEIGHTS & FRAME	1.2	15	D FD	YS	+
1076	BPO_S	08/08/84	M 2	O FLOOR LOADS & MTG SUMMARY	0.2	14	D FD	YS	+

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1076	CDE	08/08/84	M 2	A FLOOR LOADING	0.2	17	D FD	YS	+
1077	SL_A	08/08/84	M 2	A PROJECT UPDATE	0.3	17	D XR	YR	0
1077	CDE	08/08/84	M 2	A PROJECT UPDATE	0.3	17	D XR	YE	+
1078	AM_A	08/08/84	M 2	O R MANAGEMENT	0.5	19	D XS	0	+
1078	CDE	08/08/84	M 2	A UPPER MANAGEMENT	0.5	17	D XS	0	-
1079	SE_FL	08/08/84	L 1	OO WRITTEN QUOTATION	1.3	15	D XC	YC	0
1080	CDE	08/09/84	W 1	O VESSEL LAYOUT & ELEVATION	5.0	17	D FD	YS	0
1081	CDD	08/09/84	W 1	D SCRUBBER DRAWINGS	5.0	15	D FD	DD	0
1082	CDE	08/10/84	W 1	T SOLIDS COLLECTION VESSEL	2.0	17	D FD	YS	-
1083	CDD	08/10/84	W 1	D VESSEL HEIGHT & LAYOUT	3.0	15	D ID	DD	0
1084	AD1_R	08/10/84	M 2	P GREETING IN LOBBY	0.1	23	D XS	YI	+
1084	CDE	08/10/84	M 2	P GREETING IN LOBBY	0.1	17	D XS	YI	+
1085	ASL_A	08/10/84	M 3	O GREETING ONLY	0.1	14	D XS	YI	+
1085	R1_A	08/10/84	M 3	N GREETINGS ONLY	0.1	13	D XS	YI	0
1085	CDE	08/10/84	M 3	A GREETING ONLY	0.1	17	D XS	YI	+
1086	CDE	08/10/84	M 2	C LUNCH	0.5	17	D XS	YH	+
1086	CDD	08/10/84	M 2	C LUNCH	0.5	15	D XS	YI	0
1087	AD2_R	08/10/84	M 2	C PROJECT FUNDING	0.2	23	D XC	YQ	-
1087	CDE	08/10/84	M 2	C PROJECT FUNDING	0.2	17	D XC	YE	+
1088	AM_A	08/10/84	T 2	IO FUNDING FOR GTR	0.1	19	D XC	YN	0
1088	CDE	08/10/84	T 2	OD FUNDING FOR GTR	0.1	17	D XC	YE	+
1089	CDD	08/10/84	W 1	D PIPE CALCULATIONS	2.0	15	D ID	YS	+
1090	CDE	08/10/84	W 2	D PIPE CALCULATIONS	0.8	17	D FD	YS	0
1090	CDD	08/10/84	W 2	D PIPE CALCULATIONS	0.8	15	D FD	YS	+
1091	BPO_S	08/10/84	M 2	O LETTER & SUMMARY	0.1	14	D XR	YR	-
1091	CDE	08/10/84	M 2	A BPO_S MTG SUMMARY	0.1	17	D XR	YR	0
1092	R1_A	08/10/84	M 4	L NATIONALISED INDUSTRY	0.2	13	D XS	YI	-
1092	R2_A	08/10/84	M 4	L AFTERNOON TEA	0.2	13	D XS	YI	+
1092	S2_A	08/10/84	M 4	L AFTERNOON TEA	0.2	13	D XS	0	+
1092	CDE	08/10/84	M 4	L AFTERNOON TEA	0.2	17	D XS	YH	+
1093	R1_A	08/10/84	W 2	N SOLIDS SEPARATION	1.0	13	D FD	DG	-
1093	CDE	08/10/84	W 2	A SOLIDS SEPARATION	1.0	17	D FD	DG	+
1094	BPO_S	08/10/84	M 2	O DISCUSSION ON SUMMARY	0.2	14	D XR	YR	+
1094	CDE	08/10/84	M 2	A DISCUSSION ON SUMMARY	0.2	17	D XR	YN	+
1095	DR_S	08/10/84	M 3	D DESIGN METHODS	0.6	9	D XS	YE	+
1095	CDE	08/10/84	M 3	D DESIGN METHODS	0.6	17	D XS	YE	+
1095	CDD	08/10/84	M 3	D DESIGN METHODS	0.6	15	D XS	YE	+
1096	SL_A	08/10/84	T 2	IO DETAIL DESIGN PROGRESS	0.2	17	D XR	YR	0
1096	CDE	08/10/84	T 2	OD DETAIL DESIGN PROGRESS	0.2	17	D XR	YR	0
1097	CDE	08/13/84	L 1	OO BPO_S MTG SUMMARY	2.0	17	D XR	YR	0
1098	CDD	08/13/84	W 1	D FINISH SCRUBBER CALCULATIONS	3.0	15	D FD	YS	+
1099	CDE	08/14/84	T 2	OO VESSEL SUPPORT FRAME	0.4	17	D FD	DD	+
1099	CDD	08/14/84	T 2	ID VESSEL SUPPORT FRAME	0.4	15	D FD	DD	+
1100	CDD	08/14/84	W 1	D VESSEL SUPPORT FRAME	4.0	15	D FD	DD	0
1101	SL_A	08/14/84	T 2	IO CDE NEXT VISIT	0.2	17	D XP	0	+
1101	CDE	08/14/84	T 2	OO CDE NEXT VISIT	0.2	17	D XP	0	0
1102	RM_U	08/14/84	L 1	IO CUBICLE & ELECTRICAL NEEDS	0.1	17	D XR	YR	0
1103	SL_A	08/14/84	T 2	OO SKETCH OF HEATING ELEMENTS	0.1	17	D XI	YQ	0
1103	RM_U	08/14/84	T 2	IO SKETCH OF HEATING ELEMENTS	0.1	17	D XI	0	0
1104	CDD	08/15/84	T 2	OD VESSEL SUPPORT FRAME	0.1	15	D FD	YS	0
1105	CDD	08/15/84	W 1	D SUPPORT FRAME DESIGN	4.0	15	D FD	DG	0
1106	CDE	08/16/84	L 1	IO CDE TO CALL CDD	0.1	17	D XP	0	0

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1107	CDE	08/16/84	T 2 OO	SUPPORT FRAME DESIGN	0.8	17	D FD	DG	+
1107	CDD	08/16/84	T 2 ID	SUPPORT FRAME DESIGN	0.8	15	D FD	DG	+
1108	CDD	08/16/84	W 1 D	FRAME CALCULATIONS	6.0	15	D FD	DG	0
1109	BPO_S	08/16/84	L 1 IO	FINAL SUMMARY	0.2	14	D XR	YR	0
1110	CDE	08/17/84	W 1 T	PLAN FOR DAY	0.9	17	D XP	YL	0
1111	CDD	08/17/84	W 1 D	FORCES & MOMENTS	4.0	15	D FD	YS	+
1112	AM_A	08/17/84	M 2 O	PROJECT UPDATE	0.1	19	D XR	YR	0
1112	CDE	08/17/84	M 2 A	PROJECT UPDATE	0.1	17	D XR	YE	0
1113	AM_A	08/17/84	L 1 IO	BPO_S MEETING SUMMARY	0.2	19	D XR	YR	0
1114	M_A	08/17/84	M 2 O	PROJECT UPDATE	0.2	22	D XR	YQ	+
1114	CDE	08/17/84	M 2 A	PROJECT UPDATE	0.2	17	D XR	YE	+
1115	M_A	08/17/84	L 1 IO	SUMMARY OF MEETING	0.2	22	D XR	O	0
1116	M_S	08/17/84	M 2 O	PROJECT UPDATE	0.1	22	D XR	YR	0
1116	CDE	08/17/84	M 2 A	PROJECT UPDATE	0.1	17	D XR	YE	+
1117	M_S	08/17/84	L 1 IO	BUILDING MEETING MINUTES	0.2	22	D XR	O	0
1118	AM_S	08/17/84	M 2 O	RESULTS OF SERVICES MTG	0.1	19	D XR	O	+
1118	CDE	08/17/84	M 2 A	RESULTS OF BPO MTG	0.1	17	D XR	YE	+
1119	R2_A	08/17/84	M 2 L	UPDATE & MEETING SUMMARY	0.1	13	D XR	YR	+
1119	CDE	08/17/84	M 2 L	UPDATE & MTG SUMMARY	0.1	17	D XR	YE	+
1120	SL_A	08/17/84	L 1 IO	CUBICLE & ELECTRICAL NEEDS	0.1	17	D XR	YN	0
1121	SL_A	08/17/84	T 2 IO	DETAIL DESIGN	0.1	17	D FD	YN	0
1121	CDE	08/17/84	T 2 OD	DETAIL DESIGN	0.1	17	D FD	O	0
1122	CDE	08/17/84	W 2 D	REVIEW FRAME CALCS	2.3	17	D CD	YS	0
1122	CDD	08/17/84	W 2 D	REVIEWED CALCULATIONS	2.3	15	D CD	YS	+
1123	SL_A	08/17/84	W 3 D	REVIEW NEW DESIGN	0.5	17	D CD	CD	+
1123	CDE	08/17/84	W 3 D	REVIEW NEW DESIGN	0.5	17	D CD	CD	+
1123	CDD	08/17/84	W 3 D	REVIEW NEW DESIGN	0.5	15	D CD	CD	+
1124	SL_A	08/17/84	M 2 P	FURNACE ELEMENTS	0.2	17	D FD	DG	0
1124	CDE	08/17/84	M 2 P	FURNACE ELEMENTS	0.2	17	D FD	DG	0
1125	S2_A	08/17/84	L 1 IO	RIG SPACE MEETING SUMMARY	0.1	13	D XR	YR	0
1126	BPO_S	08/17/84	M 2 P	RELATIONS BETWEEN DIVISIONS	0.2	14	D XS	YI	+
1126	CDE	08/17/84	M 2 P	RELATIONS BETWEEN DIVISIONS	0.2	17	D XS	YI	+
1127	CDD	08/20/84	W 1 D	COLUMN CALCULATIONS	4.0	15	D FD	DG	0
1128	CDD	08/21/84	W 1 D	FRAME CALCULATIONS	4.0	15	D FD	DG	-
1129	CDE	08/22/84	W 1 T	PLAN FOR DAY	0.9	17	D XP	YL	0
1130	CDE	08/22/84	W 2 D	FRAME & BEARINGS	1.5	17	D FD	YS	+
1130	CDD	08/22/84	W 2 D	FRAME & BEARINGS	1.5	15	D ID	DD	+
1131	DR_S	08/22/84	W 2 D	LOOKING FOR BEARING CATALOG	0.3	9	D XI	DD	+
1131	CDE	08/22/84	W 2 D	LOOKING FOR BEARING CATALOG	0.3	17	D XI	YF	-
1132	CDE	08/22/84	W 1 E	SIZE OF FORKLIFT	0.3	17	D XI	DG	+
1133	R2_A	08/22/84	W 2 L	TEST RIG LAYOUT	0.3	13	D ID	II	+
1133	CDE	08/22/84	W 2 L	GTR LAYOUT	0.3	17	D ID	DG	+
1134	CDE	08/22/84	W 2 D	PUMP LAYOUT	0.2	17	D ID	DG	0
1134	CDD	08/22/84	W 2 D	PUMP LAYOUT	0.2	15	D ID	DG	+
1135	R1_A	08/22/84	W 2 N	MEETING SUMMARY & LAYOUT	0.3	13	D ID	OG	0
1135	CDE	08/22/84	W 2 A	BPO_S MTG / LAYOUT	0.3	17	D ID	DG	+
1136	S1_A	08/22/84	M 3 P	WORKING WITH S1_P	0.1	13	D XR	YR	+
1136	S1_P	08/22/84	M 3 P	WORKING WITH S1_A	0.1	13	D XR	YR	+
1136	CDE	08/22/84	M 3 P	PROJECT UPDATE	0.1	17	D XR	YR	+
1137	SL_A	08/22/84	M 2 O	PROJECT PROGRESS	1.6	17	D XR	YR	+
1137	CDE	08/22/84	M 2 A	PROJECT PROGRESS	1.6	17	D XR	YE	+
1138	AM_A	08/22/84	M 2 O	UPDATE	0.2	19	D XR	YR	0

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1138	CDE	08/22/84	M 2 A	PROJECT UPDATE	0.2	17	D XR	YR	0
1139	CDD	08/22/84	W 1 D	FRAME DRAWINGS	3.0	15	D FD	DD	0
1140	CDD	08/23/84	W 1 D	FRAME DRAWINGS	5.0	15	D FD	DD	0
1141	CDE	08/24/84	T 2 OO	FRAME & MONORAIL	0.5	17	D FD	DG	0
1141	CDD	08/24/84	T 2 ID	FRAME & MONORAIL	0.5	15	D FD	DG	+
1142	CDD	08/24/84	W 1 D	FRAME & WALKWAY	5.0	15	D FD	DG	-
1143	M_A	08/24/84	M 2 O	A-FORM & FUNDING	0.5	22	D XP	O	-
1143	SL_A	08/24/84	M 2 A	A-FORM & FUNDING	0.5	17	D XP	YN	-
1144	SL_A	08/24/84	T 2 IO	PROJECT FUNDING	0.2	17	D XC	YN	-
1144	CDE	08/24/84	T 2 OO	PROJECT FUNDING	0.2	17	D XC	YN	+
1145	R1_A	08/24/84	T 2 IO	REQUEST FOR MEETING	0.1	13	D XP	YN	0
1145	CDE	08/24/84	T 2 OO	REQUEST FOR MTG	0.1	17	D XP	O	0
1146	R2_A	08/24/84	T 2 IL	ARRANGE MEETING WITH CDD	0.1	13	D XP	O	0
1146	CDE	08/24/84	T 2 OO	R2_A TO MEET WITH CDD	0.1	17	D XP	O	0
1147	CDD	08/27/84	W 1 D	UPPER FRAME STRUCTURE	6.0	15	D FD	DD	0
1148	CDD	08/28/84	W 1 D	UPPER FRAME STRUCTURE	5.0	15	D FD	DD	0
1149	CDE	08/29/84	W 1 T	PLAN FOR DAY	0.9	17	D XP	YL	0
1150	CDE	08/29/84	W 2 D	REVIEWED DRAWINGS	2.0	17	D CD	CD	+
1150	CDD	08/29/84	W 2 D	REVIEWED DRAWINGS	2.0	15	D CD	CD	+
1151	R2_A	08/29/84	M 2 E	REQUESTED R2_A TO COME	0.1	13	D XP	O	+
1151	CDE	08/29/84	M 2 E	R2_A TO COME TO D.O.	0.1	17	D XP	YH	+
1152	R2_A	08/29/84	M 3 D	TAR VESSELS & FRAME	0.5	13	D ID	OG	+
1152	CDE	08/29/84	M 3 D	TAR VESSELS/FRAME	0.5	17	D ID	DG	+
1152	CDD	08/29/84	W 3 D	TEST RIG LAYOUT	0.5	15	D ID	DG	+
1153	BPO_S	08/29/84	M 2 D	VALVES OUTSIDE BLDG	0.5	14	D ID	DG	+
1153	CDE	08/29/84	M 2 D	VALVES OUTSIDE BLDG	0.5	17	D ID	DG	+
1154	DR_S	08/29/84	M 3 D	CALCULATION SHEETS	0.5	9	D PD	YE	+
1154	CDE	08/29/84	M 3 D	CALCULATION SHEETS	0.5	17	D PD	YS	-
1154	CDD	08/29/84	M 3 D	CALCULATION SHEETS	0.5	15	D PD	YP	-
1155	CDE	08/29/84	W 1 D	CALCULATION SHEETS	1.3	17	D PD	YS	+
1156	CDD	08/30/84	W 1 D	COPYING OUT CALCULATIONS	5.0	15	D PD	YR	+
1157	CDE	08/31/84	T 2 OO	CALCS & DWGS	0.3	17	D PD	YQ	0
1157	CDD	08/31/84	T 2 ID	CALCULATIONS & DRAWINGS	0.3	15	D PD	YS	-
1158	CDE	08/31/84	T 2 OO	CHAIN HOIST RAIL	0.2	17	D FD	YQ	0
1158	SE_FL	08/31/84	T 2 IO	CHAIN HOIST RAIL INFO TO CDE	0.2	15	D FD	YS	0
1159	CDD	08/31/84	W 1 D	CALCULATIONS & DRAWINGS	4.0	15	D PD	YS	+
1160	CDE	08/31/84	T 2 OO	RUNWAY BEAM RADIUS	0.3	17	D XI	YS	+
1160	CDD	08/31/84	T 2 ID	RUNWAY BEAM RADIUS	0.3	15	D XI	YS	+
1161	R2_A	09/04/84	T 1 OL	TRYING TO CONTACT CDE	0.1	13	D XC	O	0
1162	DE_S	09/04/84	M 2 D	REVIEW OF DETAIL DRAWINGS	6.0	14	D CD	YQ	-
1162	CDD	09/04/84	W 2 D	REVIEW OF STEELWORK	6.0	15	D ID	YR	-
1163	R2_A	09/04/84	M 3 D	RIG LAYOUT	0.2	13	D ID	OG	-
1163	DE_S	09/04/84	M 3 D	EXPLANATIONS	0.2	14	D ID	YQ	-
1163	CDD	09/04/84	M 3 D	VESSEL LAYOUT	0.2	15	D ID	YR	-
1164	DE_S	09/04/84	T 2 ID	REQUEST FOR UPDATE	0.2	14	D XR	YQ	-
1164	CDE	09/04/84	T 2 OE	CDE REQUEST FOR UPDATE	0.2	17	D XR	YQ	-
1165	CDE	09/05/84	W 1 E	CHANGE OF PLANS	0.2	17	D XP	O	-
1166	DR_S	09/05/84	M 3 P	GREETINGS	0.1	9	D XS	YE	+
1166	CDE	09/05/84	M 3 P	GREETINGS TO DR_S	0.1	17	D XS	YI	+
1167	R1_A	09/05/84	M 2 O	NOTICE OF MEETING	0.1	13	D XP	YN	0
1167	CDE	09/05/84	M 2 A	NOTICE OF MTG/H.H.	0.1	17	D XP	O	+
1168	CDE	09/05/84	W 2 D	YESTERDAY'S FIASCO	0.4	17	D XS	YH	-

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1168	CDD	09/05/84	W 2 D	YESTERDAY'S FIASCO	0.4	15	D XS	YH	-
1169	DR_S	09/05/84	M 3 P	TEA! (AND YESTERDAY)	0.3	9	D XS	YE	-
1169	CDE	09/05/84	M 3 P	TEA! (AND YESTERDAY)	0.3	17	D XS	YH	+
1169	CDD	09/05/84	M 3 P	TEA (& YESTERDAY)	0.3	15	D XS	YH	+
1170	DE_S	09/05/84	M 3 D	REVIEW OF PROGRESS	0.8	14	D ID	DG	-
1170	CDE	09/05/84	M 3 D	EXPLANATION OF STEELWORK	0.8	17	D ID	DG	-
1170	CDD	09/05/84	M 3 D	EXPLANATION OF STEELWORK	0.8	15	D ID	YI	-
1171	R1_A	09/05/84	N 1 OO	MEETING CANCELLED	0.1	13	D XP	YI	0
1172	CDE	09/05/84	L 1 ID	MTG WITH SE CANCELLED	0.1	17	D XP	0	-
1173	R1_A	09/05/84	M 2 N	GENERAL UPDATE	0.1	13	D XR	YR	0
1173	CDE	09/05/84	M 2 A	GENERAL UPDATE	0.1	17	D XR	YR	0
1174	R2_A	09/05/84	M 2 L	PROJECT TECHNICAL INFO	0.3	13	D XI	YF	+
1174	CDE	09/05/84	M 2 L	PROJECT TECHNICAL INFO	0.3	17	D XI	YF	0
1175	M_A	09/05/84	M 2 O	A-FORM & FUNDING	0.3	22	D XC	0	-
1175	SL_A	09/05/84	M 2 A	A-FORM & FUNDING	0.3	17	D XC	YN	-
1176	SL_A	09/05/84	M 2 O	FUTURE OF PROJECT	1.6	17	D XC	YN	-
1176	CDE	09/05/84	M 2 A	FUTURE OF PROJECT	1.6	17	D XC	YN	-
1177	AM_A	09/07/84	L 1 IO	CDE VISIT TO M	0.2	19	D XR	YR	+
1178	CDE	09/10/84	W 1 T	PLAN FOR DAY	0.9	17	D XP	YL	0
1179	DE_S	09/10/84	M 3 D	PROJECT REPORTS GTR 1 & 2	0.1	14	D XR	YR	-
1179	DR_S	09/10/84	M 3 D	PROJECT REPORTS GTR 1 & 2	0.1	9	D XR	YR	-
1179	CDE	09/10/84	M 3 D	GTR-1 & GTR-2 REPORTS	0.1	17	D XR	YR	0
1180	CDE	09/10/84	M 2 D	STEELWORK DETAILS	0.3	17	D FD	DD	+
1180	CDD	09/10/84	M 2 D	STEELWORK DETAILS	0.3	15	D FD	DD	0
1181	AM_S	09/10/84	M 2 O	DESIGN MANAGEMENT	0.1	19	D XI	YT	-
1181	CDE	09/10/84	M 2 A	DESIGN MANAGEMENT	0.1	17	D XI	YE	+
1182	BPO_S	09/10/84	M 2 P	GREETING ONLY	0.1	14	D XS	YI	+
1182	CDE	09/10/84	M 2 P	GREETING TO BPO_S	0.1	17	D XS	YI	+
1183	SL_A	09/10/84	M 5 L	GENERAL TALK	0.2	17	D XS	YI	+
1183	ASL_A	09/10/84	M 5 L	GENERAL TALK	0.2	14	D XS	0	+
1183	R1_A	09/10/84	M 5 L	GENERAL TALK	0.2	13	D XS	YH	+
1183	R2_A	09/10/84	M 5 L	REPORT GTR-3	0.2	13	D XS	YR	+
1183	CDE	09/10/84	M 5 L	AFTERNOON TEA	0.2	17	D XS	YI	+
1184	AM_A	09/10/84	M 2 O	D.O. & GTR FUNDING	0.7	19	D XC	YI	+
1184	CDE	09/10/84	M 2 A	D.O. & GTR FUNDING	0.7	17	D XC	YI	-
1185	M_A	09/10/84	M 5 A	SEE NEW EQUIPMENT	0.1	22	D XS	YI	+
1185	AM_A	09/10/84	M 5 A	SEE NEW EQUIPMENT	0.1	19	D XS	YI	+
1185	SL_A	09/10/84	M 5 A	SEE NEW EQUIPMENT	0.1	17	D XS	YI	+
1185	R1_A	09/10/84	M 5 N	NEW EQUIPMENT COME	0.1	13	D XS	YI	+
1185	CDE	09/10/84	M 5 A	SEE NEW EQUIPMENT	0.1	17	D XS	YH	+
1186	CDE	09/10/84	W 1 D	CHECK SCRUBBER DRAWINGS	0.5	17	D CD	CD	+
1187	BPO_S	09/10/84	M 5 D	OFFERED SPACE FOR PRINT M/C	0.2	14	D XS	YI	+
1187	DE_S	09/10/84	M 5 D	SITE FOR PRINT MACHINE	0.2	14	D XS	0	-
1187	DR_S	09/10/84	M 5 D	SPACE FOR PRINT M/C	0.2	9	D XS	0	0
1187	CDE	09/10/84	M 5 D	SPACE FOR PRINT M/C	0.2	17	D XS	YH	-
1187	CDD	09/10/84	M 5 D	SPACE FOR PRINT MACHINE	0.2	15	D XS	YI	+
1188	CDE	09/10/84	W 2 D	STEELWORK DRAWINGS	0.1	17	D FD	DD	-
1188	CDD	09/10/84	W 2 D	STEELWORK DRAWINGS	0.1	15	D FD	DD	-
1189	GI_S	09/10/84	M 2 D	ATTITUDE TO DE_S	0.2	8	D XS	YI	-
1189	CDE	09/10/84	M 2 D	ATTITUDE TO DE_S	0.2	17	D XS	YI	0
1190	SL_A	09/10/84	M 2 N	SERVICE FROM D.O.	0.8	17	D XR	YR	-
1190	CDE	09/10/84	M 2 A	SERVICE FROM D.O.	0.8	17	D XR	YR	-

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INT/NO	PERSON	DATE	TYPE/L	TOPIC	HRS	£/H	P/ACT	TQ	M
1191	CDE	09/17/84	W 1 T	DETAIL DESIGN PROGRESS	0.9	17	D XR	YR	-
1192	R1_A	09/17/84	M 2 O	GREETING ONLY	0.1	13	D XS	YI	+
1192	CDE	09/17/84	M 2 A	GREETING ONLY	0.1	17	D XS	YI	+
1193	CDE	09/17/84	M 2 D	INTERFERENCE BY DE_S	0.2	17	D XS	YI	0
1193	CDD	09/17/84	M 2 D	DESIGN ENGINEER DE_S	0.2	15	D XS	YI	-
1194	DE_S	09/17/84	M 3 D	DRAWING NUMBERS	1.0	14	D ID	YF	-
1194	CDE	09/17/84	M 3 D	NUMBERING DWGS	1.0	17	D ID	YF	-
1194	CDD	09/17/84	M 3 D	NUMBERING OF DRAWINGS	1.0	15	D ID	YF	-
1195	DE_S	09/17/84	M 3 D	SITUATION REGARDING GI_S	2.0	14	D XS	YI	-
1195	CDE	09/17/84	M 3 D	SALARIES & GI_S	2.0	17	D XS	YH	+
1195	CDD	09/17/84	M 3 D	SALARIES AND GI_S	2.0	15	D XS	YI	-
1196	CDE	09/17/84	W 1 D	DRAWING REGISTER	1.5	17	D ID	YF	+
1197	DE_S	09/17/84	M 2 D	PERSONAL SITUATION OF DE_S	0.5	14	D XS	YI	-
1197	CDE	09/17/84	M 2 D	PERSONAL SITUATION OF DE_S	0.5	17	D XS	YI	0
1198	CDE	09/17/84	L 1 OD	DRAWING REGISTER	0.3	17	D ID	YF	0
1199	CDE	09/28/84	W 1 T	PLAN FOR DAY	0.9	17	D XP	YL	0
1200	ASL_A	09/28/84	M 2 O	POOR STATE OF PROJECT	0.2	14	D XR	YR	-
1200	CDE	09/28/84	M 2 A	POOR STATE OF PROJECT	0.2	17	D XR	YR	-
1201	CDE	09/28/84	M 2 D	CDD LEAVING JOB	0.2	17	D XP	YI	-
1201	CDD	09/28/84	M 2 D	CDD WANTS TO LEAVE	0.2	15	D XP	YN	-
1202	DE_S	09/28/84	M 3 D	D.O. SUPERVISION	0.1	14	D XS	YI	-
1202	CDE	09/28/84	M 3 D	SORTING THINGS OUT	0.1	17	D XS	YI	+
1202	CDD	09/28/84	M 3 D	SORTING THINGS OUT	0.1	15	D XS	YN	-
1203	AM_A	09/28/84	M 2 A	NO PROGRESS IN D.O.	0.2	19	D XR	YT	-
1203	CDE	09/28/84	M 2 A	NO PROGRESS IN D.O.	0.2	17	D XR	YN	-
1204	M_S	09/28/84	M 2 O	DETAIL DESIGN PROGRESS	0.1	22	D XP	YR	0
1204	CDE	09/28/84	M 2 A	DETAIL DESIGN PROGRESS	0.1	17	D XP	YN	-
1205	AM_S	09/28/84	M 2 O	CONTRACT DESIGN DRAFTSMAN	0.3	19	D XR	YN	+
1205	CDE	09/28/84	M 2 A	CONTRACT DESIGN DRAFTSMAN	0.3	17	D XR	YN	+
1206	CDE	09/28/84	M 2 P	AM_A WILL SEE CDD	0.1	17	D XP	YN	+
1206	CDD	09/28/84	M 2 P	CDD WILL SEE AM_S	0.1	15	D XP	YN	-
1207	SL_A	09/28/84	M 2 O	FUTURE OF PROJECT	1.6	17	D XP	YN	-
1207	CDE	09/28/84	M 2 A	FUTURE OF PROJECT	1.6	17	D XP	YN	-
1208	SL_A	10/10/84	M 2 D	D.O. SITUATION & GTR	0.2	17	D XP	YI	+
1208	CDD	10/10/84	M 2 D	D.O. SITUATION & GTR	0.2	15	D XP	YN	+
1209	AM_S	10/10/84	M 2 O	CONTRACT DESIGN DRAFTSMAN	0.2	19	D XR	YT	-
1209	SL_A	10/10/84	M 2 A	CDD UNHAPPY	0.2	17	D XR	YI	+
1210	SL_A	10/10/84	T 2 IO	CDD & DETAIL DESIGN	0.5	17	D XP	YI	-
1210	CDE	10/10/84	T 2 OO	CDD & DETAIL DESIGN	0.5	15	D XP	YI	0
1211	CDD	10/10/84	W 1 D	CRANE GANTRY DRAWINGS	6.0	15	D FD	DD	+
1212	CDE	10/11/84	W 1 T	PLAN FOR DAY	0.4	17	D XP	YL	0
1213	ASL_A	10/11/84	M 3 N	GREETING ONLY	0.1	14	D XS	YI	+
1213	R1_A	10/11/84	M 3 N	GREETING ONLY	0.1	13	D XS	YH	+
1213	CDE	10/11/84	M 3 A	GREETING ONLY	0.1	17	D XS	YH	+
1214	CDE	10/11/84	M 2 A	OTHER USES OF GTR	2.0	17	D XP	YN	0
1215	DE_S	10/11/84	W 3 D	STEELWORK DRAWINGS	0.5	14	D FD	DD	-
1215	CDE	10/11/84	W 3 D	STEELWORK DWGS	0.5	17	D FD	DD	-
1215	CDD	10/11/84	W 3 D	STEELWORK DRAWINGS	0.5	15	D FD	DD	+
1216	CDE	10/11/84	L 1 OA	WEEKLY REPORTS	0.3	17	D XR	YR	0
1217	SL_A	10/11/84	L 1 IO	WEEKLY REPORTS	0.1	17	D XR	YR	0
1218	AM_A	10/11/84	N 1 IO	WEEKLY REPORTS	0.1	19	D XR	YR	0
1219	SL_A	10/16/84	T 2 IO	D.O. & WEEKLY REPORTS	0.5	17	D XR	YN	0

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INT/NO	PERSON	DATE	TYPE/L	TOPIC	HRS	£/H	P/ACT	TQ	M
1219	CDE	10/16/84	T 2 OO	D.O. & WEEKLY REPORTS	0.5	17	D XR	YN	0
1220	AM_S	10/18/84	T 2 1O	DETAIL DESIGN PROGRESS	0.1	19	D XR	YR	+
1220	CDE	10/18/84	T 2 OO	DETAIL DESIGN PROGRESS	0.1	17	D XR	YQ	0
1221	DE_S	10/18/84	T 2 OD	CDE REQUESTED UPDATE ON DWGS	0.2	14	D XR	YQ	+
1221	CDE	10/18/84	T 2 1O	CDE ASKED ABOUT DWGS	0.2	17	D XR	YQ	0
1222	AM_S	10/19/84	M 2 O	DESIGN & DRAFTING	0.5	19	D XP	YN	+
1222	CDD	10/19/84	M 2 A	CDD LEAVING R	0.5	15	D XP	YN	0
1223	R1_A	10/22/84	T 2 OO	ARRANGE MEETING	0.1	13	D XP	O	0
1223	CDE	10/22/84	T 2 1H	ARRANGE MTG WITH CDE	0.1	17	D XP	O	-
1224	SL_A	10/22/84	T 2 OO	MEETING TIME	0.1	17	D XP	O	0
1224	CDE	10/22/84	T 2 1H	SL_A WANTS MTG 10.30	0.1	17	D XP	O	-
1225	SL_A	10/22/84	T 2 OO	MEETING TIME	0.1	17	D XP	O	0
1225	CDE	10/22/84	T 2 1H	SECOND MTG AFTERNOON	0.1	17	D XP	O	-
1226	DE_S	10/22/84	T 2 OD	CDD IS LEAVING	0.2	14	D XR	Y1	0
1226	CDE	10/22/84	T 2 1H	CDD IS LEAVING	0.2	17	D XR	Y1	-
1227	DE_S	10/23/84	T 2 1D	ARRANGED SCHEDULE	0.1	14	D XP	YN	0
1227	CDE	10/23/84	T 2 OH	ARRANGED SCHEDULE	0.1	17	D XP	Y1	-
1228	CDE	10/23/84	T 2 OH	CALCS & DWGS	0.1	17	D FD	Y1	+
1228	CDD	10/23/84	T 2 1D	CALCULATIONS & DRAWINGS	0.1	15	D FD	DD	+
1229	CDE	10/23/84	W 1 H	SECONDARY PROJECT	2.0	17	D XH	Y1	0
1230	CDE	10/24/84	W 1 T	PLAN FOR DAY	0.9	17	D XP	YL	0
1231	R1_A	10/24/84	M 2 O	GREETING ONLY	0.1	13	D XS	Y1	+
1231	CDE	10/24/84	M 2 A	GREETING ONLY	0.1	17	D XS	Y1	+
1232	SL_A	10/24/84	M 3 R	COAL HYDROGENATION PROJECT	1.8	17	D XH	Y1	-
1232	CDE	10/24/84	M 3 R	COAL HYDROGENATION PROJECT	1.8	17	D XH	Y1	0
1233	R1_A	10/24/84	M 5 C	VALVES & COSTS	2.7	13	D XC	YN	+
1233	R2_A	10/24/84	M 5 C	QUOTE FOR VALVES/CONTROLS	2.7	13	D XC	YN	+
1233	CDE	10/24/84	M 5 C	VALVES & COSTS	2.7	17	D XC	YN	+
1233	SE1_VA	10/24/84	M 5 C	VALVES & COSTS	2.7	15	D XC	YN	+
1233	SE2_VA	10/24/84	M 5 C	VALVES & COSTS	2.7	15	D XC	YN	+
1234	DE_S	10/24/84	M 4 D	OBTAINED DWGS FOR MEETING	0.1	14	D XS	Y1	+
1234	G1_S	10/24/84	M 4 D	COLLECTED DRAWINGS FOR MTG	0.1	8	D XS	O	+
1234	CDE	10/24/84	M 4 D	DWGS FOR MEETING	0.1	17	D XS	Y1	+
1234	CDD	10/24/84	M 4 D	COPIES OF DRAWINGS	0.1	15	D XS	Y1	+
1235	R1_A	10/24/84	M 3 O	VALVE COST ESTIMATE	0.5	13	D XC	YN	+
1235	R2_A	10/24/84	M 3 A	VALVE COST ESTIMATE	0.5	13	D XC	YN	+
1235	CDE	10/24/84	M 3 A	VALVE COST ESTIMATE	0.5	17	D XC	YN	0
1236	DE_S	10/24/84	M 2 D	PAYING SALES ENGRS FOR HELP	0.1	14	D XC	O	-
1236	CDE	10/24/84	M 2 D	PAYMENT OF VALVE COMPANY	0.1	17	D XC	YN	0
1237	SL_A	10/24/84	M 2 O	TERMINATING PROJECT	0.3	17	D XP	YN	-
1237	CDE	10/24/84	M 2 A	TERMINATING PROJECT	0.3	17	D XP	YN	0
1238	DE_S	10/24/84	M 3 D	CDD NOT LEAVING NOW	0.3	14	D XR	YN	+
1238	CDE	10/24/84	M 3 D	CDD NOT NOW LEAVING	0.3	17	D XR	YE	+
1238	CDD	10/24/84	M 3 D	CDD NOT LEAVING NOW	0.3	15	D XR	YN	+
1239	SL_A	10/24/84	M 2 O	CDD STAYING ON	0.1	17	D XR	Y1	+
1239	CDE	10/24/84	M 2 A	CDD STAYING ON	0.1	17	D XR	YE	+
1240	CDE	10/24/84	L 1 OA	CDD STAYING ON	0.2	17	D XR	YE	+
1241	R1_A	10/24/84	N 1 1O	CONTRACT DRAFTSMAN	0.1	13	D XP	YR	0
1242	R2_A	10/24/84	N 1 1L	CONTRACT DRAFTSMAN	0.1	13	D XP	Y1	0
1243	CDE	10/25/84	W 1 O	CLASSIFYING VALVES	2.0	17	D XC	SP	0
1244	CDE	10/26/84	W 1 T	PLAN FOR DAY	0.3	17	D XP	YL	0
1245	DE_S	10/26/84	W 4 D	SCRUBBER DRAWINGS	0.5	14	D FD	O	-

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INT/NO	PERSON	DATE	TYPE/L	TOPIC	HRS	£/H	P/ACT	TQ	M
1245	G1_S	10/26/84	W 4 D	SCRUBBER DRAWINGS	0.5	8	D FD	YH	-
1245	CDE	10/26/84	W 4 D	SCRUBBER DRAWINGS	0.5	17	D FD	DD	-
1245	CDD	10/26/84	W 4 D	SCRUBBER DWGS/CALCULATIONS	0.5	15	D FD	DD	+
1246	G1_S	10/26/84	M 3 D	STORIES ABOUT DE_S	0.3	8	D XS	YH	+
1246	CDE	10/26/84	M 3 D	STORIES ABOUT DE_S	0.3	17	D XS	YH	0
1246	CDD	10/26/84	M 3 D	STORIES ABOUT DE_S	0.3	15	D XS	YH	+
1247	CDE	10/26/84	W 1 D	CHECKING SCRUBBER DWGS	1.1	17	D CD	CD	0
1248	CDD	10/26/84	W 1 D	WRITING UP CALCULATIONS	1.0	15	D PD	YR	0
1249	M_A	10/26/84	M 5 D	PROJECT FUNDING	0.2	22	D XC	YN	-
1249	DE_S	10/26/84	M 5 D	FUNDING FOR GTR	0.2	14	D XC	O	-
1249	G1_S	10/26/84	M 5 D	FUNDING FOR GTR	0.2	8	D XC	O	0
1249	CDE	10/26/84	M 5 D	FUNDING FOR GTR	0.2	17	D XC	YQ	0
1249	CDD	10/26/84	M 5 D	FUNDING FOR GTR	0.2	15	D XC	YN	0
1250	G1_S	10/26/84	M 3 D	CDD EXPERIENCES	0.5	8	D XS	YH	+
1250	CDE	10/26/84	M 3 D	PERSONAL EXPERIENCES	0.5	17	D XS	Y1	+
1250	CDD	10/26/84	M 3 D	PERSONAL EXPERIENCES	0.5	15	D XS	Y1	0
1251	DE_S	10/26/84	M 3 C	EDUCATION ETC - LUNCH	0.5	14	D XS	O	+
1251	CDE	10/26/84	M 3 C	LUNCH/EDUCATION	0.5	17	D XS	Y1	+
1251	CDD	10/26/84	M 3 C	LUNCH - EDUCATION	0.5	15	D XS	Y1	+
1252	CDE	10/26/84	M 2 E	JOB EXPERIENCES	0.7	17	D XS	Y1	+
1252	CDD	10/26/84	M 2 E	JOB EXPERIENCES	0.7	15	D XS	Y1	+
1253	DE_S	10/26/84	W 1 D	READING SUN	0.5	14	D XS	O	+
1254	DE_S	10/26/84	W 1 D	READING SUN	2.0	14	D XS	O	+
1255	CDE	10/26/84	W 1 D	CHECKING SCRUBBER DWGS	2.2	17	D CD	CD	+
1256	CDD	10/26/84	W 1 D	WRITING UP CALCULATIONS	2.3	15	D PD	YR	+
1257	M_A	10/26/84	M 2 O	A-FORM & FUNDING	0.5	22	D XC	YN	-
1257	CDE	10/26/84	M 2 A	A-FORM & FUNDING	0.5	17	D XC	YN	0
1258	CDE	10/31/84	W 1 T	PLAN FOR DAY	0.3	17	D XP	YL	0
1259	ASL_A	10/31/84	M 2 O	GREETING ONLY	0.1	14	D XS	Y1	+
1259	CDE	10/31/84	M 2 A	GREETING ONLY	0.1	17	D XS	Y1	+
1260	R2_A	10/31/84	M 2 L	VALVES COST ESTIMATE	0.1	13	D XC	YC	+
1260	CDE	10/31/84	M 2 L	VALVES COST ESTIMATE	0.1	17	D XC	YR	+
1261	DE_S	10/31/84	M 4 D	GENERAL CHATTER	0.5	14	D XS	YH	+
1261	DR_S	10/31/84	M 4 D	GENERAL CHATTER	0.5	9	D XS	YH	+
1261	G1_S	10/31/84	M 4 D	GENERAL CHATTER	0.5	8	D XS	YH	+
1261	CDE	10/31/84	M 4 D	GENERAL CHATTER	0.5	17	D XS	Y1	0
1262	SL_P	10/31/84	M 2 P	SECONDARY PROJECT	0.1	17	D XH	YQ	+
1262	CDE	10/31/84	M 2 P	SECONDARY PROJECT	0.1	17	D XH	Y1	0
1263	CDE	10/31/84	W 1 D	CHECKING STEELWORK DWGS	1.1	17	D CD	CD	-
1264	DE_S	10/31/84	M 4 D	PHOTOGRAPHY IN D.O.	0.4	14	D XS	YH	+
1264	DR_S	10/31/84	M 4 D	PHOTOGRAPHS IN D.O.	0.4	9	D XS	YH	+
1264	G1_S	10/31/84	M 4 D	PHOTOS IN D.O.	0.4	8	D XS	YH	+
1264	CDE	10/31/84	M 4 D	PHOTOGRAPHS IN D.O.	0.4	17	D XS	YH	+
1265	DE_S	10/31/84	M 2 C	PERSONAL BUSINESS OF DE_S	0.7	14	D XS	YH	+
1265	CDE	10/31/84	M 2 C	LUNCH	0.7	17	D XS	Y1	+
1266	DE_S	10/31/84	M 3 D	CDD BACK FROM DENTIST	0.3	14	D XS	YH	+
1266	CDE	10/31/84	M 3 D	CDD BEEN TO DENTIST	0.3	17	D XS	YH	+
1266	CDD	10/31/84	M 3 D	GREETINGS & STORIES	0.3	15	D XS	YH	+
1267	R1_A	10/31/84	T 2 OO	SALESPERSON COMING	0.1	13	D X1	YN	0
1267	CDE	10/31/84	T 2 1D	SE CONTROLS SALESMAN COMING	0.1	17	D X1	YN	0
1268	CDE	10/31/84	W 1 D	CHECKING STEELWORK DWGS	1.4	17	D CD	CD	+
1269	DE_S	10/31/84	W 3 D	CAPILLARY CELL	1.5	14	D XH	Y1	+

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INT/NO	PERSON	DATE	TYPE/L	TOPIC	HRS	£/H	P/ACT	TQ	M
1269	CDE	10/31/84	W 3 D	CAPILLARY CELL	1.5	17	D XH	YH	+
1269	CDD	10/31/84	W 3 D	CAPILLARY CELL	1.5	15	D XH	YI	0
1270	R1_A	10/31/84	M 4 O	INSTRUMENTATION	1.0	13	D XC	YN	+
1270	R2_A	10/31/84	M 4 A	INSTRUMENTATION	1.0	13	D XC	YN	+
1270	CDE	10/31/84	M 4 A	INSTRUMENTATION	1.0	17	D XC	YN	+
1270	SE_FL	10/31/84	M 4 O	INSTRUMENTATION	1.0	15	D XC	YN	+
1271	M_A	10/31/84	M 2 O	REACTOR PRESSURE/UPDATE	0.3	22	D XR	YR	+
1271	CDE	10/31/84	M 2 A	REACTOR PRESSURE/UPDATE	0.3	17	D XR	YR	0
1272	SL_A	10/31/84	M 2 O	WEEKLY REPORTS & PROJECT	0.4	17	D XR	YR	0
1272	CDE	10/31/84	M 2 A	WEEKLY REPORTS / PROJECT	0.4	17	D XR	YR	0
1273	AM_A	11/08/84	L 1 OO	WEEKLY REPORT WORDING	1.5	19	D XR	YR	+
1274	CDE	11/08/84	W 1 O	REPORT GTR-5	5.0	17	D XR	YR	0
1275	CDE	11/09/84	W 1 T	PLAN FOR DAY	0.2	17	D XP	YL	0
1276	ASL_A	11/09/84	M 3 O	GENERAL CHAT	0.4	14	D XS	YI	+
1276	R1_A	11/09/84	M 3 N	GENERAL CHAT	0.4	13	D XS	YI	+
1276	CDE	11/09/84	M 3 A	GENERAL CHAT	0.4	17	D XS	YI	0
1277	DE_S	11/09/84	W 3 D	CAPILLARY CELL	2.0	14	D XH	YQ	+
1277	CDE	11/09/84	W 3 D	CAPILLARY CELL-SECONDARYPROJ	2.0	17	D XH	YI	+
1277	CDD	11/09/84	W 3 D	CAPILLARY CELL	2.0	15	D XH	YI	0
1278	GI_S	11/09/84	M 2 D	PHOTO OF GI_S	0.1	8	D XS	YH	+
1278	CDE	11/09/84	M 2 D	PHOTO OF GI_S	0.1	17	D XS	YH	+
1279	DE_S	11/09/84	M 3 C	PERSONAL LIFE OF DE_S	0.5	14	D XS	YH	+
1279	CDE	11/09/84	M 3 D	PERSONAL LIFE OF DE_S	0.5	17	D XS	YH	+
1279	CDD	11/09/84	M 3 C	LUNCH/ DE_S PRIVATE WORK	0.5	15	D XS	YI	+
1280	CDE	11/09/84	W 1 D	BLANK SPECIFICATION SHEETS	1.0	17	D XH	YI	+
1281	DE_S	11/09/84	M 4 A	CAPILLARY CELL	1.5	14	D XH	0	-
1281	CDE	11/09/84	M 4 A	CAPILLARY CELL SPECIFICATION	1.5	17	D XH	YQ	0
1281	CDD	11/09/84	M 4 A	SPECIFICATION FOR CAP. CELL	1.5	15	D XH	YI	+
1282	DE_S	11/09/84	W 3 D	CAPILLARY CELL	1.8	14	D XH	0	-
1282	CDE	11/09/84	W 3 D	CAPILLARY CELL SPECIFICATION	1.8	17	D XH	YI	+
1282	CDD	11/09/84	W 3 D	TIDYING UP CAP. CELL SPEC.	1.8	15	D XH	YI	+
1283	CDE	11/09/84	L 1 OA	WEEKLY REPORTS	0.2	17	D XR	YR	0
1284	SL_A	11/09/84	L 1 IO	WEEKLY REPORTS	0.1	17	D XR	YR	0
1285	AM_A	11/09/84	M 2 O	WEEKLY REPORTS & FUNDING	0.2	19	D XR	YR	0
1285	CDE	11/09/84	M 2 A	WEEKLY REPORTS/FUNDING	0.2	17	D XR	YR	0
1286	CDE	11/12/84	L 1 IO	WEEKLY REPORT WORDING	0.3	17	D XR	YR	0
1287	CDE	11/12/84	W 1 H	REPORT GTR-5	5.0	17	D XR	YR	0
1288	CDE	11/13/84	W 1 O	REPORT GTR-5	9.0	17	D XR	YR	+
1289	AM_A	11/13/84	L 1 OO	D.O. & POOR PROGRESS	0.3	19	D XP	YI	-
1290	CDE	11/14/84	W 1 T	PLAN FOR DAY	0.9	17	D XP	YL	0
1291	M_A	11/14/84	L 1 IO	WEEKLY REPORTS FROM CDE	0.3	22	D XR	YR	0
1292	M_S	11/14/84	L 1 IO	CDE WEEKLY REPORTS	0.3	22	D XR	0	-
1293	SL_A	11/14/84	L 1 IO	WEEKLY REPORTS	0.1	17	D XR	YR	0
1294	DE_S	11/14/84	W 3 D	CAPILLARY CELL	0.2	14	D XH	YI	-
1294	CDE	11/14/84	W 3 D	CAPILLARY CELL GASKETS	0.2	17	D XH	YI	+
1294	CDD	11/14/84	W 3 D	KALREZ GASKETS	0.2	15	D XH	YI	+
1295	CDE	11/14/84	W 1 B	CHECKING STEELWORK DWGS	3.0	17	D CD	CD	+
1296	CDE	11/14/84	W 2 B	PAHL & BEITZ METHOD	0.8	17	D XS	YI	+
1296	CDD	11/14/84	W 2 B	PAHL & BEITZ METHOD	0.8	15	D XS	YE	+
1297	AD2_R	11/14/84	M 3 B	PROJECT PROGRESS	0.5	23	D XC	YN	+
1297	CDE	11/14/84	M 3 B	DWGS & FUNDING	0.5	17	D XC	YN	+
1297	CDD	11/14/84	M 3 B	DRAWINGS & FUNDING	0.5	15	D XC	YN	+

GTR PROJECT INTERCHANGES BY DATE AND NUMBER

INT/NO	PERSON	DATE	TYPE/L	TOPIC	HRS	£/H	P/ACT	TQ	M
1298	DE_S	11/14/84	M 5 D	GENERAL TOPICS	0.3	14	D XS	YI	-
1298	DR_S	11/14/84	M 5 D	GENERAL TOPICS	0.3	9	D XS	0	+
1298	GI_S	11/14/84	M 5 D	GENERAL CHAT	0.3	8	D XS	YE	+
1298	CDE	11/14/84	M 5 D	GENERAL CHAT	0.3	17	D XS	YI	+
1298	CDD	11/14/84	M 5 D	GENERAL CHAT	0.3	15	D XS	YI	+
1299	SL_A	11/14/84	M 2 O	PROJECT STATUS	1.4	17	D XR	YR	+
1299	CDE	11/14/84	M 2 A	PROJECT STATUS	1.4	17	D XR	YR	-
1300	SL_P	11/19/84	T 2 OO	COAL PERM. RIG	0.4	17	D XH	YQ	+
1300	CDE	11/19/84	T 2 IO	COAL PERM RIG SPEC	0.4	17	D XH	YI	+
1301	CDE	11/20/84	W 1 O	REPORT GTR-5	3.0	17	D XR	YR	+
1302	CDE	11/21/84	W 1 T	PLAN FOR DAY	0.9	17	D XP	YL	0
1303	SL_P	11/21/84	W 2 O	COAL PERMEABILITY RIG	4.0	17	D XH	YI	0
1303	CDE	11/21/84	W 2 A	COAL PERM RIG SPEC	4.0	17	D XH	YE	+
1304	DR_S	11/21/84	M 4 D	PAHL & BEITZ/DESIGN APPROACH	1.0	9	D XS	YE	+
1304	GI_S	11/21/84	M 4 D	PAHL & BEITZ/DESIGN	1.0	8	D XS	YH	+
1304	CDE	11/21/84	M 4 D	PAHL & BEITZ PROCEDURES	1.0	17	D XS	YE	+
1304	CDD	11/21/84	M 4 D	PAHL & BEITZ / DESIGN	1.0	15	D XS	YI	+
1305	CDE	11/21/84	L 1 OA	PROJECT UPDATE	0.1	17	D XR	YR	0
1306	AM_A	11/21/84	N 1 IO	UPDATE	0.1	19	D XR	YR	0
1307	AD1_R	11/21/84	M 2 P	GREETING IN CORRIDOR	0.1	23	D XS	YI	+
1307	CDE	11/21/84	M 2 P	GREETING IN CORRIDOR	0.1	17	D XS	YI	+
1308	AD2_R	11/21/84	M 2 B	PROJECT/DRWG. OFFICE/GENERAL	0.5	23	D XR	YR	-
1308	CDE	11/21/84	M 2 B	GTR/D.O./GENERAL	0.5	17	D XR	YR	+
1309	CDE	11/27/84	W 1 O	GTR-5/WEEKLY REPORTS	6.0	17	D XR	YR	0
1310	CDE	11/28/84	W 1 T	PLAN FOR DAY	0.9	17	D XP	YL	0
1311	ASL_A	11/28/84	M 3 O	VALVE QUOTE & GENERAL	0.3	14	D XC	0	+
1311	R1_A	11/28/84	M 3 N	VALVE QUOTE	0.3	13	D XC	YN	+
1311	CDE	11/28/84	M 3 A	VALVE QUOTE	0.3	17	D XC	YN	0
1312	SL_A	11/28/84	M 2 O	REPORT GTR-5	1.5	17	D XR	YR	0
1312	CDE	11/28/84	M 2 A	REPORT GTR-5	1.5	17	D XR	YR	0
1313	CDE	11/28/84	L 1 OA	REPORT GTR-5	0.2	17	D XR	YR	0
1314	AM_A	11/28/84	N 1 IO	REPORT GTR-5	0.6	19	D XR	YR	0
1315	CDE	11/28/84	W 1 D	COPIES OF PAPERS	0.5	17	D XI	YI	0
1316	AM_S	11/28/84	M 2 O	DESIGN PROGRESS	0.3	19	D XR	YR	-
1316	CDE	11/28/84	M 2 A	DESIGN PROGRESS	0.3	17	D XR	YQ	-
1317	CDE	11/28/84	M 2 C	LUNCH/AM_S & DE_S	0.3	17	D XS	YI	+
1317	CDD	11/28/84	M 2 C	INTERACTION BETWN. AM_S+DE_S	0.3	15	D XS	YI	+
1318	SL_P	11/28/84	M 2 P	COAL PERMEABILITY RIG	0.2	17	D XH	YR	+
1318	CDE	11/28/84	M 2 P	COAL PERMEABILITY RIG	0.2	17	D XH	YE	+
1319	R2_A	11/28/84	M 2 L	VALVE QUOTE/TECH INFO	0.2	13	D XI	YN	0
1319	CDE	11/28/84	M 2 L	VALVE QUOTE/TECH INFO	0.2	17	D XI	YN	0
1320	R1_A	11/28/84	M 3 O	CONAX FITTING	1.3	13	D XI	YI	+
1320	CDE	11/28/84	M 3 A	CONAX FITTINGS	1.3	17	D XI	YI	+
1321	DE_S	11/28/84	M 6 D	HOLIDAY FLATS/CHICKEN FARMS	1.5	14	D XS	YH	+
1321	DR_S	11/28/84	M 6 D	HOLIDAY FLATS/CHICKEN FARMS	1.5	9	D XS	YH	+
1321	GI_S	11/28/84	M 6 D	HOLIDAY FLATS/CHICKEN FARM	1.5	8	D XS	YH	+
1321	CDE	11/28/84	M 6 D	HOLIDAYS/CHICKEN FARMS	1.5	17	D XS	YH	+
1321	CDD	11/28/84	M 6 D	HOLIDAY FLATS/CHICKEN FARM	1.5	15	D XS	YH	+
1322	CDE	11/28/84	M 2 B	PAHL & BEITZ/GTR	0.2	17	D XR	YE	+
1323	AM_S	11/28/84	M 3 O	CHAT	0.1	19	D XS	YI	+
1323	BPO_S	11/28/84	M 3 O	GOODBYE ONLY	0.1	14	D XS	YI	+
1323	CDE	11/28/84	M 3 A	GOODBYE FOR DAY	0.1	17	D XS	YI	+

GTR PROJECT INTERCHANGES BY DATE AND NUMBER

INT/NO	PERSON	DATE	TYPE/L	TOPIC	HRS	£/H	P/ACT	TQ	M
1324	AM_A	11/28/84	M 2	O PROJECT WON'T GO AHEAD	0.4	19	D XP	YN	-
1324	CDE	11/28/84	M 2	A END OF PROJECT COMING	0.4	17	D XP	YN	-
1325	CDE	11/29/84	L 1	OO MODIFIED WEEKLY REPORTS	0.7	17	D XR	YR	0
1326	AM_A	11/30/84	L 1	IO MODIFIED WEEKLY REPORTS	0.3	19	D XR	YR	0
1327	SL_A	11/30/84	L 1	IO REVISED WEEKLY REPORTS	0.1	17	D XR	YR	0
1328	M_A	12/06/84	M 3	A DRAWING OFFICE PERFORMANCE	0.8	22	D XP	0	-
1328	M_S	12/06/84	M 3	O DRAWING OFFICE	0.8	22	D XP	YN	0
1328	AM_S	12/06/84	M 3	O DRAWING OFFICE	0.8	19	D XP	YQ	0
1329	CDE	12/06/84	W 1	T PLAN FOR DAY	0.4	17	D XP	YL	0
1330	DE_S	12/06/84	M 4	D GREETINGS ONLY	0.2	14	D XS	0	-
1330	DR_S	12/06/84	M 4	D GREETINGS	0.2	9	D XS	YH	+
1330	CDE	12/06/84	M 4	D GREETINGS ONLY	0.2	17	D XS	YH	+
1330	CDD	12/06/84	M 4	D GREETINGS	0.2	15	D XS	YI	-
1331	AM_A	12/06/84	M 2	O GENERAL REVIEW & PLANNING	1.5	19	D XR	YR	+
1331	CDE	12/06/84	M 2	A GENERAL REVIEW/PLANNING	1.5	17	D XR	YR	0
1332	DR_S	12/06/84	M 3	D BANTER & STORIES	0.2	9	D XS	YH	-
1332	CDE	12/06/84	M 3	D BANTER & STORIES	0.2	17	D XS	YH	+
1332	CDD	12/06/84	M 3	D D.O. STORIES	0.2	15	D XS	YH	-
1333	DE_S	12/06/84	M 4	D PROBLEMS & STORIES	0.2	14	D XS	0	-
1333	DR_S	12/06/84	M 4	D PROBLEMS IN D.O.	0.2	9	D XS	YI	-
1333	CDE	12/06/84	M 4	D PROBLEMS IN D.O.	0.2	17	D XS	YH	+
1333	CDD	12/06/84	M 4	D PROBLEMS IN D.O.	0.2	15	D XS	YI	-
1334	BPO_S	12/06/84	M 2	P BPO_S NEEDS DWG - COAL STORE	0.2	14	D FD	DD	+
1334	CDE	12/06/84	M 2	P DWGS OF COAL STORE	0.2	17	D FD	DD	0
1335	CDE	12/06/84	W 2	A SECONDARY PROJECT	0.8	17	D XH	YI	0
1336	AM_A	12/06/84	M 2	O BUILDINGS PROJECT OFFICER	0.2	19	D FD	DD	-
1336	CDE	12/06/84	M 2	A BPO_S REQUEST	0.2	17	D FD	DD	0
1337	CDE	12/07/84	W 1	O REPORT GTR-5	1.0	17	D XR	YR	0
1338	BPO_S	12/10/84	T 2	IO SPECIFIC DWG NEEDS	0.2	14	D FD	DD	+
1338	CDE	12/10/84	T 2	OO SPECIFIC DWG NEEDS FOR BPO_S	0.2	17	D FD	DD	0
1339	CDE	12/13/84	W 1	T PLAN FOR DAY	0.4	17	D XP	YL	0
1340	R2_A	12/13/84	M 2	L REPORT GTR-5	0.1	13	D XR	YR	0
1340	CDE	12/13/84	M 2	L REPORT GTR-5	0.1	17	D XR	YR	0
1341	R1_A	12/13/84	M 2	O REPORT GTR-5	0.2	13	D XR	YR	+
1341	CDE	12/13/84	M 2	A REPORT GTR-5	0.2	17	D XR	YR	0
1342	SL_A	12/13/84	M 2	A LAST CDE VISIT DATE	0.1	17	D XP	0	0
1342	CDE	12/13/84	M 2	A LAST CDE VISIT DATE	0.1	17	D XP	0	0
1343	AM_A	12/13/84	M 2	O REPORTS & UPDATE	0.2	19	D XR	YR	0
1343	CDE	12/13/84	M 2	A REPORTS & UPDATE	0.2	17	D XR	YR	0
1344	M_A	12/13/84	M 2	O GTR-5 REPORT	0.1	22	D XR	YQ	+
1344	CDE	12/13/84	M 2	A REPORT GTR-5	0.1	17	D XR	YR	+
1345	M_S	12/13/84	M 2	O GTR-5 REPORT & GOODBYE	0.2	22	D XR	YR	+
1345	CDE	12/13/84	M 2	A REPORT GTR-5 & GOODBYE	0.2	17	D XR	YR	+
1346	DE_S	12/13/84	M 2	D GTR-5 & LAST DAY PLAN	0.1	14	D XR	0	0
1346	CDE	12/13/84	M 2	D GTR-5 & CDE LAST VISIT	0.1	17	D XR	YR	+
1347	SO_S	12/13/84	M 2	O CDE WANTED BPO_S	0.1	14	D FD	0	+
1347	CDE	12/13/84	M 2	A BPO_S OUTSIDE ON NEW SITE	0.1	17	D FD	0	+
1348	DE_S	12/13/84	M 3	D INTRODUCTION TO OTHER SALES	0.2	14	D XI	0	+
1348	CDE	12/13/84	M 3	D HOKE VALVES	0.2	17	D XI	YP	+
1348	SE_FL	12/13/84	M 3	D HOKE VALVES	0.2	15	D XI	YP	+
1349	R1_A	12/13/84	M 2	N USE OFFICE AS BASE	0.1	13	D XS	YH	+
1349	CDE	12/13/84	M 2	A USE R1_A OFFICE AS BASE	0.1	17	D XS	YI	+

GTR PROJECT INTERCHANGES BY DATE AND NUMBER

INT/NO	PERSON	DATE	TYPE/L	TOPIC	HRS	£/H	P/ACT	TQ	M
1350	BPO_S	12/13/84	M 2	E CDE DELIVERED DWG	0.1	14	D FD	DD	+
1350	CDE	12/13/84	M 2	E DWG TO BPO_S	0.1	17	D FD	DD	+
1351	SL_P	12/13/84	M 2	P HIGH PRESSURE PLASTOMETER	0.1	17	D XH	YQ	+
1351	CDE	12/13/84	M 2	P HIGH PRESSURE PLASTOMETER	0.1	17	D XH	YI	+
1352	R2_A	12/13/84	M 2	L REPORT GTR-5	0.3	13	D XR	YR	+
1352	CDE	12/13/84	M 2	L REPORT GTR-5	0.3	17	D XR	YR	+
1353	DE_S	12/17/84	T 2	ID PROGRESS ON DRAWINGS	0.0	14	D XR	0	0
1353	CDE	12/17/84	T 2	OO PROGRESS ON DWGS	0.1	17	D XR	YQ	-
1354	CDE	12/17/84	T 2	OO DWG PRINTS/CALCS	0.2	17	D PD	DD	+
1354	CDD	12/17/84	T 2	ID PRINTS OF DWGS/ CALCULATIONS	0.2	15	D PD	DD	+
1355	DR_S	12/17/84	W 1	D ARRANGING DOR DWG PRINTS	1.0	9	D PD	DD	+
1356	CDE	12/19/84	W 1	T PLAN FOR DAY	0.9	17	D XP	YL	0
1357	R2_A	12/19/84	M 2	L TECHNICAL INFORMATION	0.1	13	D XI	YF	0
1357	CDE	12/19/84	M 2	L TECHNICAL INFO	0.1	17	D XI	YF	+
1358	CDE	12/19/84	W 2	A SECONDARY PROJECT	1.0	17	D XH	YI	0
1359	ASL_A	12/19/84	M 3	O PROBLEMS ON GTR	0.3	14	D XS	YI	-
1359	R1_A	12/19/84	M 3	N SELF-PERCEPTION INVENTORY	0.3	13	D XS	YI	-
1359	CDE	12/19/84	M 3	A SELF PERCEPTION INVENTORY	0.3	17	D XS	YI	+
1360	SL_P	12/19/84	W 2	O HIGH PRESSURE PLASTOMETER	2.0	17	D XH	YR	0
1360	CDE	12/19/84	W 2	A HIGH PRESSURE PLASTOMETER	2.0	17	D XH	YI	0
1361	DR_S	12/19/84	W 2	D PRINTS & CALC. COPIES	0.6	9	D PD	DD	+
1361	CDE	12/19/84	W 2	D PRINTS & CALCS COPIES	0.6	17	D PD	DD	+
1362	CDD	12/19/84	N 1	OD FINAL NOTES	0.1	15	D PD	YR	+
1363	CDE	12/19/84	L 1	ID FINAL NOTES	0.1	17	D PD	YL	+
1364	DE_S	12/19/84	T 2	IH HEALTH OF DE_S	0.2	14	D XS	0	-
1364	CDE	12/19/84	T 2	OD DE_S IN HOSPITAL	0.2	17	D XS	YI	0
1365	CDE	12/19/84	W 1	D COPIES OF CALCS	0.5	17	D PD	YS	0
1366	AM_A	12/19/84	M 3	N WEEKLY REPORTS	0.1	19	D XR	YR	-
1366	SL_A	12/19/84	M 3	A WEEKLY REPORTS	0.1	17	D XR	YR	-
1366	CDE	12/19/84	M 3	A WEEKLY REPORTS	0.1	17	D XR	YR	0
1367	M_A	12/19/84	M 2	O ARRANGE TIME TO MEET	0.1	22	D XP	0	-
1367	CDE	12/19/84	M 2	A ARRANGE TIME TO MEET	0.1	17	D XP	0	0
1368	CDE	12/19/84	W 1	D FINISHED & TIDIED	0.5	17	D PD	YI	0
1369	AM_S	12/19/84	M 2	O GOODBYE FOR NOW	0.1	19	D XS	YI	+
1369	CDE	12/19/84	M 2	A GOODBYE FOR NOW	0.1	17	D XS	YI	+
1370	M_A	12/19/84	M 2	O REVIEW GTR PROJECT	0.5	22	D XR	YR	+
1370	CDE	12/19/84	M 2	A REVIEW GTR PROJECT	0.5	17	D XR	YR	+
1371	SL_A	12/19/84	M 2	O FINAL MEETING	0.2	17	D XR	YI	0
1371	CDE	12/19/84	M 2	A FINAL SL_A MEETING	0.2	17	D XR	YR	0
1372	R1_A	12/19/84	M 3	L GOODBYE	0.2	13	D XS	YR	+
1372	R2_A	12/19/84	M 3	L GOODBYE	0.2	13	D XS	YR	+
1372	CDE	12/19/84	M 3	L GOODBYE FOR NOW	0.2	17	D XS	YR	+
1373	AM_A	12/19/84	M 2	O PROJECT WRAP-UP	0.2	19	D XR	YR	+
1373	CDE	12/19/84	M 2	A PROJECT WRAP-UP	0.2	17	D XR	YR	+

APPENDIX A.2

GASIFIER TEST RIG PROJECT - CASE HISTORY

A.2.1 BACKGROUND

Task

Of the projects available at the time, the one which best fulfilled the research requirements happened to involve the design of test equipment in one research division of a large corporation. It was not considered an ideal setting for the participant observation field study, as it would not result in a product for sale in a competitive market, but it did have the following features which were considered to be important advantages:

(i) A relatively complex and 'ill-defined' engineering design problem;

(ii) A design team involving different groups and levels in the Company;

(iii) A project schedule which closely matched that of the research;

(iv) A willingness on the part of the Company to support the research.

The task was to design, then to construct and commission, a high-pressure high-temperature materials test rig. Although the main needs for the rig had been identified, it was seen as having several possible uses and the requirements were thus 'ill-defined'. No design specification existed. The research staff had previously been discussing how to improve the effectiveness of in-house equipment design work (confidential report) and were keen to try a new approach. A problem in the past, for example, had been in the communications between research staff (who specify and use the equipment) and the service section staff (who design and construct it). A series of rigs had been constructed and operated by the same project team, so that this project was seen as another in a progressing sequence, but as this rig would involve the difficult problem of handling flowing coal at temperature and pressure the design task was considered to be high in 'novelty'. It was also considered to be high in 'complexity', as the rig would necessarily consist of a central 'reactor' together with a series of sub-systems including: an electronic control system; a pressurized coal feed system; a gas feed system; a gas scrubber; a tar separator; and a solids-removal system. Approval times at each phase in the design process were anticipated to be lengthy, allowing more time for the field research.

Team

The core project team initially included two Managers; one Section Leader; two Research Scientists; one Design Engineer; and the participant observer as a Contract Design Engineer. As was normal practice on such projects no person was assigned to it full-time; everyone had other responsibilities, including the contract design engineer. It was agreed at the beginning that the project team should be flexible and that specialist help would be called on as required. In particular, a control system design engineer would be needed during the Embodiment Design phase, and a detail designer during the Detail Design phase. Although everyone in the team had been involved with previous similar projects this one was larger and more complex than others designed 'in-house'. It was felt that the project could perhaps serve as a 'model' for future projects.

Procedure

One thing stressed by the project team during initial meetings was that they had no structured approach to the design of special purpose equipment and were keen to develop one. The interest was in an integrated procedure rather than in merely the application of certain techniques. This fitted in with the objectives of the field research, as a more structured design approach would provide a framework for gathering and analysing the data. Several possibilities were considered and the German approach of Pahl and Beitz (B47), which was being translated into English at the time [Wallace (B68 and B48)], was chosen for the following reasons:

(i) The procedures are described in sufficient detail for direct use by team members unfamiliar with the use of design procedures.

(ii) Work follows a clearly defined course and the procedural steps could be used for categorizing and analysing the field research data.

A decision was taken to structure the project according to the Pahl and Beitz approach, hold to it as closely as appropriate, but not be confined solely to its use. Techniques drawn from other sources would be applied where appropriate.

Participant Observer

The project team's interest was in the test rig, not in the research, but there was willingness to allow the collection of observational data by the researcher, subject to the Company's usual confidentiality agreement and mutual understanding on personal issues. Credibility of the researcher as a design engineer from the Company's viewpoint had developed from a visit by a research scientist to Chicago (U.S.A.) two years previously, where he had seen a number of high-pressure high-temperature materials test systems in operation [for example see Hales, Bhattacharyya, and Lamoureux (A17)]. It was this visit which later prompted the offer of a project with full research funding, and which enabled problems associated with participant observation to be readily overcome. Although the participant observer lacked experience in field research there were compensating advantages:

(i) Ten years professional engineering design experience;

(ii) Management experience on design of similar equipment;

(iii) Familiarity with coal gasification terminology and problems;

(iv) Previous contact with project sponsor.

Field Data

Detailed notes were made on all aspects of the project. A working routine was quickly established involving a minimum of one visit a week to the Company, with weekly reports covering progress on both the project and the research (See Appendix A.3). Full project progress reports (Appendix A.3) were submitted every six months (with copies of the weekly reports in the appendices). This set of 6 reports provided a compact and fully detailed record of the 116 weeks of the design project, together with the research. Before each visit to the Company a work plan for the day was written, then what actually happened was recorded as it happened and more detailed notes were written after the day's work. Personal design work was done in a hard-bound notebook while observational field notes were recorded in an identical notebook alongside. 76 hours of audio tape-recordings were made (specific events and typical design work sessions), and a total of 1180 pages of field notes were accumulated. When the project started there was little guidance on what to record and what to omit. It was decided to record as much as possible and from as many viewpoints as possible, making sure that for each event or 'interchange' (Appendix C) the date, topic, time and place was noted.

A.2.2 PROJECT SUMMARY

Initial Proposal

On 18 May 1982 a project proposal was submitted to the Company, outlining the design approach together with a cost estimate for the combined design and research work. The project plan covered the three-year period from October 1982 to October 1985. This proposal was accepted on 2 August 1982 subject to the following conditions:

(i) No guarantee that management approvals could be timed as shown on the provisional plan.

(ii) No guarantee that construction would be approved in time for completion to the provisional plan.

(iii) No guarantee of dedicated technician support for construction.

A contract was drawn up, and the design effort started on 1 October 1982.

Project Brief

(i) To provide the Company with a permanent high pressure test facility primarily capable of simulating particular slagging coal gasifier environments on a laboratory scale, but readily adaptable to other types of test programme in the future.

(ii) To commission the equipment and initiate long-term materials tests under specified high pressure, high temperature conditions, subject to funding approval.

(iii) To improve the 'in-house' design approach for special-purpose test equipment by introduction of more formal design procedures.

Design Task

(i) Design a high pressure test rig system to meet the project brief.

(ii) Introduce and follow the design steps summarized in Appendix D.3.

(iii) Follow the schedule through detail design then through construction and commissioning subject to funding approval.

Clarification of the Task (See Appendix A.3, Report GTR-1)

A simple project organization was set up as shown in Figure A-1 (Figures follow the text) and this provided a flexible working structure which was adequate for all phases of the project. The Pahl and Beitz questioning checklist was used to help formulate the technical design problem, and a list of 'Demands and Wishes' from those associated with the project was used to compile the design specification for the rig. This twenty-page document comprehensively covered the test rig design, construction and operation. It provided requirements and criteria for the selection and evaluation of conceptual solutions to the design problem. Three copies of the specification were circulated for review and modification by a set date. Against each of the 308 specified requirements the contributor's name was recorded, together with the date of any changes made, as shown on the sample sheet in Figure A-2. At a project meeting on 13 January 1983, three months into the project and on schedule, each item was reviewed and the design specification finalized.

There were two changes made at a later date:

(i) The design pressure was increased from 100 Bar (1500 psig) to 170 Bar (2500 psig).

(ii) The design temperature was increased from 1100°C to 1300°C.

The final design and operating conditions are listed below:

Design Pressure	: 170 Bar (2500 psig) max.
Initial Working Range	: 23-85 Bar (350-1250 psig)
Design Temperature	: 1300°C max.
Nominal Operating Range	: 500-1050°C
Design Life	: 10 years
Test Time per Run	: 1000 hours continuous
Equipment Operation	: 7 days/week
Automatic Control	: 24 hours/day
Safety Levels	: Warning; Alarm; Shutdown
Solids Feedrate	: 1 Kg/hour approx.
Gas Flowrate	: 60 SCF/hour approx.

Conceptual Design (See Appendix A.3, Report GTR-2)

The overall function of the test rig was diagrammatically represented and broken down by sub-function as shown in Figure A-3, then further by sub-sub-function as recommended by Pahl and Beitz. This was done by the participant observer, in conjunction with others on certain of the sub-functions. Most of the sub-systems could be designed using equipment that was commercially available, but the reactor vessel assembly had to be custom designed. Five intuitive concepts evolved for this, two of which are shown in Figure A-4 and the others in Appendix A.3, but at the same time the Pahl and Beitz method for generating solutions then selecting and combining them was applied. A series of 8 matrices gave a large number of possible solutions which were reduced by systematic selection and combination to the four final matrices shown in Figure A-5. Selection charts as shown in Figure A-6 were used to decide on the most appropriate solutions, leaving three viable concepts. These matched three of the five intuitive concepts. By general agreement the best features of each were combined into a single practicable reactor concept as shown in Figure A-7. Its modular nature was considered to be important as this would allow various internal configurations to be tried, if necessary, without any changes to the pressure vessel or its control systems.

Budget price quotations for the reactor vessel, its internal components and the coal feed system were obtained for a first cost estimate which was compiled on standard sheets as shown in Figure A-8. This was itemized by sub-system and the total including reserves according to confidence level amounted to £102,505.00, excluding site assembly and commissioning. The final concept and cost estimate was presented to the project manager on 25 April 1983, just over 6 months into the project and close to schedule. A draft application for construction approval was then submitted.

<u>Embodiment Design</u> (See Appendix A.3, Reports GTR-3 and GTR-5)

Up to 3 June 1983 the project had progressed close to the agreed schedule, but three obstacles then arose:

(i) Participant observer was hospitalized with a serious illness;
(ii) First-year research report and examination (participant observer);
(iii) A cost justification was required for the construction phase of the project and the draft application for approval needed many changes.

The first two of these curtailed the participant observer's input to the project for more than a month, and the application for project approval was not processed during this time as a debate had arisen in the Company over the perceived value of the materials test programme itself. This was a matter to be resolved by research scientists, managers and directors in various parts of the Company, rather than by the design team. Finally a revised application was drafted by the contract design engineer with input from research staff and this was submitted to the project management on 2 August 1983. The problems during these three months considerably delayed the embodiment design work. Once the application for project approval had been resubmitted, work was concentrated on design of the reactor assembly.

The concept was reviewed and then developed based on comments received; preliminary calculations for the pressure vessel and gas kinetics were carried out, and each sub-system was examined with reference to the Pahl and Beitz checklist for embodiment design. Careful note was taken of the recommended guidelines for 'clarity', 'simplicity' and 'safety'.

A schematic of the proposed test rig system is shown in Figure A-9 and the system is briefly described below:
A purpose-built dense phase conveying system (A) feeds fine-graded coal to lock hopper (B) from which it is augered, under dry nitrogen conditions, into the top of reactor vessel (C). The coal passes through the reaction chamber and is removed by a second auger at the bottom. Discharged solids pass into water-filled holding vessel (D) and are periodically removed through double-valve system (E). A hot mixture of gases and steam is fed in at the bottom of the reaction chamber to produce the gas composition required at the level of the specimens in the coal bed. After separation from the vapourised tars within the chamber, the gas exits at the top of the vessel. Then, after a second stage tar removal, the gases are passed to the scrubbing system (F) before exhausting safely to atmosphere, or are recirculated through gas filter (G) to mixing vessel (H), depending on the operating conditions. Fresh gases are continuously metered into mixing vessel (H) and the resultant composition is monitored by gas chromatograph (I). The gas mixture is pressurized by Haskel pump (J) in a buffer vessel from which it passes to a heating coil within the reactor vessel. Water (with ammonia) is also pumped through a heating coil within the vessel, to provide the required steam component. Control system (K) monitors certain parameters according to set points, making automatic adjustments. Manual monitoring is avoided under normal conditions, apart from daily checks. Each sub-system is essentially a stand-alone unit which "plugs-in" to the reactor vessel, providing a versatile system with possibilities for using the same units in various different configurations. The complete system is arranged to suit a standard cubicle (3 m x 6 m floor area) within a new test rig facility building.

The developed reactor assembly concept is shown in Figure A-10, and the following is a brief description of the main features:

Overall height of the assembly is 2 metres with a weight of over 5 tonnes. The double-studded, trunnion-mounted pressure vessel (F), with Grayloc (or equivalent) closures, is pressurised with nitrogen and packed with fibrous insulation (H). Internal reaction chamber (G), welded to the intermediate cap (C), contains both the coal bed, forced slowly downwards according to the removal rate set by the speed of auger (L), and the hot gas mixture, fed in through nozzles (K) to pass upwards through the coal. The internal diameter of reaction chamber (G) is 127mm (5 inches). A pressure balance is maintained across this reaction chamber wall, with automatic control of the differential. Heating is by four sets of independently-controlled electrical heating elements (I), which not only maintain the correct coal temperature at the level of test specimens (J) but also heat the incoming gases and control the tar vapour temperature. Test specimens (J) are interlocked to the hollow, central driveshaft, which itself forms part of the removeable cartridge mounted on vessel flange (A). The specimen shaft also drives a replaceable stirrer in the lower coal bed, and the contra-rotating auger may be driven either by means of a central shaft from above as shown in the figure, or else by means of an independent shaft and drive from below. Drive from above allows easy maintenance but complicates the cartridge; drive from below requires a novel shaft seal and complicates maintenance but allows more complete instrumentation on the specimens.
Coal is intermittently augered into the top of the reaction chamber under dry nitrogen conditions, while annular piston (B) is held in its upper position as shown. As the coal bed moves downwards piston (B) descends, exerting a predetermined load on the coal bed, and on reaching the end of its stroke it is retracted upwards to allow more coal to be fed in.

An important added feature in the developed concept is cylindrical shield (D) which forms an annular reservoir at its lower end, and a vapour space above in which strings of corrosion test coupons (E) may be hung. By use of external valving the pressure in this region is depressed, causing gas and tar vapour to be drawn up. A water-cooled coil around shield (D) then condenses the heavier tars, which trickle down the shield into the warmer annular reservoir so that they may be periodically drawn off as a liquid through a heated dip tube. Likewise gases are drawn off through a heated tube from the top of the vapour space. By monitoring the products exiting through the two tubes, and adjusting the temperature of the top furnace element zone accordingly, a suitable operating balance may be maintained for removal of liquids and gases.

Safety was of prime importance. The developed concept allows easy access to the vessel for maintenance, which enhances safety, and has inherently stable operating characteristics. There is no internal combustion, and all heated components are contained within a cold wall pressure vessel. Full pressure and temperature safety controls are incorporated.

At this stage two formal project presentations were made; the first was to Senior Management on 21 December 1983, and the second was to project staff and any other people interested, on 9 February 1984. Considerable debate followed the presentations and in summary the issues could be divided into two groups. Firstly, there were doubts as to how easily the rig could be made to work, and secondly were questions as to whether the cost of such a rig was justifiable for the proposed materials testing programme. Doubts raised about the operability of the rig were of a detail design nature but the cost issues were more fundamental, involving different opinions as to what materials research data would be needed for the future and how best to obtain it. The management decision on whether to continue or terminate the project was not easy, with strong external influences (from management outside the research division) against continuation, balanced by a project team pressing for continuation. Company policy and politics entered the debate and in the end no definite decision was made except that the detail design work should continue. The application for construction approval prepared in 1983 was never fully processed but authorization was given for design of the control system and possibly a hazard analysis to be carried out. Work proceeded within these constraints, but with a certain loss in momentum at all levels. A formal job number was assigned to the project within a group of other projects.

It became evident to the research staff, from the comments made, that the test rig would have wider applicability if both the design temperature and pressure were higher, so on 7 March 1983 the Section Leader increased the design pressure from 100 Bar (1500 psig) to 170 Bar (2500 psig) maximum and the design temperature from 1100°C to 1300°C. It was realized that the design problems and the cost of equipment such as valves and pressure vessels would be greatly increased by this, but the researchers considered it worthwhile if justification for construction of the test rig could be enhanced. No other design specification changes were made. The plan was for work to continue at the Company, with the contract design engineer concentrating on the reactor vessel design, and a contract (or staff) detail designer recruited for detailing the ancillary equipment. Help from the suppliers would be sought in designing equipment such as the coal supply system, and the control system would be done under contract by a qualified specialist. It was agreed in February that if a detail designer could be recruited promptly, the manufacturing drawings could be completed by the end of August 1983, even though the work would have to take low priority in the design office until such time as the project was approved for construction. A schedule was drawn up as a general guide but it was understood that without formal project approval this could not be binding.

<u>Control System Design</u> (See Appendix A.3, Report GTR-4)

Conceptual and embodiment design of the control system was undertaken as a separate task, in parallel with other detail design work. A contract was negotiated with the engineer who designed the control system for the high-pressure equipment described by Bhattacharyya, Hales and Lamoureux (A17) and arrangements were made for him to work for three weeks on the task. This was planned as an intensive work period, with one week of preparation in Chicago followed by two weeks of work in Britain as shown in Figure A-11. The contract design engineer and controls engineer planned to work closely together, calling in specialist and user help where needed, and the approach was regarded as an experiment from several viewpoints:

- o Researcher - observing a rapid 'project-within-a-project';
- o Company - tailoring the team and the approach to the task;
- o Controls Engineer - working in a different country and culture;
- o Chicago Company - employee gaining experience in another country;
- o Project Team - working with an experienced controls engineer.

The design task requirements and an information package were prepared by the contract design engineer and airmailed to Chicago on 16 April 1984. Controls were needed to monitor the test rig system in operation, record data for off-line analysis and safely maintain the required temperatures, pressures and flowrates. Response to out-of-limit conditions was required on three levels, with audio alarms, visual alarms, controlled shutdown modes and an emergency shutdown mode. To facilitate changes in test rig function at low cost, a modular and expandable control system was needed.

As shown in Figure A-12 a programmable controller operates solenoid valves and motors according to sensor inputs, initiates and supervises controlled shutdowns, monitors the controls and powers panel displays. Temperatures, reactor pressure differential and gas mixing are maintained by independant controllers. Each of the modular control cabinet panels, shown assembled in Figure A-13, was detailed together with the sensor function and process data charts needed for a hazard analysis (for samples see Appendix A.3). The work was completed to cost and schedule, with considerable involvement of Company staff during the middle week to ensure that the controls would match user requirements. A valve manufacturing company also provided expertise, their sales engineers checking requirements for each of the 150 valves and other items, as the Process and Instrumentation (P & I) diagram was finalized (too large for inclusion in this Appendix). On the last day of the three-week period (25 May, 1986) a 2-hour design review meeting was held at the Company, attended by the management staff, research staff, services staff and a safety officer. Report GTR-4, intended for use as a control system design specification, was issued, discussed and approved.

<u>Detail Design</u> (See Appendix A.3, Reports GTR-5 and GTR-6)

Although the control system design work had been completed according to plan, the detail design work on other sub-systems was severely hampered by lack of a detail designer. Response to the Company's advertisements was poor and it took until 23 July 1984 for a suitable person to be recruited. By then the following work had been carried out (for sample calulations, diagrams and meeting minutes, see Appendix A.3):

- (i) Dense-phase coal feeding system layout and pricing completed;
- (ii) Gas system schematic prepared;
- (iii) Gas, tar and solids removal systems developed (see Figure A-14);
- (iv) Control system specified, ready for detailed bids;
- (v) Pressure vessel calculations completed according to BS5500;
- (vi) Reactor vessel detail drawings partially completed;
- (vii) Safety and quality assurance issues resolved;
- (viii) Agreement negotiated on cubicle space and general system layout;

(ix) Preliminary test rig layout completed;

(x) Comprehensive set of product information accumulated and filed;

(xi) Review of the prevailing design and draughting practice completed;

(xii) Meetings held at manager and director level regarding the review.

As no management decision had been taken regarding test rig construction, the project's priority rating remained low even after the contract detail designer had started work on the detail drawings. The original project schedule and the plan for detail design both had to be abandoned, and for the remainder of the project the progress was contingent on other demands. By 31 December 1984, the following further work had been completed:

(i) Detail drawings and calculations for scrubber (see Figure A-15);

(ii) Detail drawings and calculations for reactor vessel support-frame;

(iii) Detail drawings and calculations for the working platform;

(iv) Crane runway details (partially completed);

(v) Materials selected for inner reactor chamber (see Figure A-16);

(vi) Scale layout of complete test rig system as shown in Figure A-17;

(vii) Product information files transferred to the Company;

(viii) 'Task-team' approach planned for construction and commissioning;

(ix) Design assistance provided on four other Company projects.

Early in 1985 a Company decision was taken to postpone construction of the test rig, confirmed by letter dated 4 March 1985. This decision stemmed from a change in overall Company research priorities, which had reduced research effort and funding in areas relevant to the use of the test rig. The project team had been aware that an imminent Company policy change had been a factor in the management indecision over the future of the project during the previous year, and steps had been taken so that the project could be wound up with the detail design sufficiently completed for easy re-activation at a later date. This was one reason why such emphasis had been put on detailed recording of the design work in the project reports. The winding up of the project included the following work:

(i) Completion of Report GTR-6;

(ii) Correction of faults on completed detail drawings;

(iii) Completion of certain further detail drawings;

(iv) Sketches for the solids collection and tar removal system;

(v) Arranging storage responsibilities for the project records.

GASIFIER TEST RIG

PROJECT ORGANIZATION November 1982

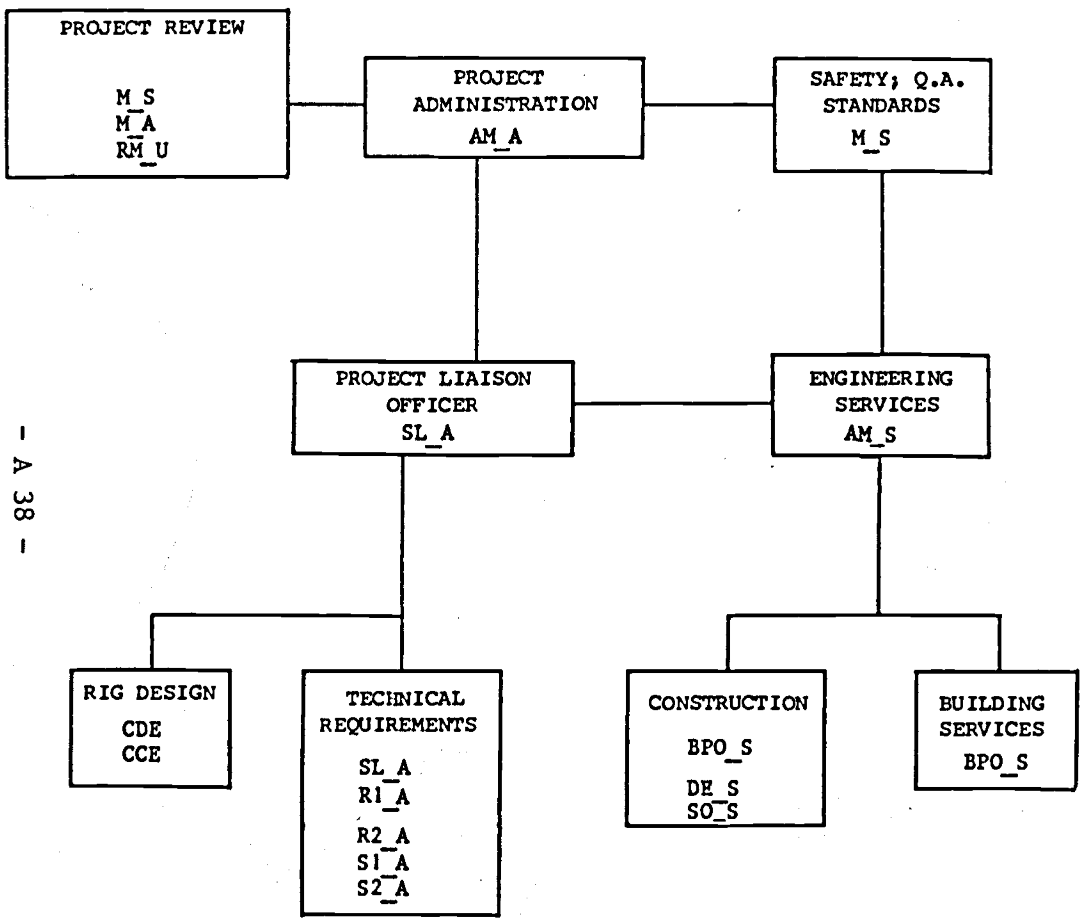


Figure A-1 Project Organization Chart (above)

Figure A-2 Sample Sheet from Design Specification (right)

COMPANY	SPECIFICATION : GASIFIER TEST RIG		ISSUED : 17/12/82 SHEET : 5 OF 20
CHANGES	**D W**	**REQUIREMENTS : ENERGY**	**RESPONSIBLE**
		TEMPERATURE :	
	D	Coal 300°C to 650°C	SL-A
	D	Don't preheat coal above 150°C	SL-A
	W	Coal 200°C to 900°C	SL-A
	D	Gas 500°C to 900°C	SL-A
	W	Gas 500°C to 1150°C	SL-A
13/1/83	W	Temperature set tolerance ± 15°C for specimen ± 5°C for materials	SL-A/ S1-A
		HEATING :	
	D	Controlled heating of ancillary vessels	SL-A
	D	Coal in reactor test section to be at uniform temp.	SL-A
13/1/83	D.	Very high preheating of input steam or O_2 to be considered (eg 900°C)	SL-A
29/12/82	D	Total heating requirements (gas/electricity) to be calculated and Services Division to be informed.	BPO-S
13/1/83	D	Heat balance for laboratory cubicle required (max 28°C)	CDE
	W.	Preheat gas and coal to suitable levels	CDE
13/1/83	W	Use waste heat to heat ancillary vessels.	DE-S
		COOLING :	
23/1/82	D	Samples to be quenched for safety in handling, depending on temperature	R2-A
	W	Means for quenching coal samples	S1-A
	W	Vessel walls kept uniformly cool for straingauging	SL-A
12/1/83	W	Efficient use of waste heat to be considered	AM-A
13/1/83	W	Dry quench with liquid nitrogen	S1-A
13/1/83	W	3rd gas (eg CO_2) to be considered for temperature control	SL-A

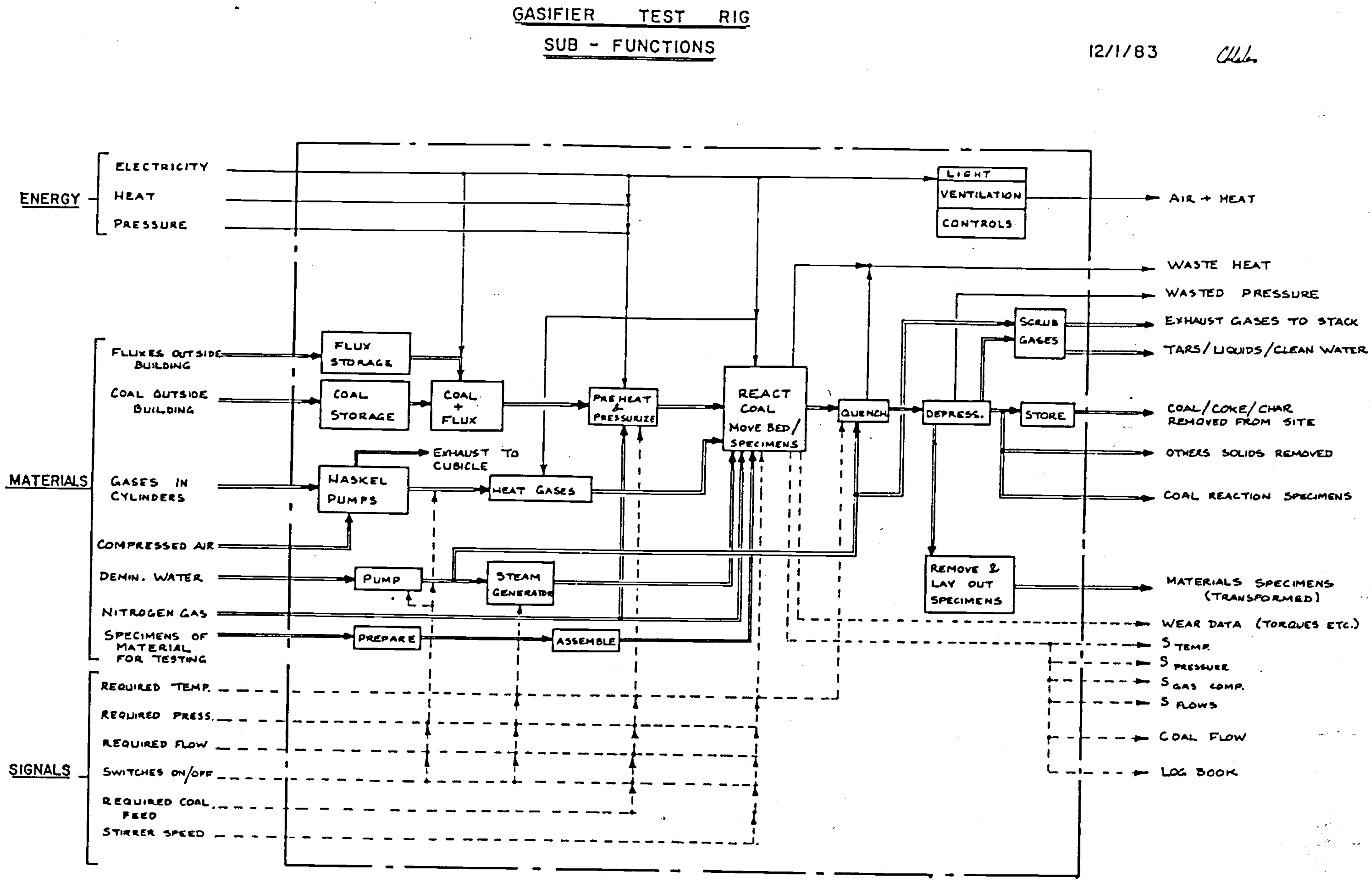


Figure A-3 Sub-Functions for Gasifier Test Rig System

- A 39 -

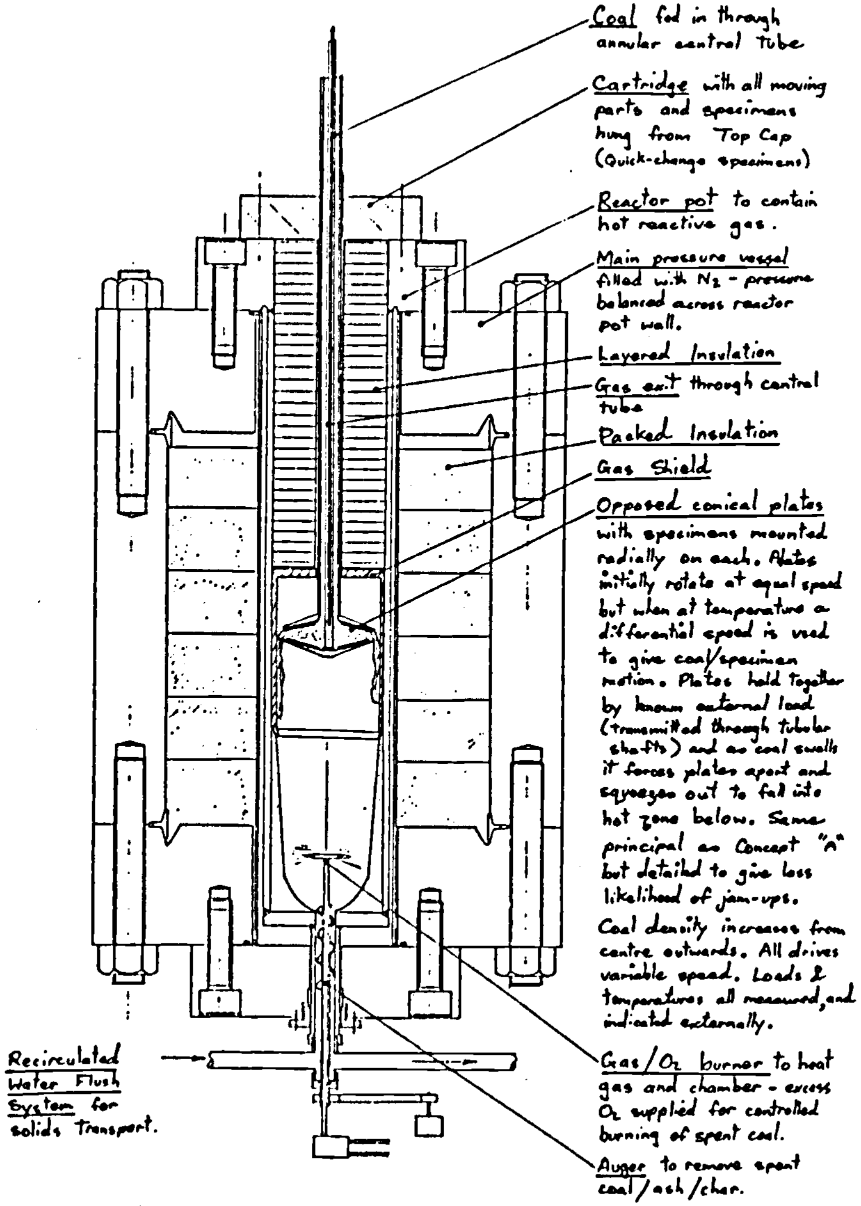


Figure A-4 (a) Centrifugal Concept

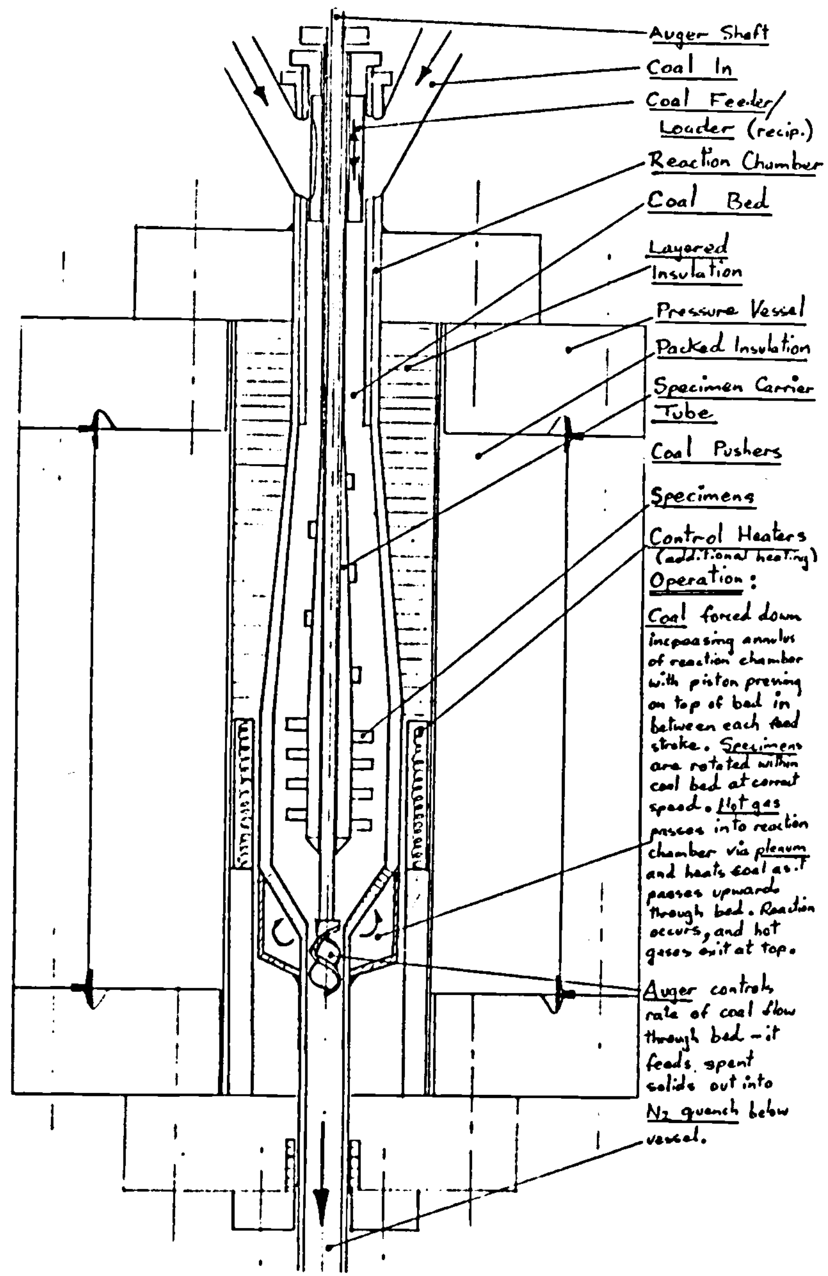
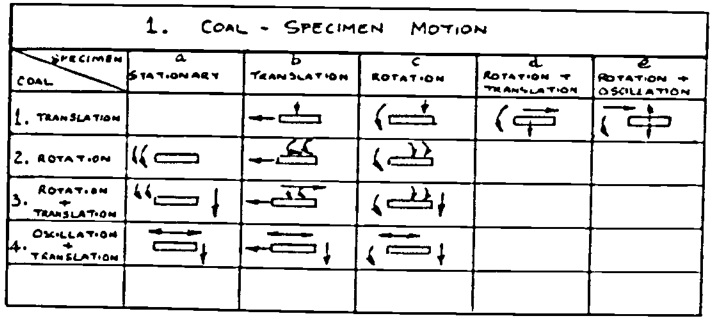


Figure A-4 (b) Fixed Bed Concept



2. FEEDING COAL + 5. METERING COAL					
ENERGY / PRINCIPLE	a (2+5) MECHANICAL	b (2) PNEUMATIC	c (2+5) HYDRAULIC	d (5) ELECTRICAL	e (5) OPTICAL
1.	AUGER/SCREW	ENTRAINED FLOW (AIR OR N)	COAL/OIL/ WATER SLURRY	TIME FLOW	TRANSPARENT PIPE + T.V. MONITOR
2.	RAM (RECIP. VALVE)			COUNT PARTICLES	
3.	METERING ROTARY VALVE				
4.	DOUBLE VALVE (LOCKHOPPER)				
5.	PELLETISING				

3. HEATING GAS + 4. HEATING COAL					
ENERGY / PRINCIPLE	a (3+4) ELECTRICAL	b (3+4) CHEMICAL	c (4) OTHER		
1.	WIRE ELEMENTS	BURN GAS (PASS THRU')	STEAM STEAM / O_2		
2.	FLUIDISED (CARBON) BED	BURN COAL (PASS GAS OVER)			
3.		BURN OIL IN COAL (PASS GAS OVER)			

6. ACCEPT COAL SWELLING (ANTI-JAMMING) + 7. LOAD COAL TO SIMULATE BED DEPTH					
ENERGY / PRINCIPLE	a (6+7) MECHANICAL	b (6+7 CENTRIFUGAL	c (6+7) PNEUMATIC	d (6+7) HYDRAULIC	
1.	(6) MAKE STRONGER	WHIRL COAL + POS. DISPL.	CYLINDER	CYLINDER	
2.	WEIGHT ON TOP				
3.	SPRING				
4.	PISTON				

Figure A-5 Four Final Combined Matrices

CAMBRIDGE UNIVERSITY	SELECTION CHART for COAL / SPECIMEN MOTION	Sheet: 1 of 4

Enter solution variant (Sv)

Solution variants (Sv) evaluated by: SELECTION CRITERIA
(+) yes
(-) no
(?) Lack of information
(!) Check specification

A: Compatible with overall task ?
B: Fulfil demands of specification ?
C: Realisable in principle ?
D: Expect permissable expenditure ?
E: Incorporate direct safety measures?
F: Preferred by designer company?
G:

DECISION
Mark solution variants:-
(+) Pursue solution
(-) Eliminate solution
(?) Collect information
(!) Check specification for changes.

SOLUTION VARIANT Sv		A	B	C	D	E	F	G	Remarks	Decision
a 2	1	+	+	−	−	−	?		C: How to replace coal? D: Expensive Drive	−
a 3	2	+	+	+	−	?	?		D: Complicated	?
a 4	3	+	−	+	−	−	−		B: Not true simulation of stirrer	−
b 1	4	+	?	?	?	?	−		B: May not simulate stirrer action C: Seals	−
b 2	5	+	+	−	?	?	?		C: How to replace coal? D: Complicated Seals	−
b 3	6	+	+	+	?	+	?		D: Complicated	?
b 4	7	+	−	+	−	?	−		B: Not true simulation, D: Complicated	−
c 1	8	+	+	+	+	?	+		This is motion as in gasifier	+
c 2	9	+	+	−	?	?	?		C: How to replace Coal?	−
c 3	10	+	+	+	?	?	?		D: Complicated	?
c 4	11	+	+	+	?	?	?		D: Complicated	−
d 1	12	+	+	+	+	?	?		Good − advantage over C1	+
e 1	13	+	+	?	?	?	?		C: Complicated	−
	14									
	15									
	16									
	17									
	18									
	19									
	20									
	21									
	22									
	23									

Date: 14/3/83	Initials: [illegible]	

Figure A-6 Sample Concept Selection Chart

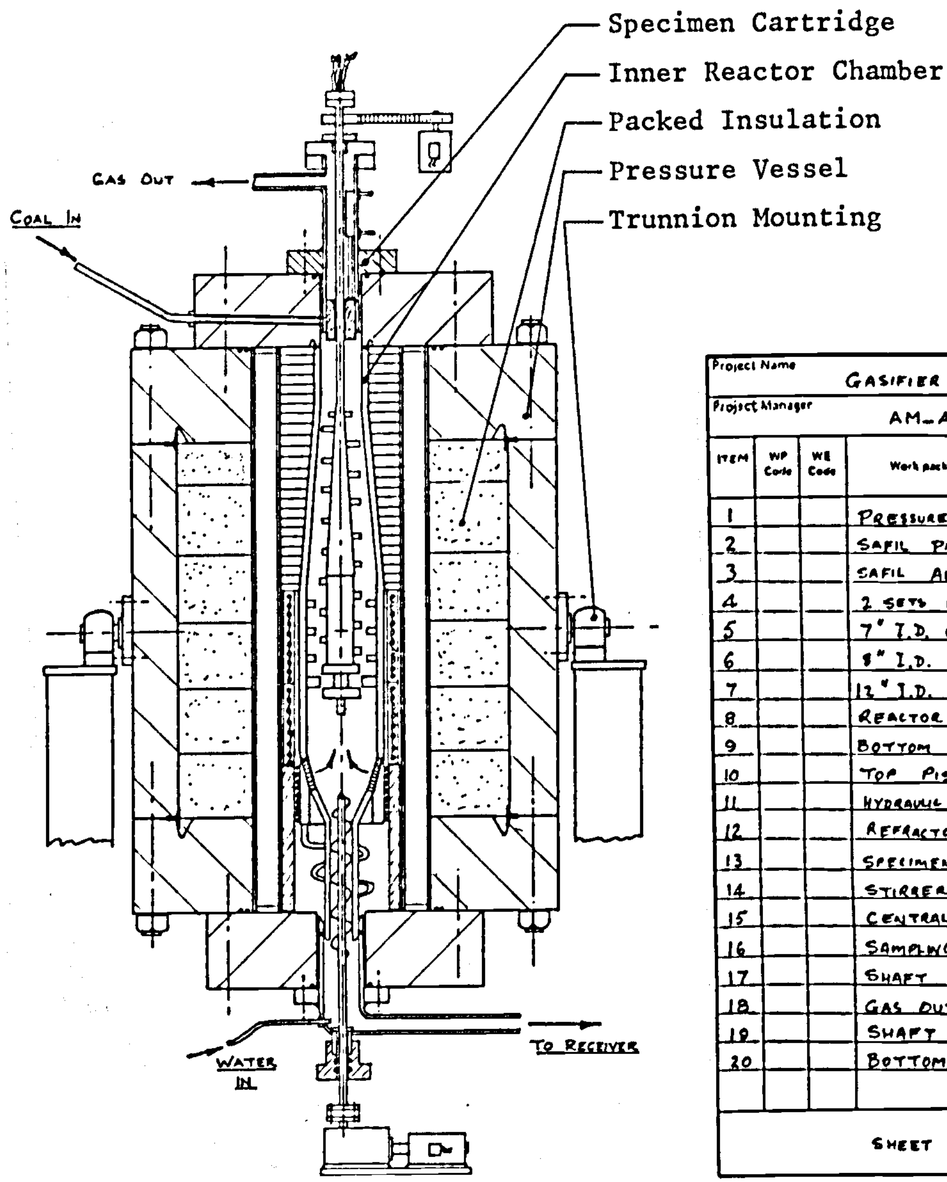


Figure A-7 Final Reactor Concept

COST CONTROL

PROJECT COST ESTIMATE DETAIL SHEET

Project Name: GASIFIER TEST RIG	Project Code:	Phase: CONSTRUCTION	Sub-System: REACTOR VESSEL	Sheet: 1 of 9
Project Manager: AM_A	Department:	Division:		Estimate prepared as at: 22/4/83

ITEM	WP Code	WE Code	Work package / element description	Labour Hours: Management	Labour Hours: Eng./Sci.	Labour Hours: Tech.	Purchased Materials/ Equipment	Contractor Estimate	Reserves: Specific	Reserves: General	Work Package: Dept./Div.	Work Package: Remarks
1			PRESSURE VESSEL COMPLETE				18,400		2,000			
2			SAFIL PACKED INSULATION				300					
3			SAFIL ALUMINA PAPER				100					
4			2 SETS RING ELEMENTS				200		50			
5			7" I.D. CERAMIC TUBE				50					
6			8" I.D. SHIELD TUBE				400					
7			12" I.D. SHIELD TUBE				600					
8			REACTOR TUBE ASSEMBLY				3,000		500			
9			BOTTOM AUGER				400					
10			TOP PISTON				50					
11			HYDRAULIC ACTUATING CYL.				480					
12			REFRACTORY LINING				100					
13			SPECIMEN SHAFT				500					
14			STIRRER BLADES				200					
15			CENTRAL TUBE				100					
16			SAMPLING TUBE / AUGER				100					
17			SHAFT BRGS. / SEALS				200					
18			GAS OUTLET PIPE ASSY.				630					
19			SHAFT DRIVE				600					
20			BOTTOM OUTLET PIPE ASSY.				200					
			SHEET SUB-TOTALS				26,640		2,550			

Figure A-8 Sample Cost Estimate Sheet

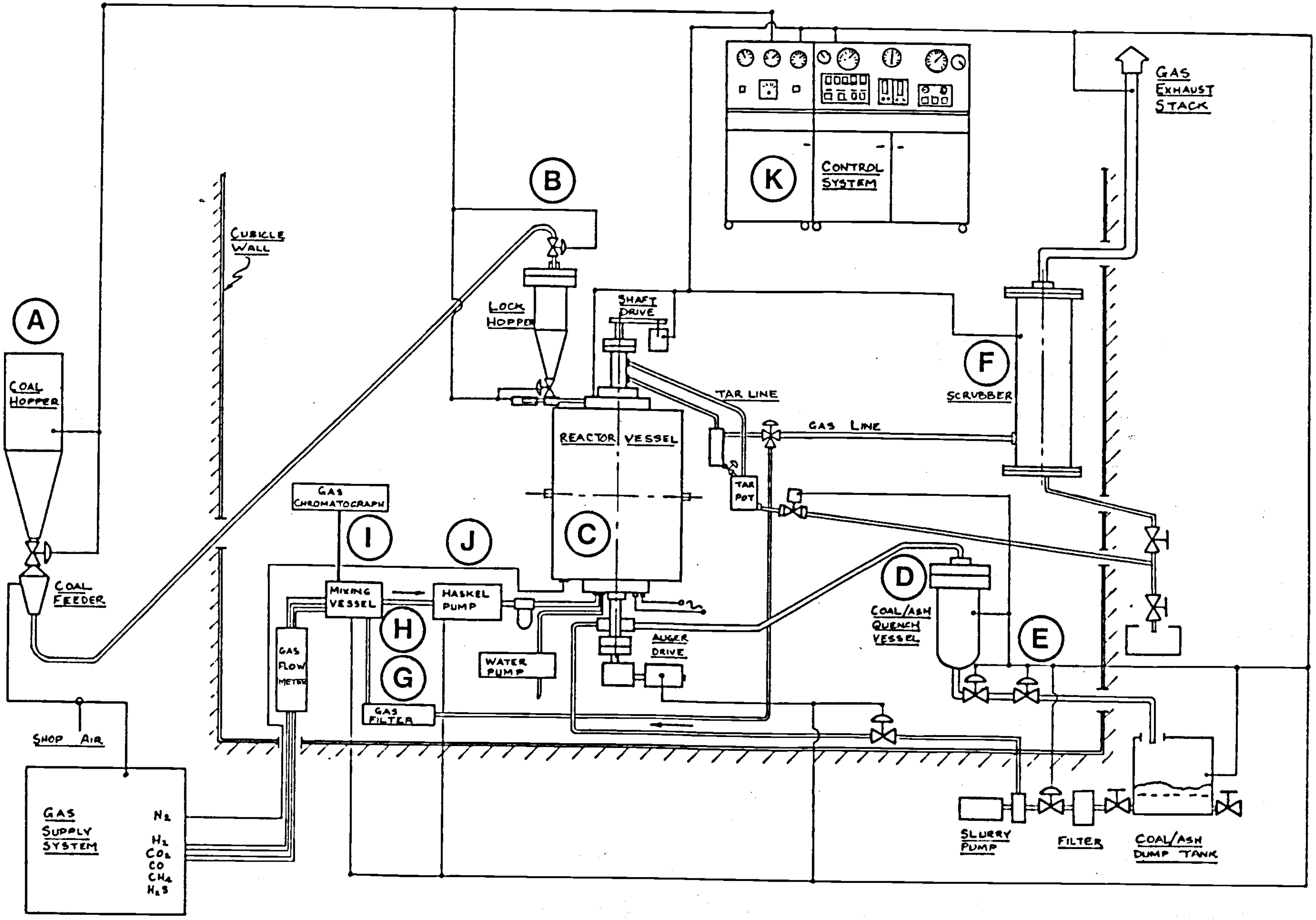


Figure A-9 Gasifier Test Rig System Schematic

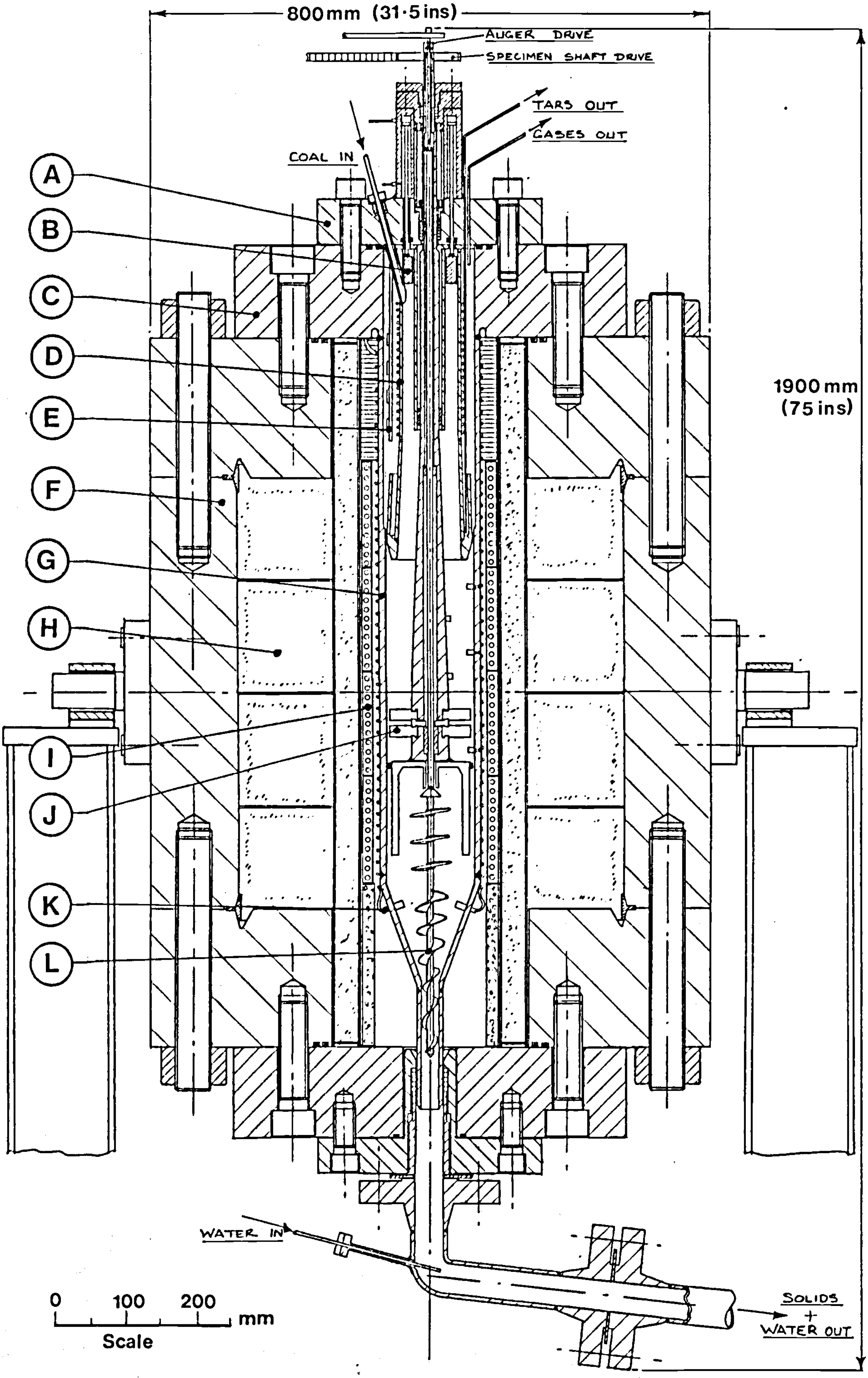


Figure A-10 Developed Reactor Concept

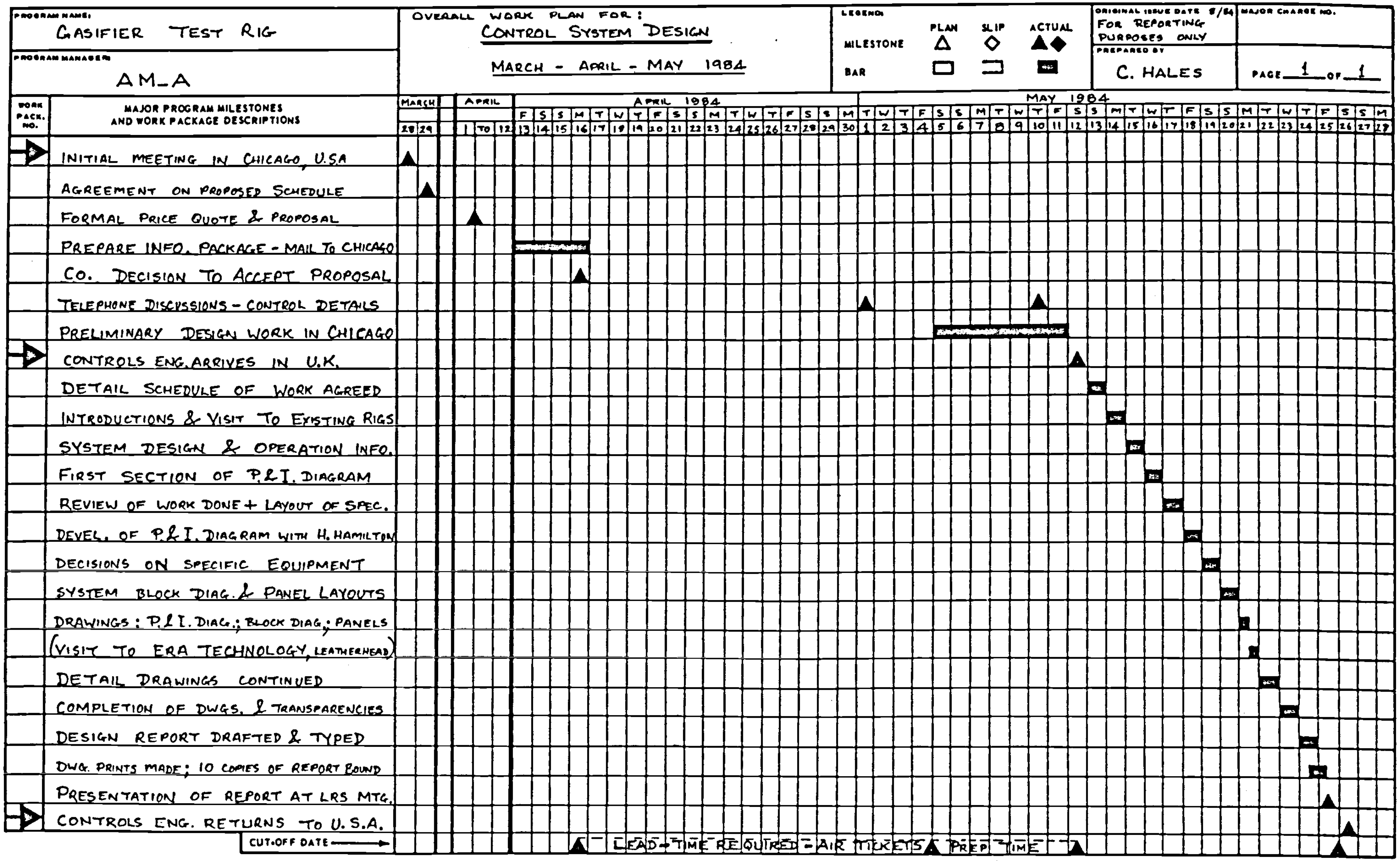


Figure A-11 Schedule for Design of Control System

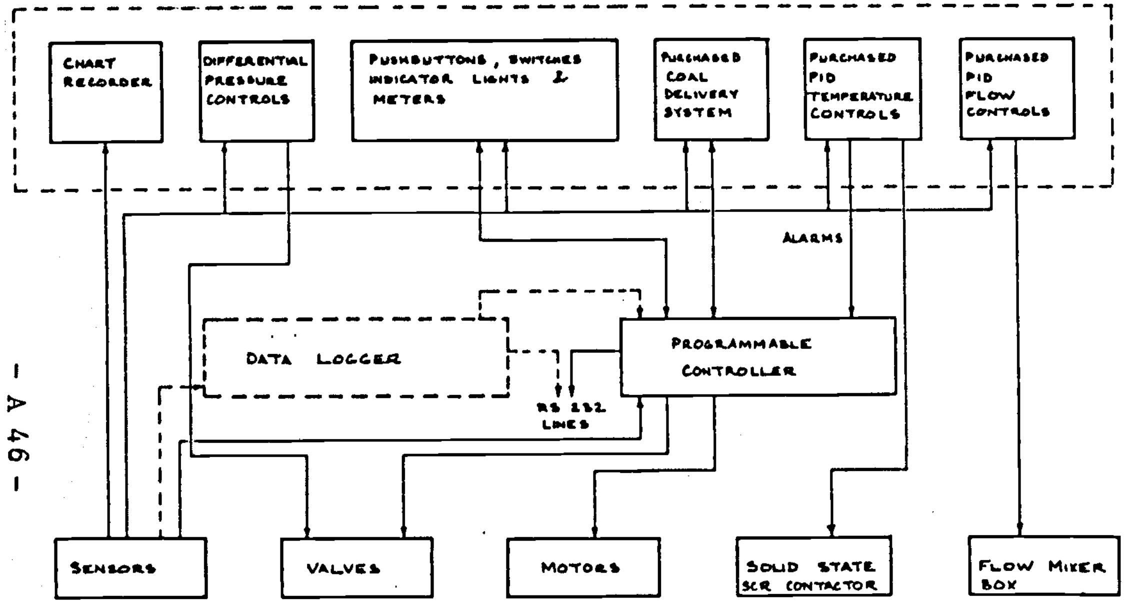


Figure A-12 Block Diagram of Control System

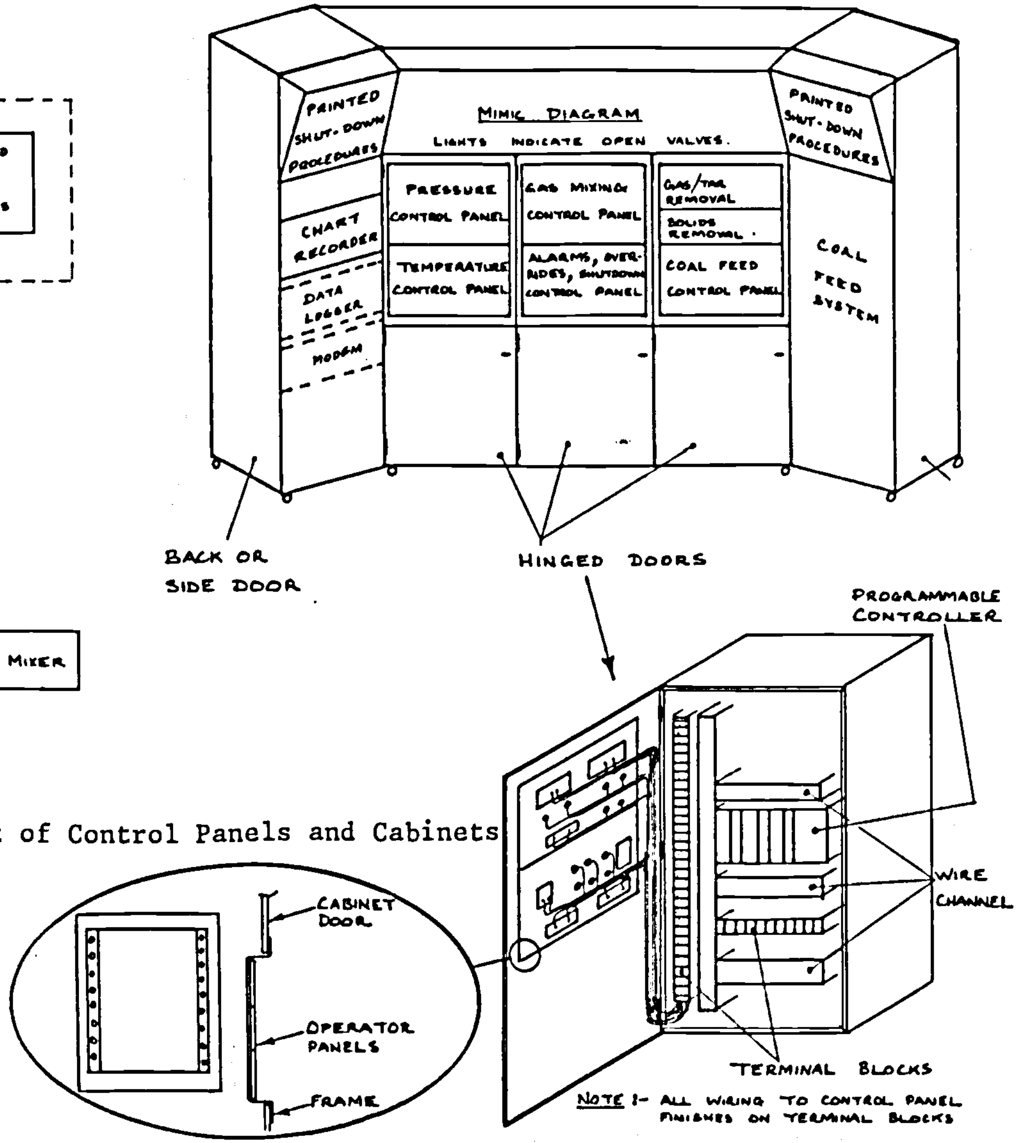


Figure A-13 Overall Layout of Control Panels and Cabinets

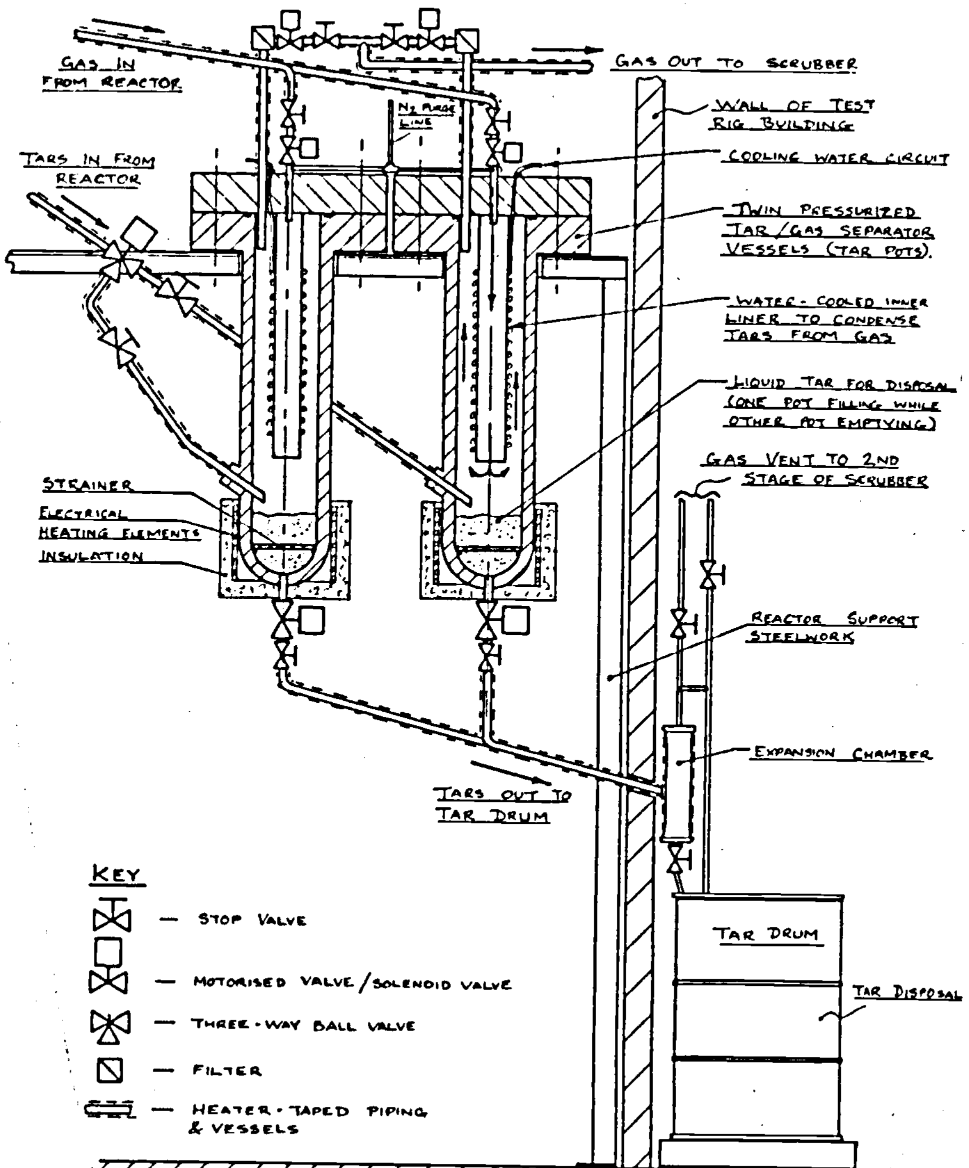


Figure A-14 (a) Tar Removal System

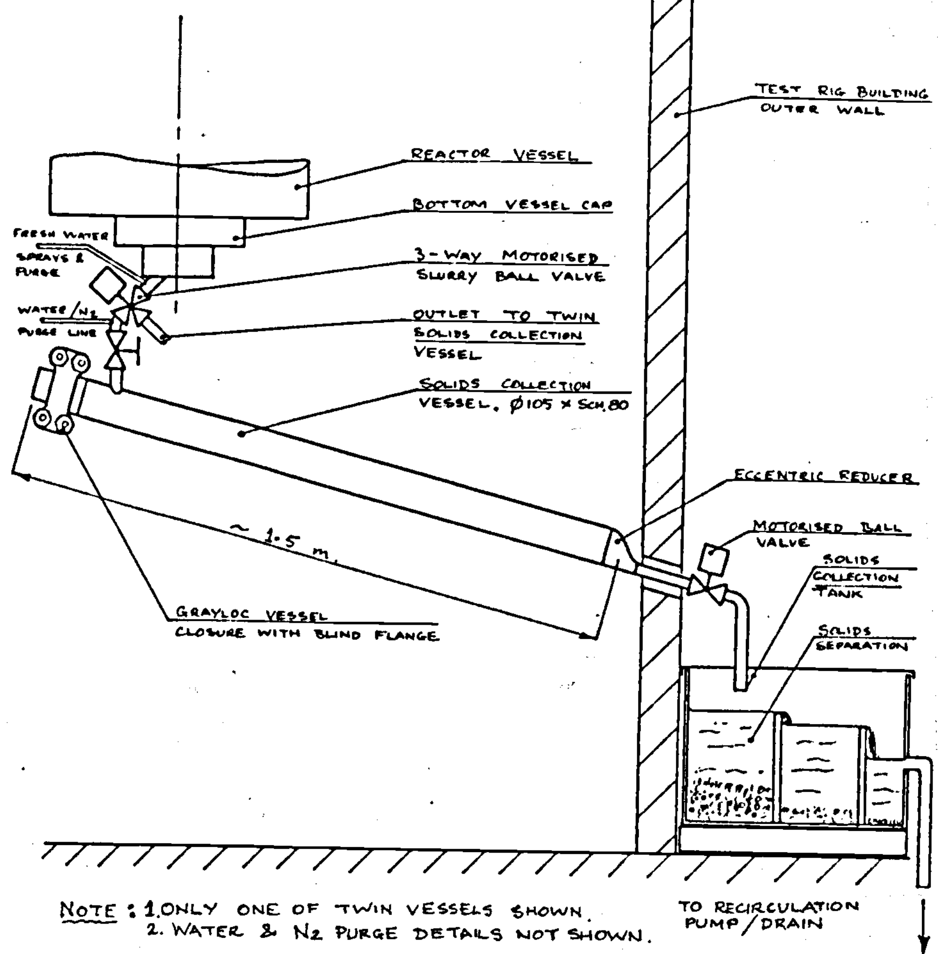


Figure A-14 (b) Solids Collection System

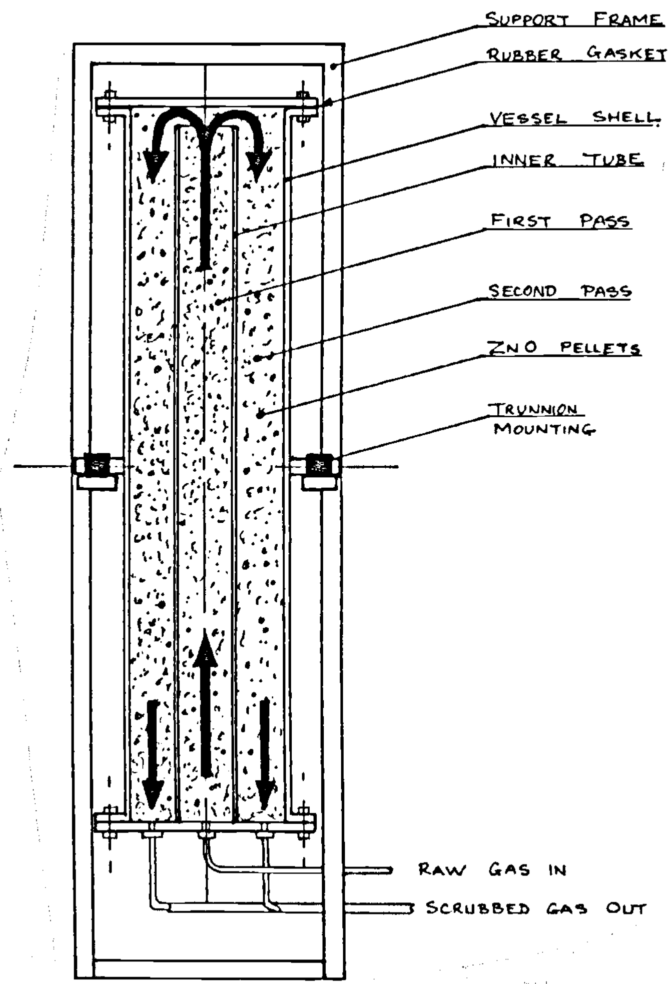


Figure A-15 Diagram of Scrubber Assembly

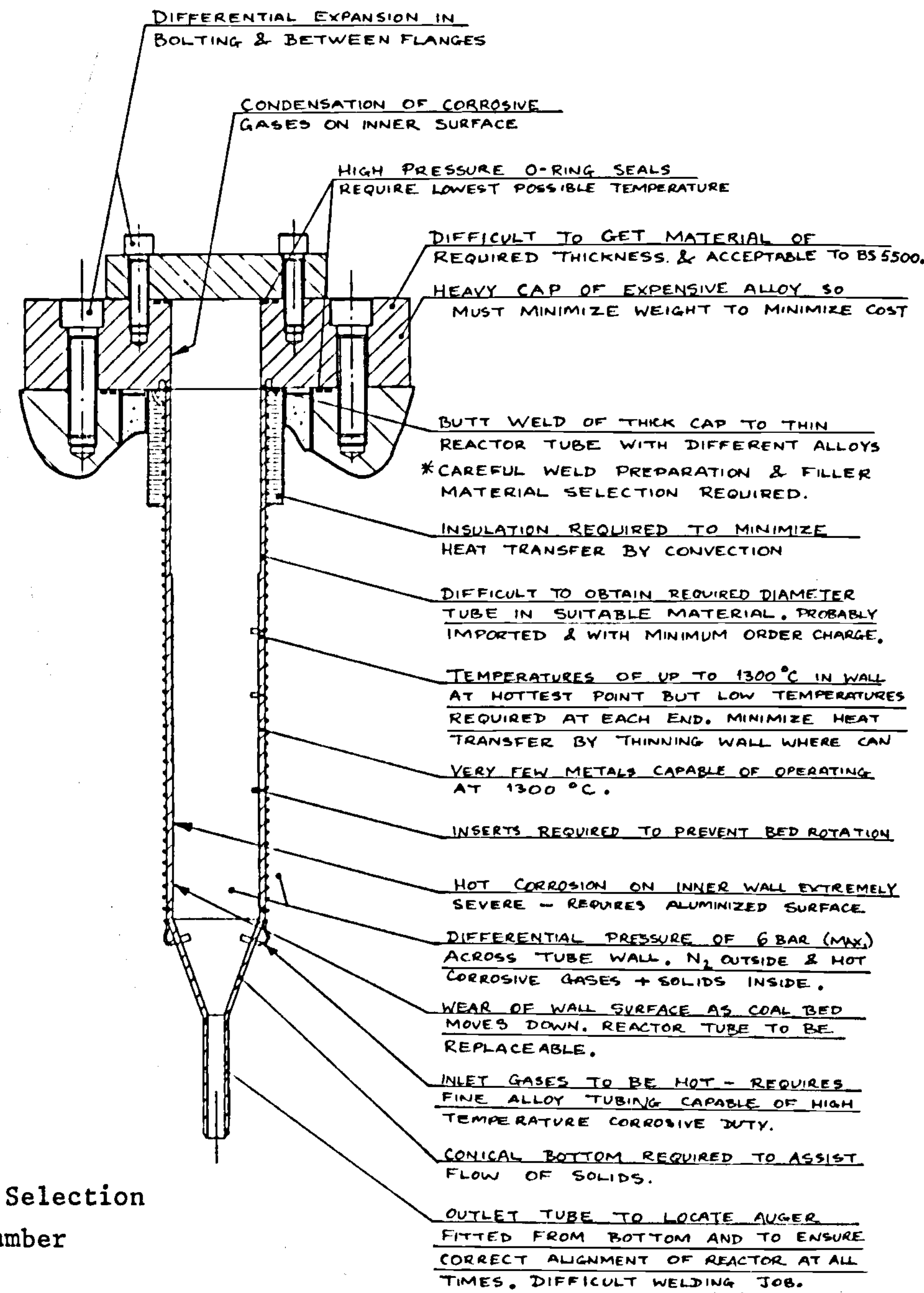


Figure A-16 Problem of Materials Selection for Inner Reactor Chamber

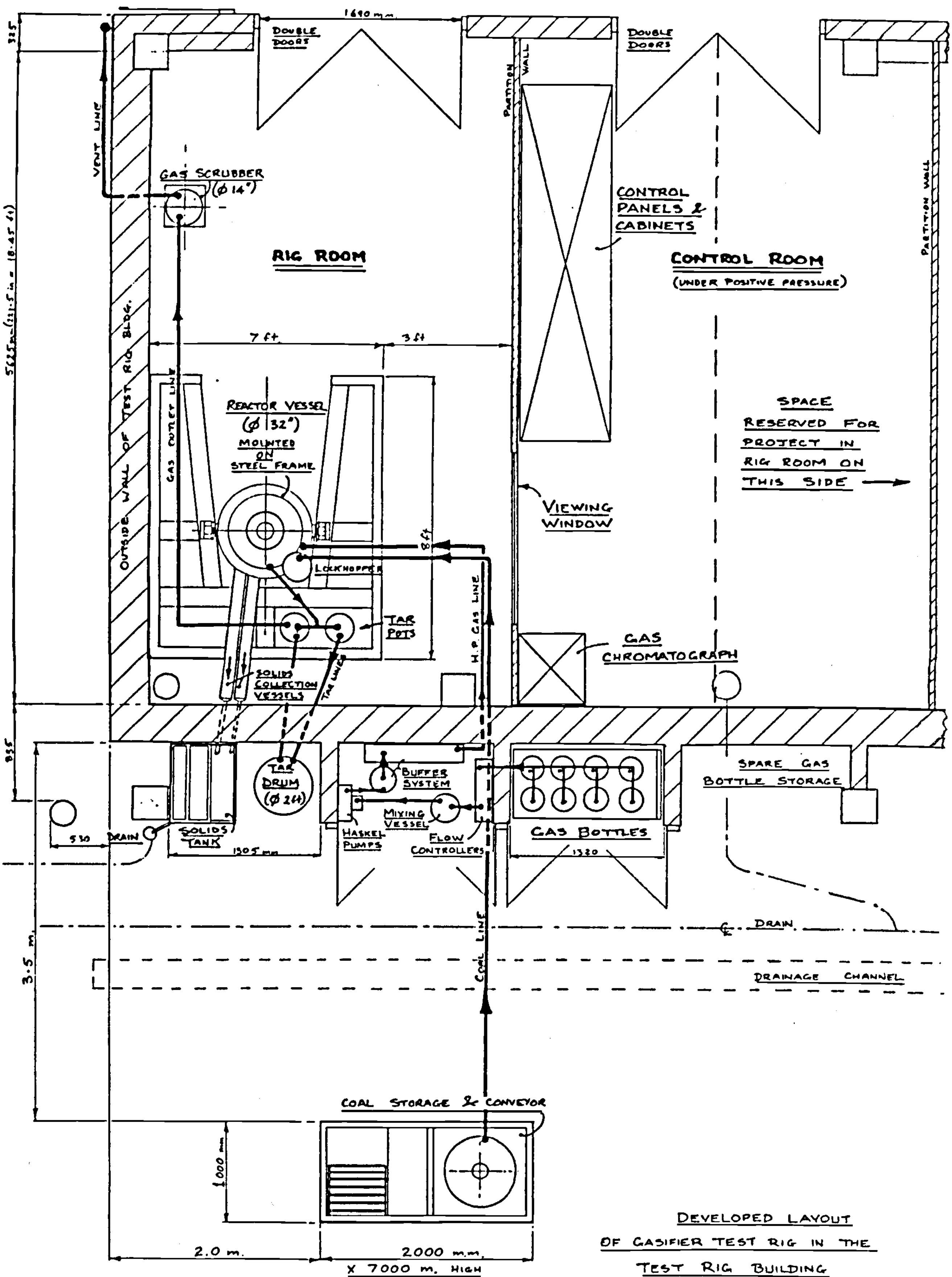


Figure A-17 Layout of Test Rig System

APPENDIX A.3

GASIFIER TEST RIG PROJECT - DESIGN REPORTS

The following reports were prepared for the Company to provide a detailed record of the complete project effort:

GTR 1 - CLARIFICATION OF TASK

GTR 2 - CONCEPTUAL DESIGN

GTR 3 - EMBODIMENT DESIGN I

GTR 4 - CONTROL SYSTEM DESIGN

GTR 5 - EMBODIMENT DESIGN II

GTR 6 - DETAIL DESIGN

As these were issued as reports within the Company, and are available for reference in the Company library, they are not reproduced here. However the summary and list of contents from each one, together with selected samples of weekly reports, correspondence and calculations, have been included in this section to indicate what further information is available regarding the project. Some additional diagrams and schedules which were referred to in the thesis are also included.

Report No. GTR 1

GASIFIER TEST RIG

[redacted]

Prepared by: C. Hales
University Engineering Department
Trumpington Street
Cambridge CB2 1PZ

December 1982

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LIST OF FIGURES

SUMMARY

Early in 1982, a proposal was put forward for the design and construction of a high-pressure test rig at [redacted], in conjunction with research at Cambridge University into effective use of engineering design methods. The proposal was accepted during August, 1982, and the project started on October 1.

This report covers the first three months' work during which the following progress was made:

- Initial discussions to clarify the task and define the problem
- Project organisation and overall schedule developed and accepted
- Discussions held on different aspects of the project with 9 [redacted] staff members from various divisions
- A double brainstorm session held to develop ideas on design and operational aspects of the test rig
- General listing of "demands and wishes" for the test rig evolved, from which a comprehensive specification has been drafted
- Cost control procedures for such a project considered
- Pahl and Beitz design method used effectively on the preliminary design work.

There has been excellent cooperation from [redacted] staff from all divisions, and this has enabled good progress to be made, keeping the project on schedule.

ISSUED: 17/12/82

COMPANY NAME	SPECIFICATION: GASIFIER TEST RIG	SHEET: 1 OF 20

CHANGES	D W	REQUIREMENTS: GEOMETRY	RESPONSIBLE
		LOCATION:	
	D	L.R.S. Test Facility, Lab. No. 2	BPO_S
	W	North end cubicle	CDE
		SIZE:	
	D	Basic rig and controls contained in single cubicle	SL_A
	D	Cubicle Width 2·94 m (9·8 ft = 115·75 ins)	BPO_S
	D	Cubicle Length 5·82 m. (19 ft = 229 ins)	"
	D	Cubicle Height 4.0 m. (13·12 ft = 157·5 ins)	"
	D	Cubicle Volume 68·443 cu.m (2443 cu.ft.)	"
	D	Floor Area 17·11 sq.m. (186 sq.ft.)	"
	D	Max Door Height 3 m (9·84 ft. = 118 ins)	"
	D	Door Width 1·4 m (4·59 ft = 55·1 in)	"
		CUBICLE / BUILDING FEATURES TO NOTE:	
	D	Windows – 50% area of explosion relief panel (translucent) ≑ 3·25 sq.m. – clear glass panel in cubicle door	"
	D	Partition wall thickness (between cubicles) 100 mm. (4 ins)	"
	D	2 Outside walls and single door to cubicle	"
		NUMBER OF TEST RIGS:	
	D	One rig	SL_A
	W	Potential for making several (max. 2-3)	Brainstorm
* 12/1/83	W	Flexibility for modification of ONE basic rig.	AM_A
		RIG ARRANGEMENT:	
	D	Control system physically separated from rig	SL_A
	D	To be capable of extension/modification	"
	D	Access panels/doors required	Brainstorm
	W	Modular or replaceable cartridge type of design	CDE/SL.A
	W	Skid mounted	SL.A
	W	Minimum reactor I.D. 6 inches.	"
	W	Specimen size approx. 4 in. long.	"

REPLACES ISSUE OF

* Change or addition.

Report No. GTR 2

GASIFIER TEST RIG

[redacted]

Prepared by: C. Hales
University Engineering Department
Trumpington Street
Cambridge CB2 1PZ

June 1983

SUMMARY

In October 1982, the design of a high-pressure test rig was initiated at THE COMPANY, in conjunction with research at Cambridge on application of engineering design methods. The formal design methods developed in Germany and detailed by Professors Pahl and Beitz (1) have been directly applied to the specification and conceptual phases of the test rig design with considerable success. The project is now ready to move into the embodiment and detail design phases, after A-Form project approval within British Gas.

This report, which leads on from report GTR 1 (2), covers the six months from December 1982 through June 1983, during which the following progress was made:

- Final specification for test rig completed and approved
- Overall function structure (inputs/outputs) developed from specification
- Functional relationships and nature of coal/specimen interface analysed
- Preliminary reactor concepts devised and discussed
- Detailed function structure procedure of Pahl and Beitz followed through, producing 1.29×10^9 possible arrangements for the reactor design
- Solutions systematically eliminated until one single, refined concept remained, based on Pahl and Beitz selection criteria
- Preliminary overall system design developed, and budget cost estimate obtained from suppliers for major subsystems
- Hardware budget cost estimate of £85,500 calculated for the complete test rig using cost control sheets as described in report GTR 1
- A-Form and cost justification completed and submitted to the Company for formal project approval
- Concepts and cost estimate presented to staff at the Company for discussion and suggestions.

Cooperation from staff at — has continued to be excellent, and with formal submission of the A-form the gasifier test rig project is now at a suitable stage for involvement of specialists within other sectors of the Company.

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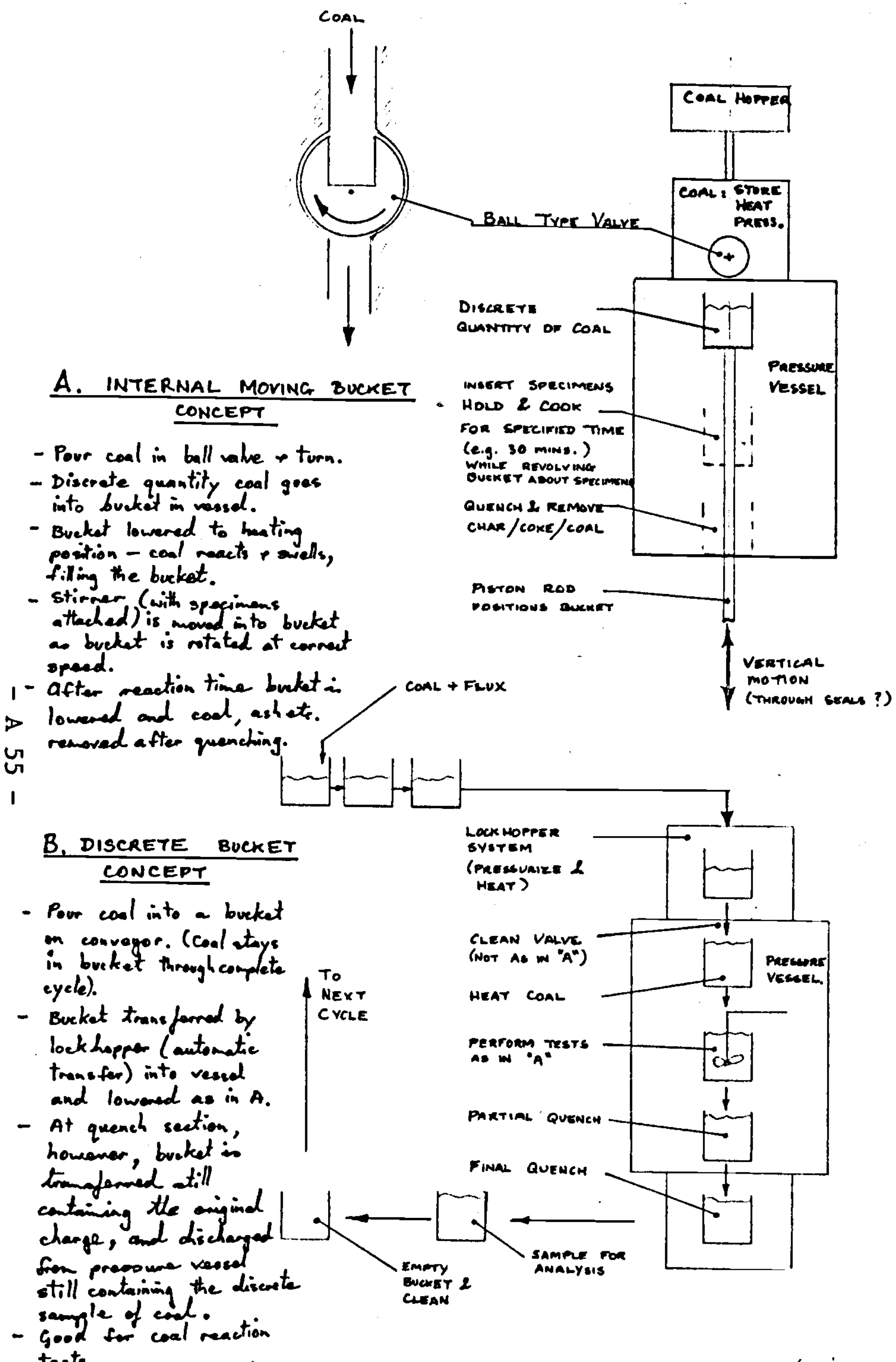

Figure 7 Bucket Concept

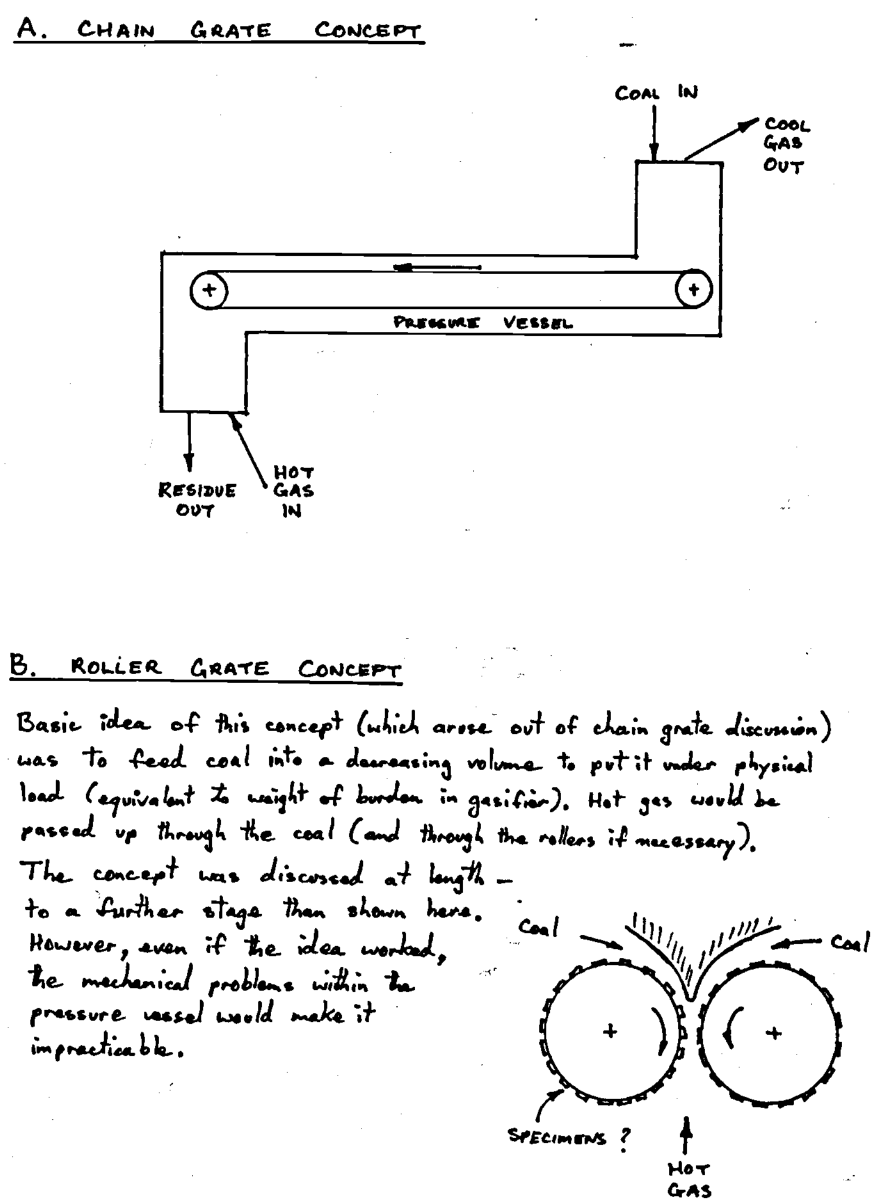

Figure 8 Moving Grate Concept

PROJECT - WEEKLY REPORT

NAME	C. HALES	WEEK	29
SEGMENT	CONCEPT SELECTION	DATE	22.4.83

1. ACCOMPLISHED THIS WEEK

1.1 Work at Company 18.4.83:

- Met with SL-A for discussion on remaining solution variants and decision on which concept to use for test rig. By discussion (recorded on tape) it became clear that the best concept would be the top fed fixed bed design with a load applied to the coal by means of a piston (hydraulically or pneumatically operated). Specimens would be mounted on a rotating shaft and coke/ash would be augered out at the bottom. Rather than heating and injecting a whole range of gases it was decided that partial combustion of the coal should take place at the bottom to generate a certain proportion of the gas mix.

The plan now is to concentrate on developing an overall cost estimate for submission on the A-form (for overall project approval). Once this has been done (in approximately 3 weeks from now), a formal presentation of the chosen test rig concept will be made to all those associated with the project. Embodiment design would then proceed, after general approval.

- Met with S1-A to discuss test rig concepts. He concurred with the choice from the point of view of coal tests, and simple operation. Note: R2-A and R1-A had both previously expressed a strong preference for this concept from the operations point of view.

1.2 Met with SE-VE, Gray Tool Company Representative St Neots 20.4.83.

Discussed pressure vessel details for test rig and calculated budget price for a 22 in. I.D. x 2500 p.s.i. vessel at £18,400. Price was detailed in such a way that a range of other prices could be calculated, the lowest being £13,300 for a 20 in. I.D. x 1500 p.s.i. vessel. These are budget prices only.

1.3 Coal Feed System - obtained budget estimate of £8,000 - 9,000 for a dense phase coal feeding system incorporating the following:

- 1-ton capacity coal hopper (outside building)
- 3 cu.ft. x 40 p.s.i. holding vessel
- 2 lb/hour feed system - 20 ft. distance into building and up to H.P. lockhopper.

1.4 2-ton Chain Hoist and Gantry. - Obtained budget quote of £875 for:

- 2-ton geared trolley + hoist
- free standing gantry on four rubber tyred wheels - - 10 ft. rail height.

1.5 Meeting with DE-U Design Engineer, University Engineering Department, Cambridge 22.4.83.

Reviewed hardware involved in test rig concept and estimated costs for all major components that had not been accounted for. This gave sufficient information for completing full cost estimate sheets.

1.6 Completed a set of 9 cost estimate detail sheets (as introduced in report GTR-1). This gives a comprehensive first estimate totalling about £85,000, broken down by sub-system.

2. PLANNED FOR NEXT WEEK

2.1 Meeting at Company to discuss cost estimates and general approach to submission of the A-form for project approval.

2.2. Meeting with C. Rodwell to discuss research programme, with particular regard to describing projects in terms of 'profiles'.

2.3 First draft of A-form with supporting justification.

2.4 General drawing to show elements of test rig system.

Report No. GTR 3

GASIFIER TEST RIG

[redacted]

Prepared by: C. Hales
University Engineering Department
Trumpington Street
Cambridge CB2 1PZ

January 1984

SUMMARY

This is the third in a series of semi-annual progress reports on the design of a high-pressure materials test rig for THE COMPANY. The work is being carried out in conjunction with research at Cambridge University on the application of particular engineering design methods. Formal design methods developed in Germany and presented by Professors Pahl and Beitz have been successfully applied to the specification and conceptual phases of the test rig design. Embodiment design, the next phase, has been completed to the point where a developed concept existed in sufficient detail to allow a full project review by the [redacted] management, and the Director of the [redacted] programme.

The report leads on from report GTR-2, and covers the six months from July 1983 through December 1983, during which the following progress was made:

- Revised A-Form and project proposal, together with cost justification, submitted to management.
- Cost estimate breakdown revised to be compatible with computer system.
- Approximate gas reactivity calculations completed by [redacted] staff.
- Technical discussions held at [redacted] which highlighted such problems as gas/tar separation and solids removal.
- Revision of basic rig internal configuration to incorporate tar/gas separation within the test chamber, together with gas recirculation to reduce operating costs.
- Development of test rig concept to a further level of detail, including preliminary vessel calculations to BS 5500.
- Parallel development, by [redacted] staff, of the proposed materials test programme.
- Formal presentation of the proposed test programme and rig design to [redacted] senior management.

Although cooperation from staff at [redacted] has continued to be excellent, progress during this six months has been slow, and the project has fallen behind schedule. Considerable time has been required for preparing and presenting the case for formal project approval and for eliciting support within the Company [redacted] generally. By the end of this reporting period, the point had been reached where a decision on the future of the project was imminent. Depending on the outcome, the design work will either terminate at an agreed level of detail, or progress through full detailing into construction and commissioning of the equipment.

CHales

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Report No. GTR 4

GASIFIER TEST RIG CONTROL SYSTEM

[redacted]

Prepared by: CCE &
C Hales
University Engineering Department
Trumpington Street
Cambridge CB2 1PZ

May 1984

PREFACE

This report covers the period 7 - 25 May 1984 during which CCE from IIT Research Institute, Chicago, U.S.A. worked for one week on conceptual design of the control system in Chicago, followed by two weeks at [redacted] and Cambridge in Britain. C. Hales prepared a brief, and sent a package of preliminary information to Chicago during late April, then gave full design and drafting assistance during the final two weeks. Excellent cooperation and assistance was given by the staff during the period, and this report was issued in conjunction with an oral presentation at a final meeting, held at [redacted] on Friday 25 May 1984.

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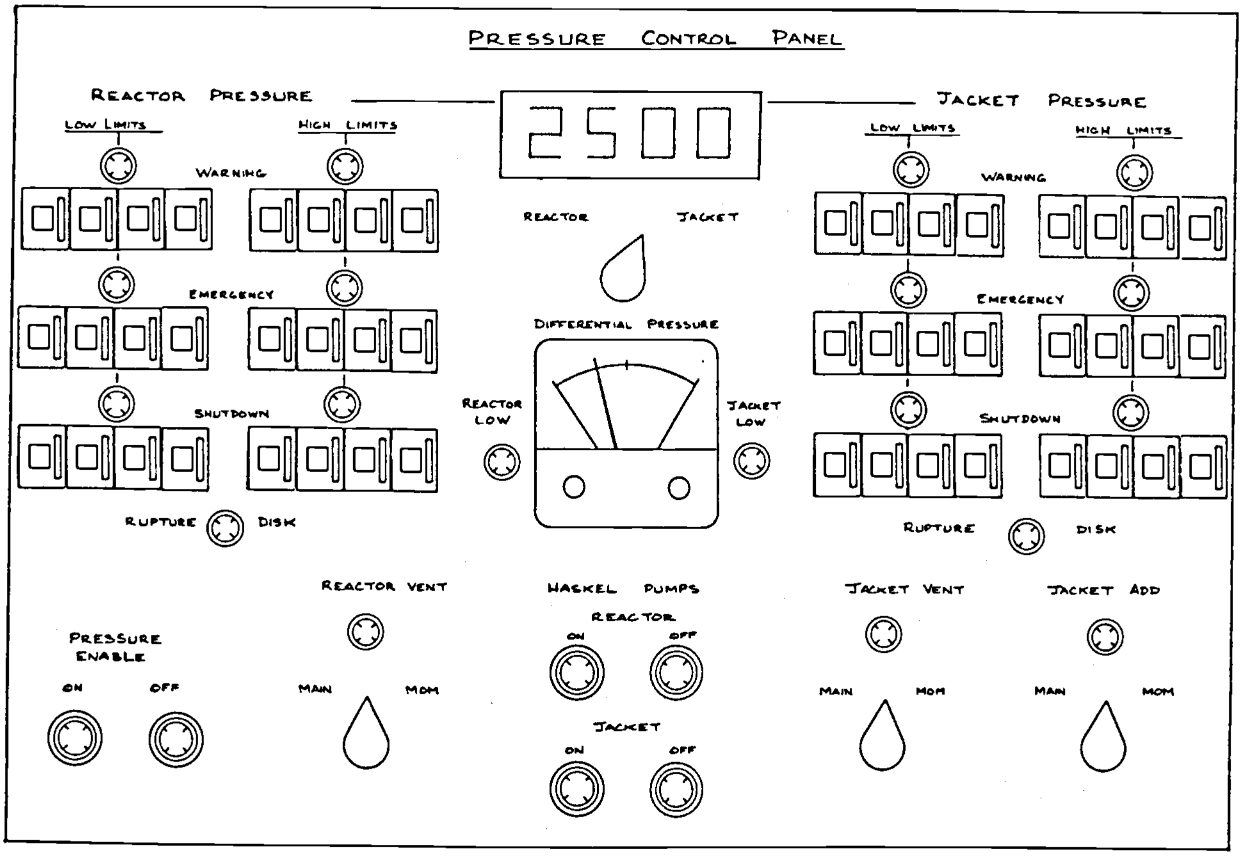
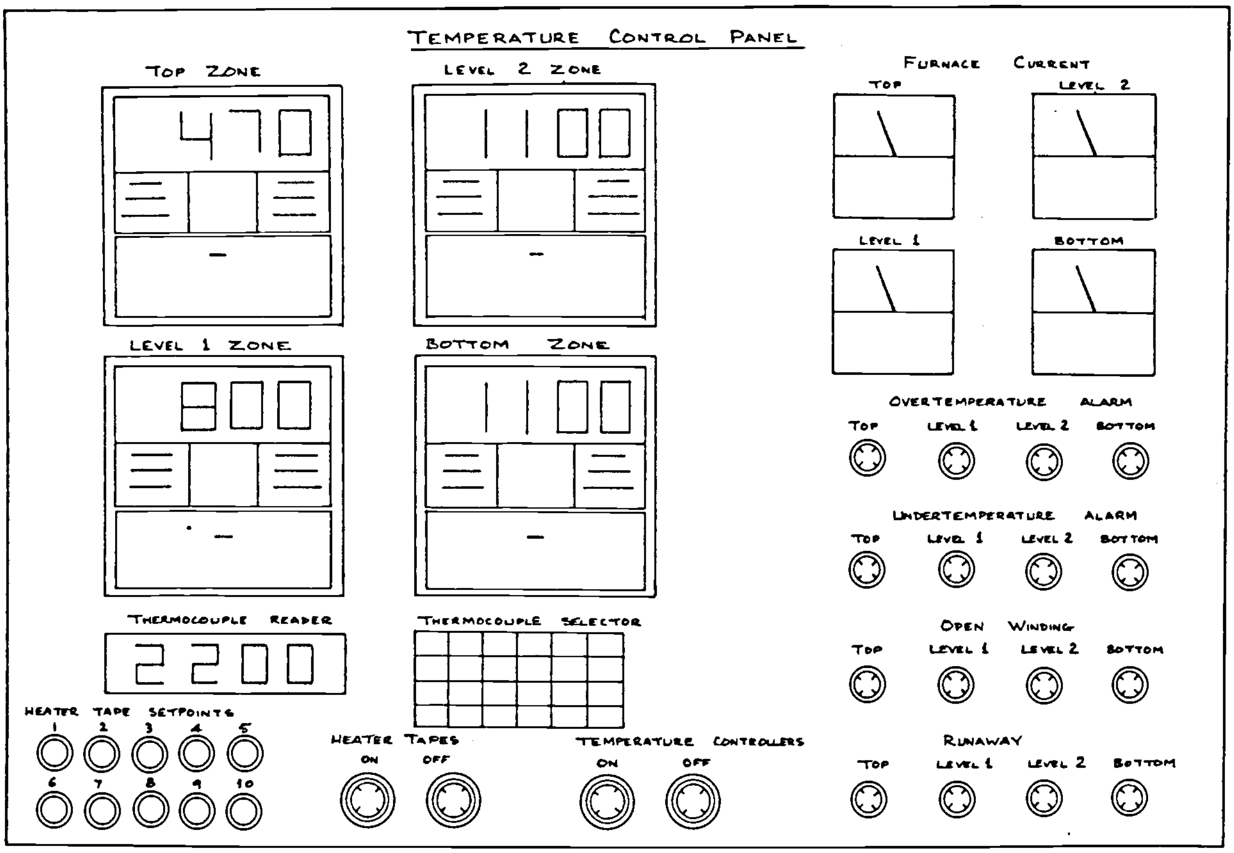


CONCEPTUAL LAYOUT OF PRESSURE CONTROL PANEL

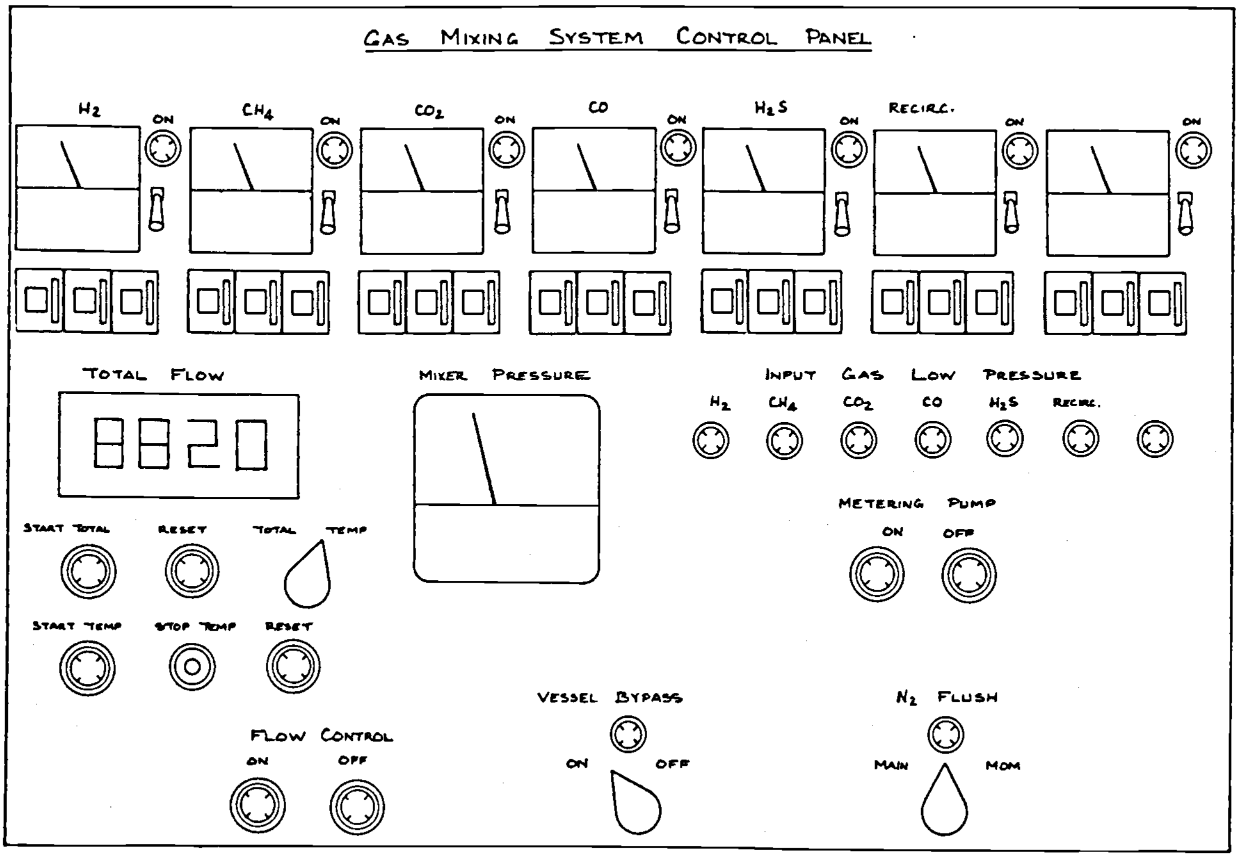
SUBSYSTEM :- PRESSURE CONTROL SYSTEM | REVISION No.:- Ø | DATE :- 29/5/84 | SHT. 1 OF 1

SENSOR DESIGNATION	SENSOR DESCRIPTION	PROCESS DATA: PRESSURE (PSIG)	PROCESS DATA: TEMP. (°C)	PROCESS DATA: FLUID	FUNCTION: DATA AQU.	FUNCTION: CONTROL	FUNCTION: ALARM/SD.
PS7	PRESSURE SWITCH; LOW SETPOINT SET @	2500	AMB	N_2	—	—	OFF
PS8	PRESSURE SWITCH; LOW SETPOINT SET @	2500		REACTOR GAS			OFF
PS9	PRESSURE SWITCH; HIGH SETPOINT SET @	2500		REACTOR GAS			DUMP
PS10	PRESSURE SWITCH, LOW SETPOINT SET @	2500		N_2			OFF
PS11	PRESSURE SWITCH; HIGH SETPOINT SET @	2500		N_2			DUMP
DPT 1	DIFFERENTIAL PRESSURE TRANSDUCER	± 50 PSID		N_2 / REACTOR GAS		X	IDLE (AFTER TIMER)
PT2	PRESSURE TRANSDUCER	2500		REACTOR GAS	X	X	LO: OFF, DUMP; HI: OFF, DUMP
PT3	PRESSURE TRANSDUCER	2500		N_2	X	X	LO: OFF, DUMP; HI: OFF, DUMP

SENSOR TABLE



CONCEPTUAL LAYOUT OF TEMPERATURE CONTROL PANEL



CONCEPTUAL LAYOUT OF GAS MIXING SYSTEM CONTROL PANEL

Report No. GTR 5

GASIFIER TEST RIG

(Embodiment Design/Detail Design)

[redacted]

Prepared by: C Hales
University Engineering Department
Trumpington Street
Cambridge CB2 1PZ

August 1984

SUMMARY

This is the fifth in a series of periodic progress reports on the design of a high pressure materials test rig for THE COMPANY. The work is being carried out in conjunction with research at Cambridge University on the application of particular engineering design methods. The formal methodology of Professors Pahl and Beitz, developed in Germany, has now been successfully applied to the Specification (Report GTR-1), Conceptual Design (Report GTR-2) and Embodiment Design (Report GTR-3) phases of the project. The basic Control System has also been designed (GTR-4).

This report leads on from GTR-3 and covers the seven months from December 1983 through July 1984 during which the following progress was made:

- Formal presentation of the proposed test rig and test programme to [redacted] staff.
- Decision by [redacted] management to proceed through the detail design phase of the project.
- Agreement with the design and drafting group ([redacted] Services Division) on assistance with the detail design and drafting work involving an estimated 200 detail drawings.
- Design conditions for test rig increased to 170 bar (2500 psi) maximum pressure and 1300°C maximum temperature.
- Coal supply system more closely defined and a formal quotation obtained.
- Basic control system design work completed.
- Preliminary meeting with [redacted] Quality Assurance Dept.
- Preliminary layout of rig in Test Rig Building.
- A Review of Design and Drafting Practice at [redacted].

Progress during the period has been patchy and slow, except for the control system design work. A major reason for this was the lack of any experienced design draftsperson to assist with the detail design, during the first six months of the period, and it caused considerable concern as the project increasingly fell behind schedule.

A review of the design and drafting situation was prepared and presented to [redacted] management in an effort to highlight some of the difficulties, together with possible approaches for improvement.

Although authorisation was given for the project to continue through detail design, no decision has been made yet as to whether the test rig will be constructed or not.

CHales
August 1984

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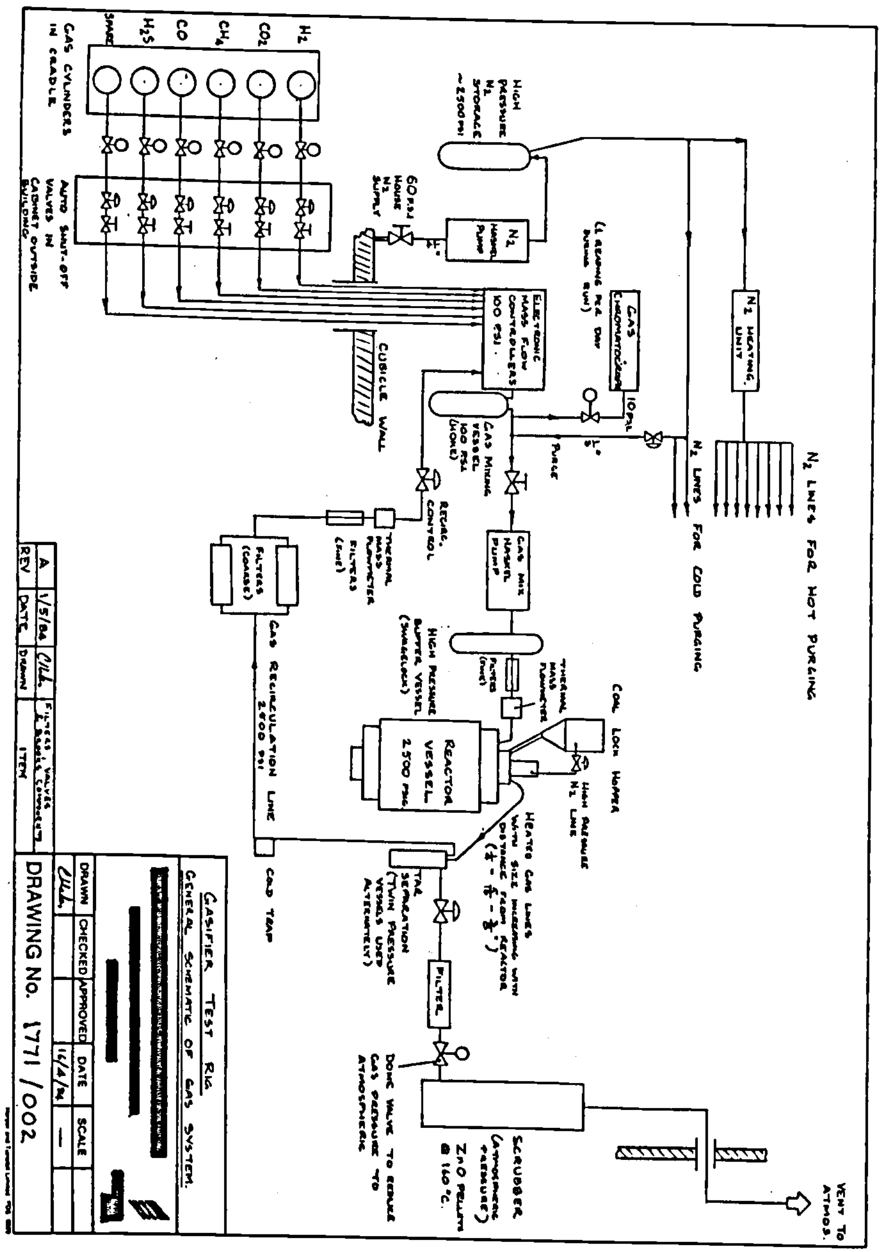


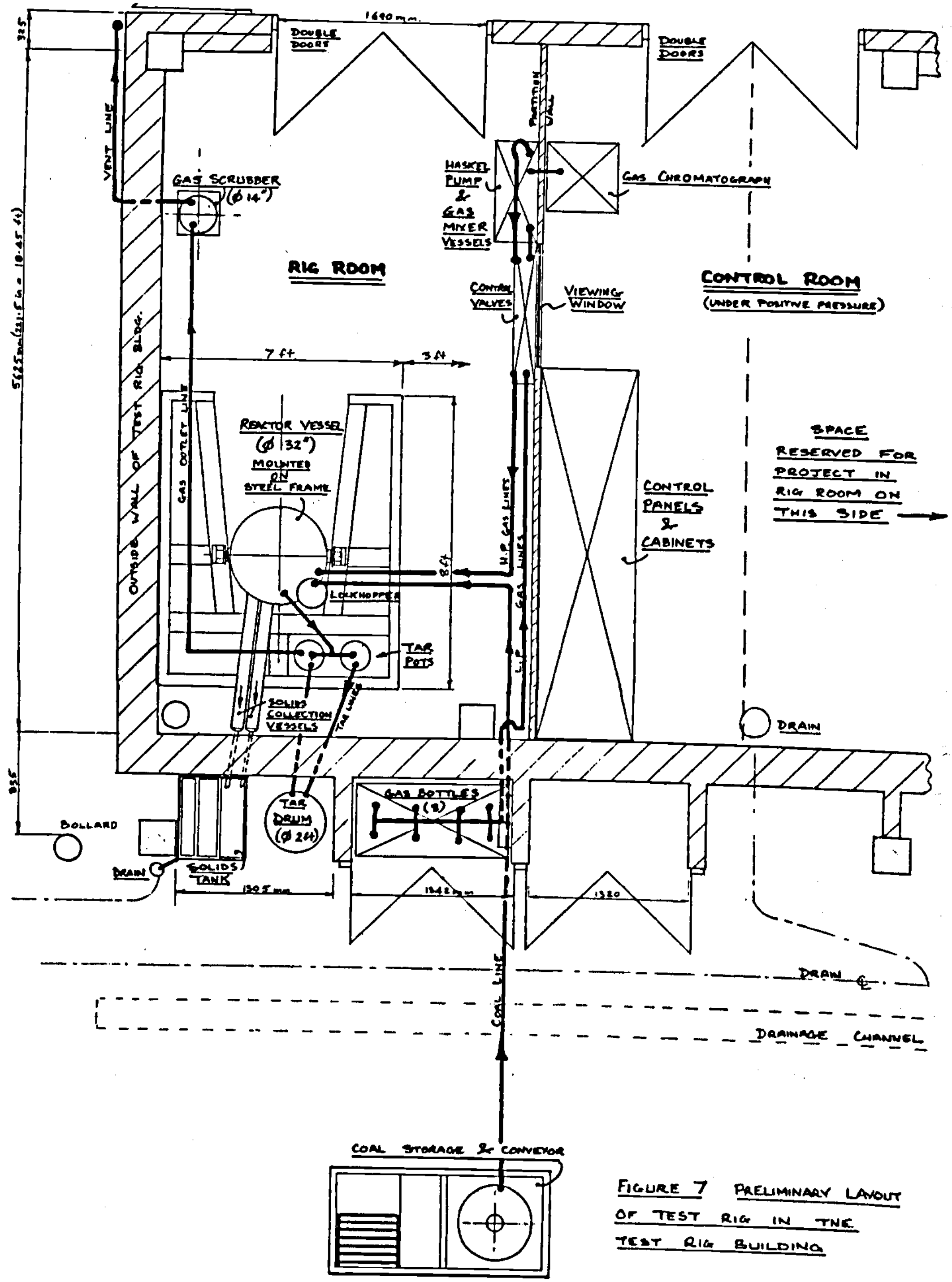
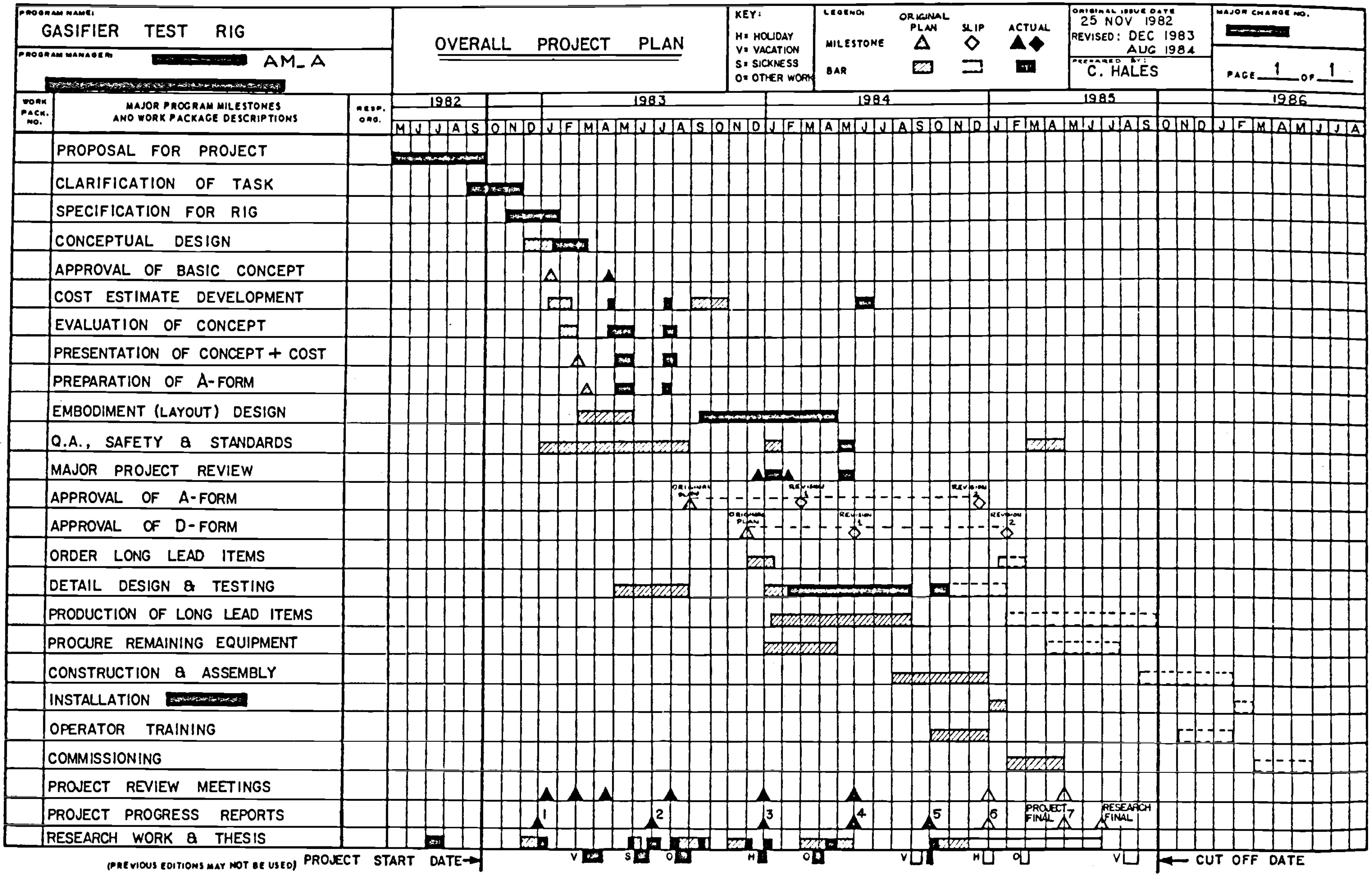


FIGURE 7 PRELIMINARY LAYOUT OF TEST RIG IN THE TEST RIG BUILDING


PROGRAM NAME:
GASIFIER TEST RIG
PROGRAM MANAGER: [redacted] AM_A
[redacted]
OVERALL PROJECT PLAN
KEY:
H= HOLIDAY
V= VACATION
S= SICKNESS
O= OTHER WORK
LEGEND: ORIGINAL PLAN SLIP ACTUAL
MILESTONE
BAR
ORIGINAL ISSUE DATE 25 NOV 1982
REVISED: DEC 1983
AUG 1984
PREPARED BY: C. HALES
MAJOR CHANGE NO. [redacted]
PAGE 1 OF 1
WORK PACK. NO.
MAJOR PROGRAM MILESTONES AND WORK PACKAGE DESCRIPTIONS
RESP. ORG.
1982
1983
1984
1985
1986
M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A
PROPOSAL FOR PROJECT
CLARIFICATION OF TASK
SPECIFICATION FOR RIG
CONCEPTUAL DESIGN
APPROVAL OF BASIC CONCEPT
COST ESTIMATE DEVELOPMENT
EVALUATION OF CONCEPT
PRESENTATION OF CONCEPT + COST
PREPARATION OF A-FORM
EMBODIMENT (LAYOUT) DESIGN
Q.A., SAFETY & STANDARDS
MAJOR PROJECT REVIEW
APPROVAL OF A-FORM
APPROVAL OF D-FORM
ORDER LONG LEAD ITEMS
DETAIL DESIGN & TESTING
PRODUCTION OF LONG LEAD ITEMS
PROCURE REMAINING EQUIPMENT
CONSTRUCTION & ASSEMBLY
INSTALLATION [redacted]
OPERATOR TRAINING
COMMISSIONING
PROJECT REVIEW MEETINGS
PROJECT PROGRESS REPORTS
RESEARCH WORK & THESIS
ORIGINAL PLAN
REVISION 1
REVISION 2
1
2
3
4
5
6
PROJECT FINAL
7
RESEARCH FINAL
V S O H O V H O V
(PREVIOUS EDITIONS MAY NOT BE USED)
PROJECT START DATE
CUT OFF DATE

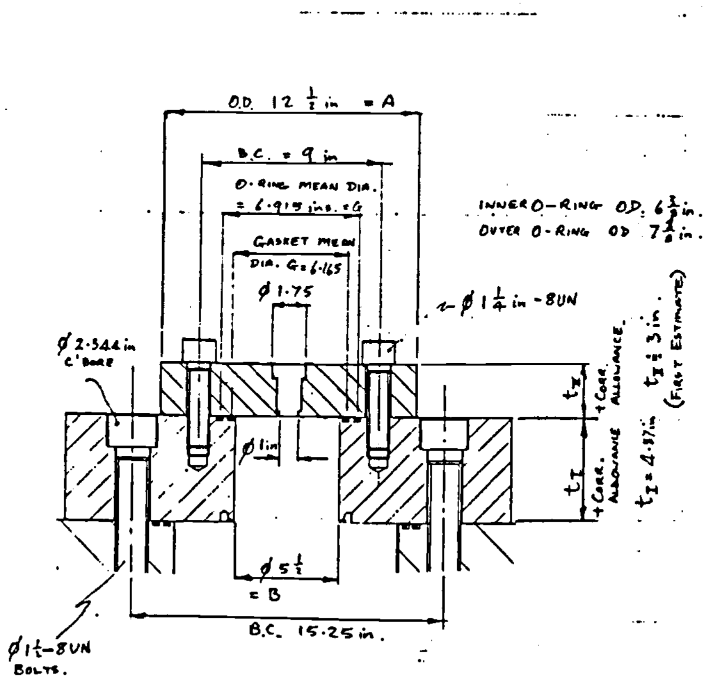


Figure 8 Top Cap Geometry.

CALCULATION SHEET

Sheet No. 37
Made by C. Hales
Checked by
Date 17/7/84
Department Cambridge University

Refers to Gasifier Test Rig
Reactor Vessel Assembly

Section	Reference	Calculation	Remarks.
8		TOP CAP	See Figure 8
8.1		MATERIAL FOR CAP - 316 S11	
		316 Type Stainless steel.	
	BS. 5500 Table 2.3(e) P.2/17	Design strength at 300 °C	
		S_f = 14,355 psi. = 99 N/mm²	Metals Handbook 9th Ed. Vol 3 p.34.
		E = 23.5 × 10⁶ psi.	
8.2		BOLTING MATERIAL	
		SA193 - B7 STEEL	
		DESIGN STRENGTH	
		S_b = 25,000 psi = 172 N/mm².	
		E = 30 × 10⁶ psi.	
8.3	BS. 5500 Footnote 3.8.1.3 (b)	FLANGE DESIGN TO ASME VIII DIVISION 1, APPENDIX Y - FLAT FACE FLANGES WITH METAL TO METAL CONTACT OUTSIDE THE BOLT CIRCLE.	
		From calculations for Intermediate Cap sufficient is known to be able to estimate cap thickness and bolting immediately.	
		The trial thickness will be 3ins.	
		Trial bolting will be 8× 1½-8UN bolts on 9in Bolt Circle.	
	Dormer Thread Handbook.	· Basic Minor Thread Diam.	
		= 1.25 - 2(0.61344) P	$P = \frac{1}{TPI}$
		= 1.0966	∴ $P = \frac{1}{8}$
		∴ Area of crossection of 1 bolt	
		$= \frac{\pi}{4} \times (1.0966)^2 = 0.9445$ ins².	
		∴ Total area of bolting, Ab	
		$A_b = 0.9445 \times 8 = 7.556$ ins².	

- A 68 -

[redacted]

CALCULATION SHEET

Refers to: GASIFIER TEST RIG — REACTOR VESSEL ASSEMBLY.

Sheet No. 38
Made by: C. Hales
Checked by:
Date: 17/7/84
Department: Cambridge University

SECTION	REFERENCE	CALCULATION	REMARKS.
		FIRST RUN USING OUTER O-RING AND DESIGN PRESSURE OF 2700 psi.	
	ASME VIII(1) APPENDIX Y. Y-3	$H = 0.785\ G^2 P$ $= 0.785\ (6.915)^2 \times 2{,}700$ i.e. $H = 101{,}349$ lb.	$G = 6.915$ in $P = 2{,}700$ psi.
		$H_D = 0.785\ B^2 P$ $= 0.785\ (5.5)^2 (2{,}700)$ i.e. $H_D = 64{,}115$ lb.	$B = 5.5$ in. $P = 2{,}700$ psi
		$H_T = H - H_D$. $= 101{,}349 - 64{,}115$ i.e. $H_T = 37{,}234$ lb.	
		$H_G = 0$	Negligible gasket load.
		$h_D = \frac{C-B}{2}$ $= \frac{9-5.5}{2}$ i.e. $h_D = 1.75$ in.	$C = 9$ in (B.C.) $B = 5.5$ in.
		$h_T = \frac{h_D + h_G}{2}$ $= \frac{1.75 + 1.043}{2}$ ∴ $h_T = 1.396$	$h_G = \frac{C-G}{2}$ $= \frac{9-6.915}{2}$ $= 1.043$
	Y-3	$M_P = H_D h_D + H_T h_T + H_G h_G$ $= (64{,}115 \times 1.75) + (37{,}234 \times 1.396)$ i.e. $M_P = 164{,}180$ in-lb.	
	Y-3	$X = \frac{E_I^*}{E_I^* + E_{II}^*}$ $= \frac{E_I t_I^3}{E_I t_I^3 + E_{II} t_{II}^3}$ $= \frac{t_I^3}{t_I^3 + t_{II}^3}$ as $E_I = E_{II}$ $= \frac{(4.87)^3}{(4.87)^3 + (3)^3}$.	$E_I = 28.5 \times 10^6$ $E_{II} = 28.5 \times 10^6$ $t_I = 4.87$ $t_{II} = 3.0$ (trial)

[redacted]

CALCULATION SHEET

Refers to: GASIFIER TEST RIG — REACTOR VESSEL ASSEMBLY

Sheet No. 39
Made by: C. Hales
Checked by:
Date: 17/7/84
Department: Cambridge University

SECTION	REFERENCE	CALCULATION	REMARKS
		i.e. $X = 0.911$	
	Y-3	$J_S = \frac{1}{B_1}\left[\frac{2h_D}{\beta} + \frac{h_C}{a}\right] + \pi r_B$	$B = B_1 = 5.5$ in. $h_D = 1.75$ in.
	Y-3	$r_B = \frac{1}{n}\left[\frac{4}{\sqrt{1-\bar{AR}^2}}\tan^{-1}\sqrt{\frac{1+\bar{AR}}{1-\bar{AR}}} - \pi - 2\bar{AR}\right]$ $= \frac{1}{8}\left[\frac{4}{0.9354}\tan^{-1}\sqrt{\frac{1.3537}{0.6463}} - \pi - 0.7074\right]$ $= \frac{1}{8}\left[4.276\ (0.9662) - \pi - 0.7074\right]$ $= \frac{1}{8}\left[0.2823\right]$ i.e. $r_B = 0.0353$	$\beta = \frac{C+B}{2B}$ $= \frac{9+5.5}{11}$ $= 1.318$ $h_C = \frac{A-C}{2}$ $= \frac{12.5-9}{2}$ ∴ $h_C = 1.75$
		∴ $J_S = \frac{1}{5.5}\left[\frac{2 \times 1.75}{1.318} + \frac{1.75}{1.95}\right] + \pi(0.0353)$ $= \frac{1}{5.5}\left[3.553\right] + 0.1109$ i.e. $J_S = 0.7569$	$a = \frac{A+C}{2B}$ $= \frac{12.5+9}{11}$ $= 1.95$
	Y-3	$J_P = \frac{1}{B_1}\left[\frac{h_D}{\beta} - \frac{h_C}{a}\right] + \pi r_B$ $= \frac{1}{5.5}\left[\frac{1.75}{1.318} + \frac{1.75}{1.95}\right] + 0.1109$ i.e. $J_P = 0.5155$	$n = 8$ bolts. $\bar{AR} = \frac{nD}{\pi C}$
	Y-3 Eq. (1)	$C_1 = \frac{-\left[0.749 - 1.567\ J_S \log_{10}\frac{A}{B_1}\right]}{1 + 1.3\ J_S}$ $= \frac{-\left[0.748 - 1.567(0.7569)(0.3565)\right]}{1 + 1.3(0.7569)}$ $= \frac{-0.3252}{1.984}$ i.e. $C_1 = -0.1639$.	$D = 1.25$ in. (bolt dia). ∴ $\bar{AR} = \frac{8 \times 1.25}{\pi \times 9}$ $= 0.3537$ $\log_{10}\frac{A}{B_1} = \log\frac{12.5}{5.5}$ $= 0.3565$
	Y-3 Eq. (2)	$C_2 = \frac{\left[\frac{\pi}{32}(P B_1^3) - 1.3\ J_P M_P\right]}{1 + 1.3\ J_S}$. $= \frac{\frac{\pi}{32}(2700)(5.5)^3 - 1.3(0.5155)(164{,}180)}{1.984}$ $= \frac{44{,}101 - 110{,}025}{1.984}$ i.e. $C_2 = -33{,}228$	

Sheet 40

[redacted]

CALCULATION SHEET

Sheet No. 40
Made by C. Hales
Checked by
Date 17/7/84
Department Cambridge University

Refers to GASIFIER TEST RIG
REACTOR VESSEL ASSEMBLY

SECTION	REFERENCE	CALCULATION	REMARKS
	Eq.(3)-(4)	$C_3 = C_4 = 0$ when $F_1' = 0$	For Class 3 Category 3 flanges.
	Y 6.3 Eq.(17)	$E_I^* \theta_{rb_I} = \dfrac{X(C_4 - C_2)}{1.206 \log\frac{A}{B} - XC_3 - (1-X)C_1}$	$X = 0.811$
		$= \dfrac{0.811(0 - (-33,223))}{1.206 \times 0.3565 - 0 - (1-0.811)(-0.434)}$	
		$= \dfrac{26,944}{0.4609}$	
		i.e. $E_I^*\theta_{rb_I} = 58,466$	$E_I^* = E_I t_I^3$, $E_{II}^* = E_{II} t_{II}^3$
	Eq.(18)	$E_{II}^*\theta_{rb_{II}} = -E_I^*\theta_{rb_I}(E_{II}^*/E_I^*)$	
		$= -58,466\left(\dfrac{1 \cdot t_{II}^3}{1 \cdot t_I^3}\right)$	as $E_I = E_{II}$
		$= -58,466\left(\dfrac{27}{115.5}\right)$	$t_I = 4.87$, $t_{II} = 3.0$
		i.e. $E_{II}^*\theta_{rb_{II}} = -13,667$	
	Eq.(20)	$M_{sII} = C_1(E_{II}^*\theta_{rb_{II}}) + C_2$	
		$= -0.1639(-13,667) - 33,223$	
		i.e. $M_{sII} = -30,988$	
	Eq.(21)	$M_{UI} = 1.206\,(E_I^*\theta_{rb_I}) \log\frac{A}{B_1}$	
		$= 1.206\,(58,466)(0.3565)$	
		$M_{UI} = 25,137$	
	Eq.(22)	$M_{UII} = 1.206\,(E_{II}^*\theta_{rb_{II}}) \log\frac{A}{B_1}$	
		$= 1.206\,(-13,667)(0.3565)$	
		$= -5,876$	
	Eq.(23)	$M_{bI} = M_{sI} - M_{UI}$	$M_{sI} = 0$ for Cat.3 Class 3 } flanges.
		$= 0 - 25,137$	
		i.e. $M_{bI} = -25,137$.	
	Eq.(26)	$E_{II}\theta_{BII} = \dfrac{-1.337\,(M_{sII} - \pi P B_1^3/32)}{t_{II}^3}$	

Sheet 41

[redacted]

CALCULATION SHEET

Sheet No. 41
Made by C. Hales
Checked by
Date 17/7/84
Department Cambridge University

Refers to GASIFIER TEST RIG
REACTOR VESSEL ASSEMBLY

SECTION	REFERENCE	CALCULATION	REMARKS
		$E_{II}\theta_{II} = \dfrac{-1.337\left[(-30,988) - \frac{\pi}{32}(250)(5.5)^3\right]}{27}$	
		$= 3,718$	
		CONTACT FORCE BETWEEN FLANGES AT h_c	
	Eq.(27)	$H_c = \dfrac{M_p + M_{bI}}{h_c}$	$h_c = 1.75$
		$= \dfrac{164,190 + (-25,137)}{1.75}$	
		i.e. $H_c = 79,453$	
		BOLT LOAD AT OPERATING CONDITIONS	
	Eq.(28)	$W_{mI} = H + H_G + H_c$	$H_G = 0$
		$= 101,349 + 79,453$	
		i.e. $W_{mI} = 180,802$	
	Eq.(29)	OPERATING BOLT STRESS	
		$\sigma_b = \dfrac{W_{mI}}{A_b}$	$A_b = 7.556$ ins^2
		$= \dfrac{180,802}{7.556}$	$S_b = 25,000$ psi.
		i.e. $\sigma_b = 23,928$ psi.	O.K.
		This is less than the allowable bolt stress and is acceptable.	
	Eq.(35)	RADIAL STRESS IN FLANGE II AT BOLT CIRCLE (TOP CAP)	
		$S_{RII} = \dfrac{6(M_p + M_{sII})}{t_{II}^2(\pi C - nD)}$	
		$= \dfrac{6(164,180 + (-30,988))}{9(\pi \times 9 - 8 \times 1.25)}$	
		i.e. $S_{RII} = 4,859$ psi.	

Report No. GTR-6

GASIFIER TEST RIG

(Detail Design)

[redacted]

Prepared by: C Hales
University Engineering Department
Trumpington Street
Cambridge CB2 1PZ

August 1985

SUMMARY

This is the sixth in a series of periodic progress reports on the design of a high pressure materials test rig for THE COMPANY. The work is being carried out in conjunction with research at Cambridge University on analysing the engineering design process as it occurs in industry. During the project the formal design procedures recommended by Professors Pahl and Beitz in Germany have been closely followed, providing a structured approach with detailed records as follows:

Report GTR-1 : Task Clarification and Specification
Report GTR-2 : Conceptual Design
Report GTR-3 : Embodiment Design I
Report GTR-4 : Control System Design
Report GTR-5 : Embodiment Design II/Detail Design I.

This particular report follows on from GTR-5 and covers the final ten months from July 1984 through May 1985 during which the following progress was made:

- Completion of detail design drawings for the gas scrubber and the reactor vessel support frame.
- Agreement reached on space allocation and zone 2 electrical requirements for the rig, together with arrangements for the coal storage and supply system.
- Finalization of the rig layout in the Test Rig Building.
- Decision made regarding the future of the test rig: construction will not proceed at this time and the design records will be formally stored for future reference.
- Detailed planning for long term storage of project design records and drawings.
- Design assistance with three other proposed test rigs.

Detail drawings of the tar/gas separators, the solids collection vessels, the solids storage tanks and the reactor vessel internals have not been completed, but it was decided at a project meeting that, as construction of the rig has been indefinitely postponed, sketches for future guidance would be adequate instead.

One final report, GTR-7, will summarize the complete project and provide guidelines for reactivating and completing the work at a future date. GTR-7 will also contain an index to the previous six reports.

August 1985

CONTENTS

LIST OF FIGURES

SUMMARY OF MEETING HELD AT [redacted] ON THURSDAY 26 JULY 1984

Conference Room 3   10.15 am

Present: DE-S
BPO-S
CDE
R2-A
SL-A

Subject: ELECTRICAL HAZARD RATING AND SPACE ALLOCATION FOR GASIFIER TEST RIG

1. ZONE 2 ELECTRICAL REQUIREMENTS

- All electrical equipment to be non-sparking and totally enclosed.
- Maximum of 300°C on the surface of any equipment.
- Fixed wiring throughout.

For this rig it was decided that the best option was the following:

1. Enclose all the control cabinets and date acquisition equipment in a sealed control cubicle (within the Zone 2 lab. area) operating at slightly positive air pressure relative to the Lab.

2. In addition feed a small, continuous flow of air (from the shop air supply) to each control cabinet, in order to ensure a positive air pressure inside the cabinets in the event of pressure equalization between 'control room' and the Lab. Control cabinets to be dustproof (not necessarily fully sealed), and the Services Division will install the necessary airlines. Project to provide regulator.

3. All solenoid valves, motors, electronic gas flow controllers etc must have BASEEFA (or equivalent) rating for Zone 2 electrical. Maintenance tools should be pneumatic rather than electrical.

4. No electrical outlets (sockets) will be allowed in the Lab. area but, if necessary, they will be allowed within the control room.

2. SPACE ALLOCATED FOR THE GASIFIER TEST RIG

1. After a detailed discussion it was agreed that although it would be physically possible to install the complete test rig and associated control room within the space of a single Lab. module, it would be extremely unwise to do so, for the following reasons:

/cont...

- Safety hazard for operators and maintenance staff, due to lack of room and handling heavy components and a cluttered floor space.
- Loss in modularity and flexibility of the system, which would restrict its use on different projects in the future.
- Access difficulties to the test rig, entailing the use of an inner door with pressure equalization problems.
- Tortuous escape path for operators in the event of an emergency.
- Minimal access for visitors or non-operator personnel.
- Minimal space for maintenance work and storage of tools and equipment with heavy reliance on use of central building preparation room.

2. Other possibilities were considered such as the use of two complete modules, the relocation of the rig in a different module and module sharing between projects.

An acceptable compromise was evolved as follows (subject to confirmation and agreement by Station Directorate):

- Locate all pressurized test equipment in the north end module, with its own double door entrance.
- Convert the adjacent module into a separate, sealed and pressurized control room by partitioning up to the roof and incorporating polycarbonate viewing windows on each side. This work will be provided by the Services Division on the understanding that the control room will be shared by the Gasifier Test Rig Project and the project to the south of the control room. Entrance to the control room will be direct, and quite separate from entrance to the test rig cubicle.
- Normal security for access to the control room, but the use of a special procedure for access to the gasifier test rig module will be required.
- All electrical wiring in rig area to be MICE or MICC pyrocable, and an emergency shut-down button to be provided by the Services Division outside the laboratory.
- Steel panelling to be used as a safety shield where necessary along the control room wall (partition wall).

/cont...

3. COAL STORAGE AND GAS STORAGE

The position of the coal storage and feeding system structure on the forecourt in front of the north module of Lab.2 is acceptable as was shown on the plan of the rig system. The suggestion by that the structure should be made large enough to allow a certain capacity of additional gas and coal storage was appreciated and will provide an excellent operational buffer storage facility. The possibility of using 10-bottle cradles for gas storage is under consideration. If necessary the bottle bays for the test rig module may be extended by up to six inches outwards.

4. POWER SUPPLY

It appears that sufficient power will be available for the rig, based on first order approximations, but a closer definition of power requirements is needed. This will be possible only after all the ancillary equipment has been sized and selected. One general point is that starting loads for heavy power users should be staggered, using intervals of about two minutes.

5. REMOTE CONTROL OF RIG

A 32-channel fibre optic link is provided between the Test Rig Facility and the computer in the main building. This gives the equivalent of two twisted wire pairs of communication per module, one for transmitting and one for receiving. The fibre optic link terminates on a panel in the upstairs office of the Test Rig Facility.

ACTION ITEMS

1. Management approval of module space to be allocated to the Gasifier Test Rig in the event that the rig is constructed. Written notification of this.

   Responsible: BPO-S

2. Written confirmation that all valves and equipment to be supplied by Hale Hamilton would meet the BASEEFA (or equivalent) rating to meet the Zone 2 electrical specification.

   Responsible: R2-A

/cont...

3. Written confirmation that all valves, flowmeters and other equipment to be supplied by Brooks Instruments would meet the BASEEFA (or equivalent) rating to meet the Zone 2 electrical specification.

   Responsible: C Hales

C Hales
Research Engineer

8 August 1984

Distribution: DE-S
AM-A
S2-A
M-S
BPO-S
M-A
AM-S
R2-A
SL-A
RM-U
R1-A

PROJECT - WEEKLY REPORT

NAME	C. HALES	WEEK	97
SEGMENT	DETAIL DESIGN	DATE	10.8.84

1. ACCOMPLISHED THIS WEEK

1.1 Work at [redacted] on 6.8.84 (2.45 - 5.15 pm)

- Discussion with CDD regarding type of rubber to use for scrubber gaskets. C Hales decided on silicone rubber so as to be safe on temperature rating.
- Quick meeting with BPO-S. C Hales will write a note summarizing what was discussed and agreed to at the meeting held on 24.7.84. This will be distributed on approval by BPO-S.
- Meeting with AM-A. Discussed the following:
  - o Progress with detail design.
  - o Weekly reports up to No.97.
  - o How to get an estimate of scrubber performance.
  - o Abstracts of 4 papers to be submitted for ICED-85.
  - o Opening ceremony for Test Rig Facility and SL-A's idea for a House Committee.
  - o Lack of progress on A-form submission.
  - o Test rig layout in the building module.

1.2 Telephone call regarding Scrubber on 7.8.84

DE-U, Chemical Eng. Dept., Cambridge University

- He has looked through various papers and completed a series of calculations on the scrubbing of H_2S using ZnO. These are very approximate (but adequate for us).
- Results were as follows:
  1. ZnO to ZnS reaction loses efficiency with time.
  2. For existing 10 in. diam. scrubber and flowrate of 2 cu.ft./hour bed would last 100,000 hours if there was 100% reaction. For 12 in. diam. bed and 60 cu.ft./hour flowrate, equivalent life would be about 7,000 hours. As the maximum practicable conversion is about 50% these values should be reduced to about 50,000 and 3,000 hours respectively.
  3. The reaction is highly non linear and therefore predictions based on scale-up are unreliable.

97/2

  4. The higher the reaction temperature the better the reaction efficiency, up to 700°C.
  5. Experiments should be carried out to find the length of bed required using the time taken for H_2S concentration to rise in the output gas as a criteria.

1.3 Work at [redacted] on 8.8.84 (3.00 pm - 6.05 pm)

(3-3.20) - Discussed details of vessel frame with CDD.

(3.20-4) - Discussed floor loadings under vessel frame with BPO-S (280 lb/ft^2 = 15 KN/m^2 max.). Live load of 100 lb/ft^2 to be added to vessel dead load over whole frame (i.e. an additional 2½ tons). Discussed column feet, grouting etc. then the proposed 2 ton gantry crane. He didn't like the proposed runway column positions - on edge of floor pad - will cause cracks.

(4-5.10) - Further discussions with CDD on the vessel supports.

- Worked out a base arrangement for frame.

(5.15) - Updated SL-A on project progress.

(5.25-5.50) - Updated AM-A on project progress and discussed some points of concern over the Test Rig Building.

1.4 Work at CUED on 9.8.84

- Wrote 4-page summary on the meeting held with BPO-S, on 26.7.84 together with letter to BPO-S.

(6.30-8.30 pm) - Worked out heights and levels for vessels.

1.5 Work at [redacted] on 10.8.84 (11.15 am - 5.30 pm)

(11.15-12.10) - Worked out layout of solids collection vessels in cafeteria at Liverpool St. Station (as had headache). Also solids tank outside building (1 hour).

- Brief chat with AD1-R in lobby.
- Brief chat with AD2-R in LRS cafeteria. Updated him on project progress.

(2-2.50) - Went through new solids collection vessel layout with CDD. Looks OK. Timely as he was doing calculations based on old layout.

(2.50-4) - Discussions with R1-A but little of use to project.

(4-4.10) - BPO-S read the draft summary of the meeting and approved it, with minor additions. Services Div. will pay for providing the test rig control room.

- Updated SL-A on project progress by phone.

(4.10-5.30) - Explained more of background to project and research to CDD and DR-S. Went through work to be done by CDD.

APPENDIX B

FIELD RESEARCH ISSUES

B.1 OVERALL APPROACH

Observation-based studies are commonly divided into four groups within a spectrum of observer involvement [Burgess (C6), Denzin (C8)]:

(i) Complete observer;

(ii) Observer-as-participant;

(iii) Participant-as-observer;

(iv) Complete participant.

From the engineering design point of view this may be simplified into just three categories, each with a different degree of researcher involvement:

(i) Direct observation

(ii) Participant observation

(iii) Action research

Direct Observation

The researcher remains as unobtrusive as possible, recording what happens without taking part. It has the advantage that the field-work is wholly devoted to gathering data, but the disadvantage that the observer is one step removed from the process under study, as discussed by Thomas and Carroll (C32). They found that even with video recordings interpretation of direct observation data is difficult in engineering design. What goes on while the observer is absent is generally lost.

Participant Observation

The researcher takes part in the activity, at the same time observing and recording events as they occur. This has the advantage that more subtle aspects of engineering design can be explored. Madge (C20) suggests that it can help to reduce distortion as the researcher comes to think in the same way as the respondents, while they tend to behave unselfconsciously. Disadvantages are that the field-work is split between doing the job and recording what goes on (quite different parallel activities) and that the data is more likely to be affected by researcher bias. Adams and Preiss; Argyris; Mann and Likert; Candill and Roberts; Le Clair and Bain (C1) all contribute on these points, offering advice to the participant observer. Denzin (C8) lists six problems to be overcome:

(i) Gaining entry to the group (with repeated returns);

(ii) Establishing and maintaining a social identity permitting ongoing social relationships and observations;

(iii) Fitting in with the natural flow and rhythm without trying to change the behaviour of those observed;

(iv) Remaining objective and alert to deception in the light of new experiences;

(v) Developing a reliable method of recording field notes;

(vi) Knowing when to finish, then leaving at the proper time.

Origins, definitions, problems and applications of participant observation from the sociological and social anthropological points of view are fully discussed in the report by Drucker-Brown (C9), commissioned by the then Social Science Research Council in Britain. To the design researcher the report shows that despite the common use of participant observation as a research method in the social sciences there is still much debate over terminology, types of interaction and strategies to be used. It was the method considered appropriate for gathering data on this project (C11).

Action Research

The researcher as a 'complete participant' not only influences the whole situation through deep involvement, but actively plans to do so [Zeisel (C37)]. It is a different from participant observation and is used for a different purpose, as shown by Wilson (B71). In general while participant observation is used for developing understanding of an activity, action research is used for experimenting with new approaches for carrying out an activity. The only time that action research was specifically used during this study was for the planned experiment with the design of the control system. At certain other times a little 'action research' was applied to help overcome particular obstacles. It was felt better to try it and to record the fact, than remain an observer to the detriment of the project.

B.2 CASE SETTING

A 'natural' setting was used for this study rather than a 'contrived' one, [see Gregory (C11)], and the choice was limited by seven constraints:

(i) Commercial engineering design project required within a company.

(ii) Task to be complex rather than simple, requiring a team of people.

(iii) Design problem to be 'ill-defined', within a routine project.

(iv) Company environment to be accepting of a participant observer.

(v) 2-year project to start concurrently with the research programme.

(vi) Company to be interested in improving their engineering design.

(vii) Company to fund the research effort in return for design effort.

These constraints are more specific than the selection criteria for case settings offered by Burgess (C6) for example:

(i) Progression from simple to complex situations during study?

(ii) Easy access to the company for the researcher?

(iii) Possibility for researcher to take an unobtrusive role?

(iv) Permission likely for observation during touchy situations?

(v) Researcher able to participate in a series of ongoing activities?

The setting which satisfied the seven specific constraints imposed on the present study was considered to satisfy these general selection criteria.

B.3 PARTICIPANT OBSERVER

Comparisons between observation-based field studies, such as those of Bucciarelli (C5); Hastings (C12); Hykin (C13); Saren (C29); and Schalcher (C30), suggest that the personality of the researcher is an important factor in the use of participant observation. Adams and Preiss (C1) consider that the influence of the researcher on the field situation is central to the research, and the question is not how to avoid this influence but how to "...control and judge the quantity and quality of that effect". A non-threatening role which "...gradually evolves through changing perceptions..." is required, with the integrity to gain and maintain the confidence of the respondents. Encouragement of respondents is recommended by Adams and Preiss, despite the problems of bias it introduces, and typical techniques suggested are:

(i) Giving small services;

(ii) Using personal knowledge and expertise;

(iii) Using the 'therapeutic' value of an interview;

(iv) Becoming involved in respondents' concerns.

Argyris, in the same book (C1), concludes that:

(i) Researcher self-motivation with feelings of responsibility towards the organization and respect for its members is vital.

(ii) Active researcher involvement is required if expression of personal ideas and feelings is expected from respondents: a passive role only arouses anxiety.

(iii) The researcher must accept manipulation by respondents, as this shows their concern for the study and gives clues as to the forces at work in the organization.

(iv) Research findings must be communicated back to the organization.

B.4 DATA COLLECTION

Participant observation of the Gasifier Test Rig project followed patterns apparent in social psychology, social anthropology and human organization research. Careful note was taken of points emphasized in the literature, such as: positively motivating and gaining the confidence of respondents; maintaining integrity and a non-threatening role; ensuring participation of all the people involved; checking back with superiors; and handling of misunderstandings. As the procedure for the design work was clearly prescribed, the project showed immediate progress, and because the field research issues were quickly resolved useful data was collected from the start. In particular:

(i) Credibility of the participant observer was established;

(ii) Regular contact between the participant observer and respondents was established, and maintained through weekly visits;

(iii) The participant observer became actively involved and developed a regular procedure for reporting back to the company;

(iv) Conscious efforts were made to stimulate participation and response within the project.

The following techniques were used for data collection and recording:

(i) Daily journal (notebook) to record details of meetings,work, etc.;

(ii) Design notebooks;

(iii) Weekly meetings with project team members;

(iv) Audio tape-recordings of selected design sessions;

(v) Weekly reports to summarize design and research progress;

(vi) Occasional photographs.

A total of 37 people were involved in the project to the extent of having identifiable input. Within the sponsoring company these ranged from the research staff to engineering services staff, and from technician level to director level. At each level, dialogues, working sessions, small group meetings, chance meetings and larger formal meetings were recorded as 'interchanges', as defined by Baker (C2, p.1014), with extra notes on informal social contact and personal discussions. For each visit to the Company a plan for the day was written beforehand. What actually happened was recorded as it happened, and more detailed notes were written after the day's work. Although the data was specifically concerned with the the test rig project, wider issues were sometimes involved and where this took time which would otherwise have been spent on design work it was recorded. For instance designer effort was spent helping with the justification for project construction funding and on two formal presentations made on the design and draughting problems. During 116 weeks of design project time (including holidays) 100 half-day or full-day visits were made to the sponsoring company. 1373 interchanges were recorded covering 2368 hours of project effort including 120 telephone calls and 10 visits to outside organizations. The data from this amounted to 1180 pages of field notes and 76 hours of audio tapes.

Notes on data collection:

(i) Bound notebooks were found to be better than page limited diaries. They are simple, portable and fit in with engineering design work. Size-reduced photocopies were used to compile field data files.

(ii) Identical notebooks were used for design work and field notes: this facilitated unobtrusive note-taking as events occurred.

(iii) When events moved quickly it was impossible to keep up with notes. Sketchy notes were made and filled out after the day's work.

(iv) When the participant observer was strongly 'participating', field notes could not be made without disrupting the working atmosphere.

(v) Microcassette tape-recording was tolerated except under particular circumstances, and was found to be simple and unobtrusive. In the design office it became accepted in a good natured way, but at the management levels it was accepted only when technical matters were being discussed and permission had been given. If the machine was likely to inhibit a discussion it was left off, and in full view. The tape-recordings were used only as back-up and reference data.

(vi) Very little data other than time spent and work done was recorded while the participant observer was working alone.

(vii) Most notebook entries simply recorded what was said or done and there was little time for subjective interpretation or reflection.

(viii) As data was collected for over two years a lot of background and repetitive information accumulated. This seemed inefficient but it later helped in verifying changes in 'mood' etc.

(ix) It was considered important to try and gather Self-Perception data to help assess how people perceived their roles within the project team. Belbin's approach (I2) was tried, but with limited success as team members were suspicious of why a design engineer should want such information. If a researcher with credibility in social psychology also been involved, better data would have resulted.

(x) Events were usually recorded as they occurred and multiple methods of data collection were used. Cross-checks for reliability and bias could be made by 'triangulation' (comparison of data from different sources) as recommended by Denzin (C8) and Madge (C20).

B.5 POSSIBILITIES AND LIMITATIONS

For this project a stable working relationship was established between the participant observer and the Company through simple control mechanisms: if the researcher became too involved the company could withdraw observation privileges without terminating the project and if company tensions made participation risky, the researcher could withdraw to a direct observation role while maintaining contractual obligations. (Note: neither direct observation nor action research offer such simple 'fall-back positions'). Establishing a stable relationship was critical, as the focus then shifted away from the researcher towards the design project itself, and by virtue of a combined 'design engineer' and 'visitor' status the researcher gained the privilege of legitimate access at many levels in the organization. This gave the researcher the opportunity of collecting data at different 'resolution levels'. It gave the management a chance to get some feedback and the project team a new communication path to try. It also became possible for the researcher to try various design techniques and plan a few short-duration experiments within the overall project.

Main limiting factors found during this field study were:

(i) Credibility as a researcher depended on that as a design engineer.

(ii) Data was limited to what one researcher could grasp and cope with.

(iii) Fast-moving events were difficult for a single observer to record.

(iv) Design work and research work had to be carried out in parallel.

APPENDIX C

DATA PROCESSING

C.1 FIELD DATA

Raw Data Files

Integration of the raw field data into a single set of 3 files was done by photocopying all field notes, correspondence, design notes, drawings and other information at reduced scale. This resulted in 1180 sheets filed in chronological order. The following steps were then carried out:

(i) Check for ommissions and incorrect sequencing;

(ii) Removal of irrelevant notes and records;

(iii) Correlation to avoid double-counting data from multiple sources;

(iv) Marking out the 1373 identifiable events or 'interchanges' [for definition and other examples see Baker (C2)];

(v) Colour-coding the 37 project participants as shown in Figure C-1 (end of text) and flagging their involvement in each interchange.

Tape-Recordings

Audio tape-recordings were filed chronologically for use as back-up data.

Weekly Reports

Weekly reports were filed by number for use in cross-checking the data.

Gasifier Test Rig Design Reports

These six reports were to provide a detailed record for the Company rather than for the research and were not used as research data for the analysis.

C.2 INTERCHANGE DATA SHEETS

Once the field data files had been compiled and marked up it became clear that if the essential information could be extracted and transferred on to standardized sheets this would provide a categorized data summary suitable for analysis. Experiments led to development of the 'Interchange Data Sheet' shown in Figure C-2, and a set of such sheets was completed for each participant. Column entries for each record were:

Interchange Number - record number for participant - ascending order.

Date - date of interchange in time-of-day order.

Time - observed time for interchange in decimal hours (to 0.1 hour).

Type - type of interchange and the total number of people involved.

Location - location of the participant at the time of the interchange.

Topic - nature of work, discussion or activity during the interchange.

* Mood - observed 'mood' of the participant during the interchange.

Remarks - qualifying statements to add context and clarify meaning.

* This was not the 'mood' of the interchange itself. For example a person may be observed as being enthusiastic in a meeting generally observed to be quiet. Words used were taken directly from the source data and not from a menu of standard terms. The 'mood' column therefore reflects the source data commentary as accurately as possible. If no indication of 'mood' was recorded, a blank was left in the 'mood' column.

The field data was reduced to 2488 individual records on 63 Interchange Data Sheets. Entries were cross-checked (C11, p.777) and a master list of interchanges compiled. A great saving in effort could have been made if every event had been assigned an interchange number in chronological order from the start, but many could not be put in order until the records for each person had been completed and scanned. The most awkward items were letters which had been sent out with carbon copies at a particular time and were received by people at later times, after other interchanges had taken place. Unlike a telephone call, where all participants are present at the time, the writing and the receipt of letters had to be treated as separate interchanges. Two months of full-time effort was spent checking the data sheets for consistency and accuracy.

Notes on Interchange Data Sheets:

(i) Source data that was missing or out of chronological order caused errors in the interchange sheet. This was time-consuming to fix.

(ii) Errors were not easy to pick up until data sheets were finished for several participants, and by then changes were difficult to make.

(iii) To test the data sheet format those participants with only a few interchanges were considered first. In retrospect it is clear that sheets for the participant with the most interchanges should have been completed first, to structure the master list of interchanges.

The data sheets were reviewed by the project manager at the Company before being processed any further. Records were checked and in particular the manager's own set was closely examined. Although the use of certain words was questioned, and qualifying remarks were suggested, there was agreement over the data entries. Particular incidents were recalled, and the sheets checked for accuracy: again there was agreement. For example the manager found an entry for one participant which indicated an out-of-character mood known to occur only in specific circumstances. A check on the other entries or 'fields' for that record confirmed that just such circumstances had been observed. As a further check on the data sheet accuracy a book of 35 summary sheets was produced, listing the hours for all interchanges and showing which participants were involved in each one. This provided a cross-reference for verifying all quantitative entries. The format of the Interchange Data Sheets had been designed for easy transfer of records into a computer database, although at the time there was no certainty that the data could or should be handled using a computer. It was decided that an attempt to do this would be made, despite the great effort involved in entering and verifying the records, as it would facilitate quantitative analysis of the data. The book of summary sheets provided an independent means for manually cross-checking every entry into the computer database.

C.3 DATABASE FILES

Commercially available database software (dBASE III by Ashton-Tate) was initially tailored to the project by a specialist who set up an individual file for each participant. The interchange sheet format defined the main fields in the database, and additional fields were then added for entering activity and design-related technique codes. There were 3 working modes:

INPUT mode - for entering data, project phase and hourly charge rates.
EDIT mode - for editing individual files and adding categorizing codes.
ANALYSE mode - for running the sorting, browsing and calculating routines.

It was thought that when the data had been entered into the computer, and had been checked against the summary sheets, it would be possible to enter classification codes for the activities and design-related techniques, then analyse the data accordingly. Although in the end this was done, a two-month effort was first required to remove inconsistencies and errors from the data. Whereas in dealing with the data sheets manually, an error of say 0.1 hour for one participant in a particular interchange was of little consequence, it was unacceptable in the computer database. The computer would regard this as two separate interchanges and adjust everything accordingly. This became obvious once the decision had been made to use a computer, but at the stage where there were doubts as to what constituted an interchange in the first place it was not obvious. Much of the later research effort went into developing techniques for systematically linking, checking and cross-checking the data to produce a satisfactory working database. Such problems could have been greatly reduced if it had been possible to collect the field data on standardized sheets and enter it directly into a computer.

C.4 REDUCED DATABASE FILES

Once the main database had been 'debugged' it was possible to use the dBASE III indexing, sorting and summarizing facilities to create summary files concerned only with specific aspects such as hours per person per month and techniques used during each activity. The volume of the main database including all fields was 438467 bytes. From this a reduced one of 281659 bytes was derived, and this was indexed by date, person, type, phase and 'mood' to give some trial results. This in turn led to a third database which had additional key-fields for indexing by month, activity, design-related technique and combinations of these. It was this third one which became the master database from which all final tables and graphs were derived, and its volume was 336523 bytes (one 5.25 inch floppy disc). The database had been installed on a personal computer with a 10-megabyte hard-disk drive (IBM 3270 or PC XT), and by the time the necessary index files and summary files had been created, between 5 and 8 megabytes of the available disk storage was in use. File management became complicated, despite frequent 'clean-ups', and backing-up the files required a lot of manipulation and care. The main reason that so much file storage was required was that although the dBASE III package could produce the summary files it had no facility for converting these to an appropriate tabular or graphical form. The summary files had to be translated for use in another software package installed on the same hard disk, as discussed in the next section. The complete set of files and software was backed up on 9 floppy disks, and extra back-ups were made of master files.

C.5 TABLES AND GRAPHS

To produce tables for comparison with those of Pahl and Beitz, and graphs to show other results, it was necessary to translate the summary database files into 'spreadsheet' files using other available software. The Lotus 1-2-3 database, spreadsheet and graphics (combined) software package was chosen for the final data processing, after trials with other packages. Although the database facilities of this could not cope with the main data files, it could handle the summary files, which were then manipulated into the tabular formats required. This was by no means an automatic procedure, and considerable effort went into devising suitable formats including expressions for calculation of totals, percentages and means. However, once this had been done it became comparatively easy to analyse the results from various angles. Preliminary results were produced using dot-matrix printer, the final tables with an ink-jet printer and the final graphs with a flat-bed plotter. The complete set of spreadsheet files was backed-up on 8 floppy disks and additional back-ups were made of the master files.

C.6 CONCLUSIONS

(i) A manual method of reducing the raw field data by a factor of 20 in volume was developed. It resulted in Interchange Data Sheets with data in a form suitable for entry to a computer database.

(ii) Commercially available software was suitable for handling the data. Its use resulted in an overall data reduction of 24 by volume and the generation of summary tables and graphs.

(iii) By use of a computer the complete history of the 2.8 year project could be summarized on 24 data sheets (Appendix A.1), and the 2368 hours of work from 37 people could be detailed in a single table (Figure 2-14).

(iv) The master database for the project could be stored on two standard floppy disks, allowing easy transfer between computer systems.

(v) Most of the analysis effort was spent in checking and cross-checking the Interchange Data Sheet and computer database records.

(vi) If data could be collected using Interchange Data Sheets, then fed directly into a computer for analysis, most of the problems of data handling could be overcome and research time would be reduced.

KEY TO PARTICIPANT CODES - GTR PROJECT

FUNCTIONAL GROUP	PARTICIPANT	COLOUR CODE	COMPUTER CODE	NUMBER OF INTERCHANGES
DIRECTORS	Director G	G	D_G	8
	Director R	R	D_R	7
	Assistant Director 1	1	AD1_R	5
	Assistant Director 2	2	AD2_R	11
MANAGERS	Manager A		M_A	58
	Manager S		M_S	22
	Assistant Manager A	1	AM_A	154
	Assistant Manager S	2	AM_S	60
RESEARCH STAFF	Section Leader A		SL_A	212
	Section Leader P	P	SL_P	17
	Assistant Section Leader		ASL_A	35
	Researcher 1 A	1	R1_A	81
	Researcher 2 A	2	R2_A	68
	Specialist 1 A	1	S1_A	18
	Specialist 2 A	2	S2_A	7
	Specialist 1 P	P	S1_P	14
SERVICES STAFF	Building Projects Officer	1	BPO_S	40
	Services Officer	2	SO_S	4
	Design Engineer		DE_S	133
	Draughtsman	1	DR_S	65
	Graphics Illustrator	2	GI_S	27
REMOTE SUPPORT STAFF	Coordinator G	G	C_G	3
	Quality Assurance Officer	Q	QAO_H	7
	Safety Officer	S	SO_H	4
	Design Engineer 1 M	M1	DE1_M	11
	Design Engineer 2 M	M2	DE2_M	1
CONTRACT STAFF	Contract Design Engineer		CDE	1060
	Contract Controls Engineer	1	CCE	96
	Contract Detail Designer	2	CDD	101
SPECIALIST SUPPLIERS	Sales Engineer - Feeders	1	SE_FE	22
	Sales Engineer 1 - Valves	2	SE1_VA	12
	Sales Engineer 2 - Valves	3	SE2_VA	7
	Sales Engineer - Vessels	4	SE_VE	8
	Sales Engineer - Flow/Gen.	+5	SE_FL + G	37
UNIVERSITY SUPPORT	Project Monitor - CUED	K	RM_U	49
	Liason Officer - CUED	N	LO_U	21
	Design Engineer/s - CUED	A+J	DE_U	6
TOTAL OF 37 PARTICIPANTS			TOTAL	2488
TOTAL HOURS 2368.6				
AVERAGE LENGTH OF EACH INTERCHANGE = 0.95 HOURS				

Figure C-1 Colour Codes and Computer Codes for Participants: Gasifier Test Rig Project

PROJECT : GASIFIER TEST RIG						DATE: 2/5/86
PARTICIPANT : CONTRACT DESIGN ENGINEER					CODE:	SHEET 11 OF 22

INTERCHANGES No.	DATE	HRS	TYPE	LOC.	TOPIC	MOOD	REMARKS
501	(1984) 9/4	0·2	M-3	D	General on dwgs.	Questioning	Imp. versus Metric.
502	9/4	0·9	W-2	D	Steel vessel frame	Urgent	Checked dwg dims.
503	9/4	0·5	W-1	D	Graphical symbols	Urgent	Copy of std. for CCE
504	9/4	0·4	M-3	D			
505	9/4	1·8	M-2	O			
506	10/4	0·1	T↓	O			
507	10/4	2·0	L-↑	O			
508	10/4	6·5	W-1	O			
509	11/4	0·9	W-1	T			
510	11/4	0·2	M-2	O″			
511	11/4	0·3	M-3	D			
512	11/4	2·0	W-3	D			
513	11/4	0·6	M-3	C			
514	11/4	1·5	W-3	D			
515	11/4	0·1	W-2	P			
516	11/4	0·1	M-3	D			
517	11/4	0·4	M-2	O″			
518	11/4	1·2	W-2	L″			
519	11/4	1·3	M-2	O″			
520	12/4	0·1	T↑	O			
521	12/4	1·0	W-1	O			
522	12/4	8·5	W-1	O			
523	13/4	0·9	W-1	T			
524	13/4	0·1	M2	P			
525	13/4	0·2	M2	D			
526	13/4	0·5	M-2	D			
527	13/4	1·3	W-1	D			
528	13/4	0·9	M-3	C			
529	13/4	1·0	M-2	D			
530	13/4	1·8	W-2	O″			
531	13/4	0·8	M-2	O″			
532	15/4	2·0	W-1	H			
533	16/4	0·1	T↑	O			
534	16/4	0·9	W-1	T			
535	16/4	0·3	W-2	D			
536	16/4	1·5	L-↑	D			
537	16/4	0·1	M2	O″			
538	16/4	0·3	W-1	C			
539	16/4	3·8	W-1	D			
540	16/4	0·1	M2	O			
541	16/4	0·2	W2	L′			
542	16/4	0·1	T↓	D			
543	16/4	0·2	T-↑	O″			
544	16/4	0·1	L-↑	O″			
545	16/4	0·2	L-↑	O″	Letter to CCE	Neutral	Copy for SL-A
546	16/4	0·1	L↓	O	Visit to M	Enthusiastic	Visit on 18/4 to M.
547	18/4	1·1	W-1	O	Prep. for visit to M	Cheerful	Dwgs & proj description
548	18/4	1·7	M-2	E	General discussion	Cheerful	Project organization
549	18/4	2·0	W-1	E	Coal feeding tests	Pleased	Demonstrations by M
550	18/4	0·2	M2	C	Project progress	Enthusiastic	D-G gave dwg to another eng

KEY TO SYMBOLS

TYPE (ALL INTERCHANGES INVOLVE CDE EXCEPT W1, W-1 OR WHERE ANOTHER PARTICIPANT IS INDICATED IN TYPE COLUMN)

M = Meeting (formal or informal)
W = Work
T = Telephone Call
L = Letter
N = Note
– = More than just momentary
↑ = Outgoing
↓ = Incoming

Examples:

M – 3 = meeting with 3 people present
W – 1 = Work done alone
T↓ = Short incoming phone call.
M4 = Short verbal interchange with 4 people present.

LOCATIONS

O = O = Own office (of participant)
N = O′ = Office with others present (not working on GTR)
A = O″ = Someone else's office
R = R = Conference room
P = P = Corridor / Lobby / Passage
L = L = Lab. (L′ = other's lab.)
E = E = Outside the buildings / area.
C = C = Cafeteria / Canteen.

D = D = Drawing Office
T = T = Travelling (train, bus etc)
B = Li = Library
H = {H = Home, Ho = Hospital.}

Figure C-2 Sample Interchange Data Sheet

APPENDIX D

DESIGN PROCESS MODELS

D.1 FRENCH

D.2 OSTROFSKY

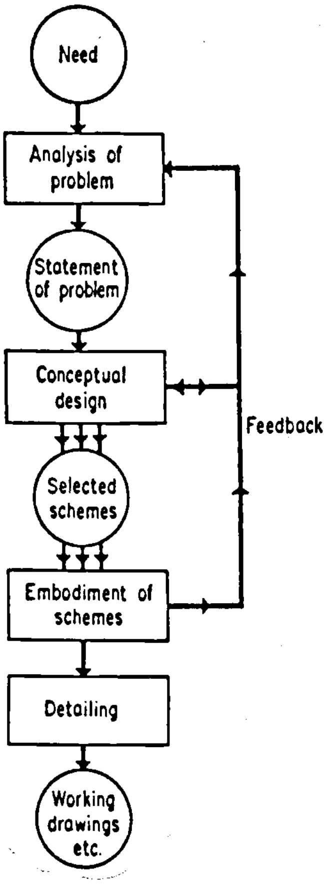
D.3 PAHL AND BEITZ

D.4 PUGH AND SMITH

D.5 EHRLENSPIEL

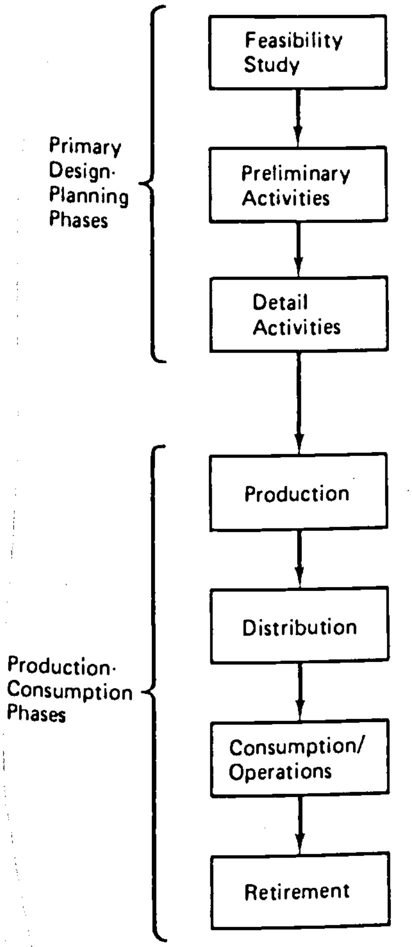
D.6 BESSANT

APPENDIX D.1 BLOCK DIAGRAM OF ENGINEERING DESIGN PROCESS
From French, M.J.:
Engineering Design - The Conceptual Stage: Ref. B24.

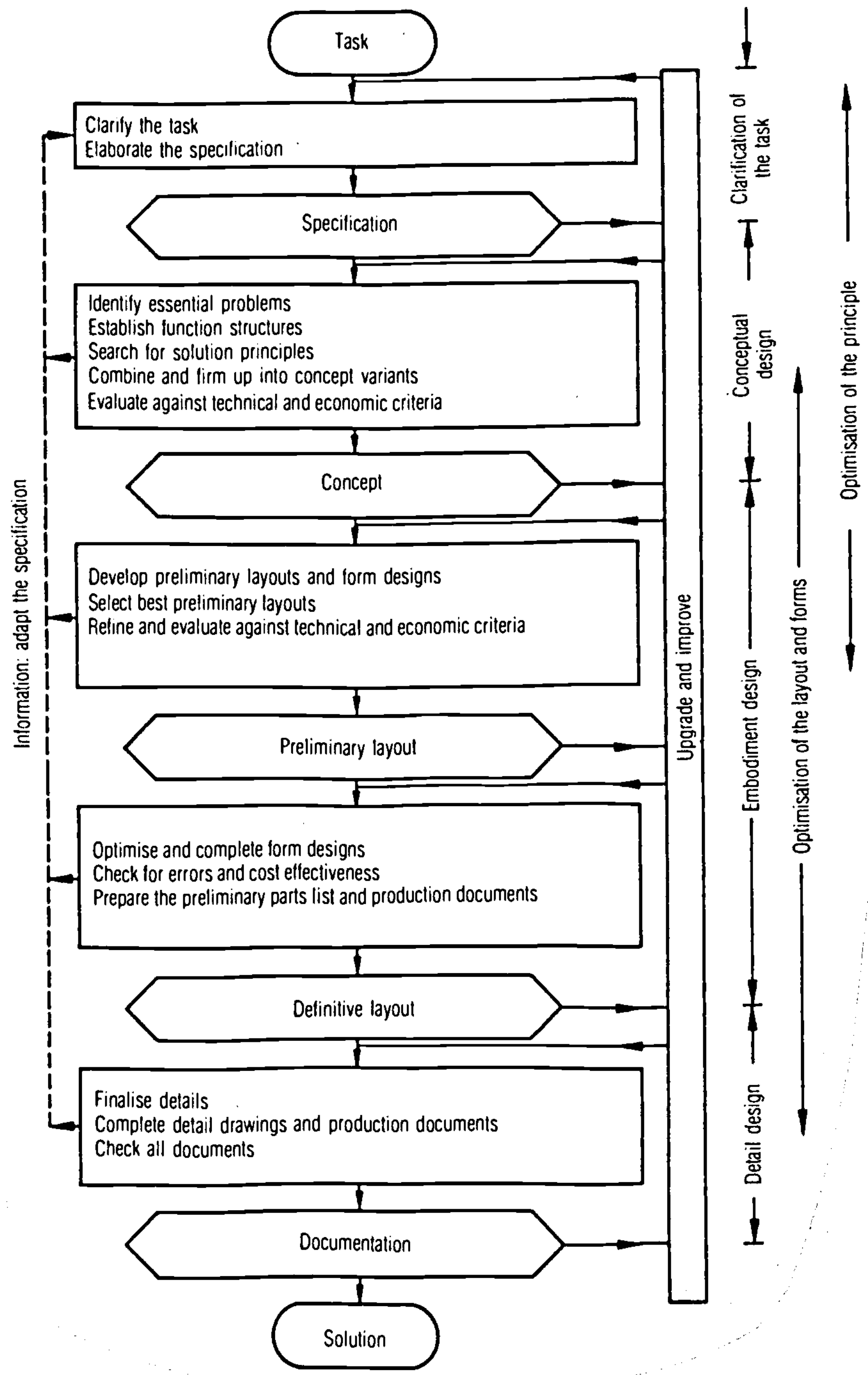


APPENDIX D.2 DESIGN MORPHOLOGY

From Ostrofsky, B.:
Design, Planning and Development Morphology:
Ref. B46.

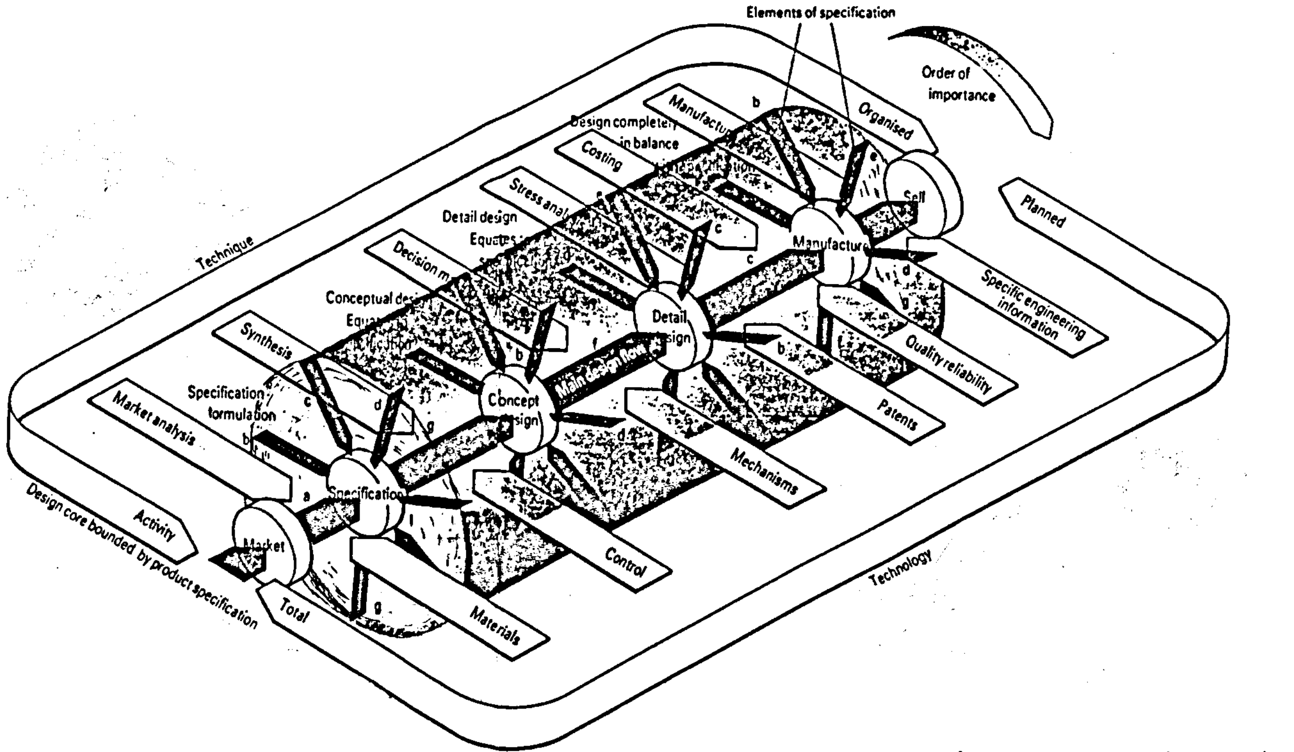


Phases of the designer-planner project life.



APPENDIX D.3 STEPS OF THE DESIGN PROCESS

From Pahl G. and W. Beitz: Engineering Design. Ref. B48.



APPENDIX D.4 DESIGN ACTIVITY MODEL - Pugh, S. and D.G. Smith: Refs. B52 & B54,

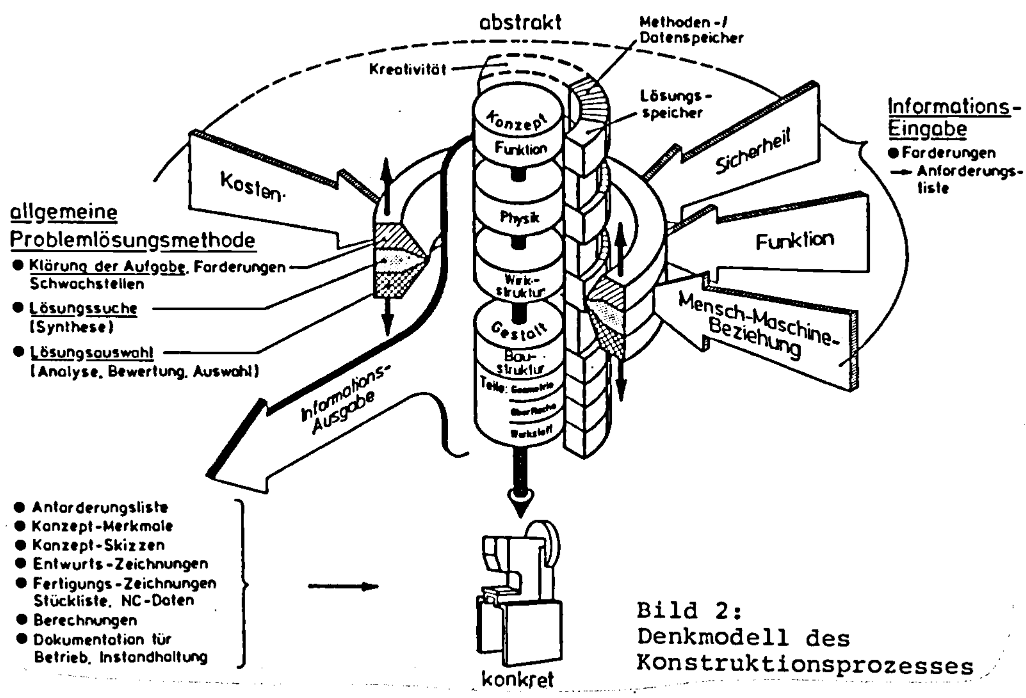
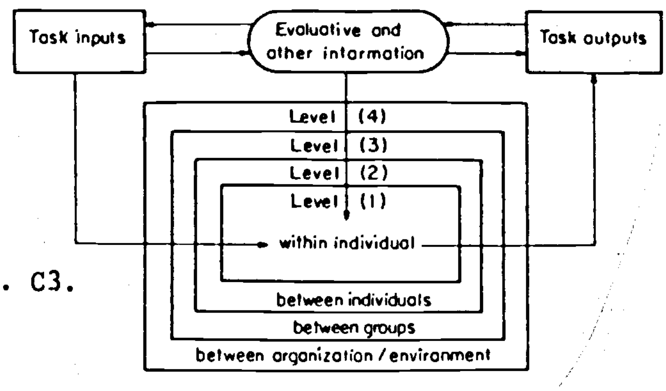


Bild 2:
Denkmodell des
Konstruktionsprozesses

APPENDIX D.5 MODEL OF THE ENGINEERING DESIGN PROCESS
Ehrlenspiel, K.: Ref. B22.

APPENDIX D.6 FRAMEWORK FOR A
MULTI-LEVEL MODEL
Bessant, J.R.: Ref. C3.



Possible framework for a multi-level model