Five years experience with VDI 2222 guideline in a large capital equipment enterprise

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This paper examines the experiences of the Escher Wyss company in the implementation of the VDI 2222 guidelines. Various practical suggestions are made to encourage acceptance of the guidelines by the user.

The continual shortening of the economic life cycle of products has not stopped even with capital goods. It is reckoned that in the 1960s a new turbine, a large diesel engine, a major boiler, or an installation concept permitted trading for about 20 years without marked change but that today this horizon of expectation has shrunk to 5-8 years.

The basis for this development will not be analysed here. Rather the effects on the enterprise will be looked at, in particular the effect on research, development and design.

The consequences of the development outlined above lead to three points:

- The development and design of new products, previously only a rare occurrence, is now a lasting difficulty.
- With capital and material costs outside the influence of the enterprise West Germany still stands in the leading group of industrialized countries. A rational operation of labour and material is therefore necessary.
- The technical and commercial risks of new products are growing in view of the increasing investment and international market needed for capital goods.

Nearly all the larger enterprises were already aware of this problem at the beginning of the 1970s and had at least attempted progress and cost monitoring of research and development. It was already known that direct and detailed control of such projects was not easy to achieve since they were based upon a difficult-to-supervise mixture of creative and routine individual activities.

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In this situation the Guideline 2222 procedure published by the VDI *Conception of technical products* was brought into practice. The whole of development and design from problem statement to production release was linked into supervizable sections with definite separation points. In this briefly described procedure outline there was no specification of any particular branch or organization, so that the necessary freedom of action remained for it to be adapted to relevant requirements. A stimulus to the use of the procedure was that successful designers had set it out, without however abandoning the theoretical support provided by the design teaching institutions. It is to the lasting credit of Dr Fritz Kesselring, the then chairman, that he led this workable synthesis of theory and practice.

In the firm of Sulzer and Escher Wyss there was support for the work of the VDI from the beginning, both with concrete help and case examples.[1] About 1972 the first tiny project was carried through with surprising technical and commercial success. This encouraged us to apply the procedure to larger projects so that very soon certain key points emerged. (See Figure 1.)

The key points of procedure were requirements lists, the methods of finding solutions (brainstorming and morphological analysis) as well as solution evaluation for concepts and schemes. An organizational key point is the introduction of a separation between project, concept,bid (or order) and execution release. Experience was essentially in the product sector of paper machines and material treatment at Escher Wyss GmbH, Ravensburg. For this product sector some 30 development projects were carried out annually by the corporate research organization at a cost of 6-8 million DM.

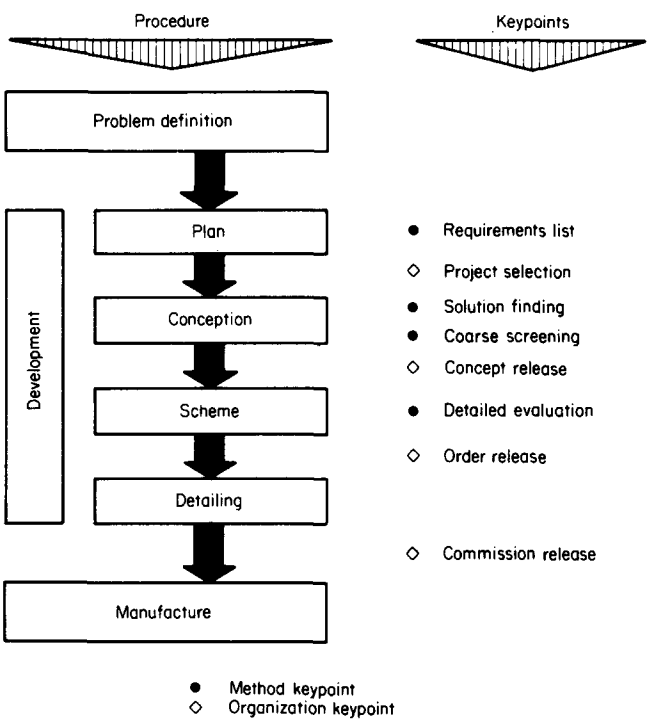

Figure 1. Method and organization keypoints from the VDI-2222 procedure

METHOD KEY POINTS OF THE PROCEDURE IN PRACTICE

Requirements lists

In the beginning it was recognized that requirements lists were an important tool in the harmonization of ideas about a new development between sales and technical departments. There already existed problem definitions in the form

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of development plans, job notices and management protocols. The interpretation of these by those who assist in carrying through the development, their written formalization as requirements lists and the approval by agreed decision-makers has brought a new development to the frequently omitted clarification of objectives. With requirements lists which we build up together with significant help from sales, it has been possible to expose what has hitherto been a dream both for the sales and technical departments and bring it down to a realizable measure. Thus, an early and constructive working unity between these two forces, although not eliminating conflict, significantly reduces it.

One of the many example is given in Figure 2 which shows an extract of the requirements list for a NIPCO calendering plant.[2] This is a device in paper-making with which the paper is polished to improve printability before it is formed into rolls.

The paper runs between several rollers; the rollers are hardened and polished. The bowing of the rollers is usually corrected by grinding. The technical interest in this development was the clear challenge of the NIPCO roller, an internally supported and hydraulically operated roller, with which thickness correction of the paper channel is possible[3] through variation of the line pressure along the roller gap with accompanying bowing compensation. The proposal is shown in terms of firm requirements, least requirements, and preferences (wishes), and their quantitative aspects. An indication of significance (1 - 4 stars) is given to direct effort to the essential points of the proposed completion and capacity framework.

Requirements list	Proposal: PT924-Link	Date: 6.5.197-
for a four-roll polishing plant	Approved: PT920-Wd	Date: 10.5.197-

Requirement	Quantification	Significance
Firm requirements		
● Bottom NIPCO roller	Type F	• • •
● Total roller-gap	30mm	• • •
● Signal track take-off	Electric	• •
● . .		
Least requirements		
● Machine width	> 2500mm	• • •
● Minimum line pressure	< 10 kp/cm²	• • •
● Maximum line pressure	> 180 kp/cm²	• • •
● Line pressure range as percentage of average	± 40 per cent	• • • •
Preferences		
● Intermediate or upper roller with/ without shaver		
● NIPCO roller without drive		
● with/ without compressor equipment		

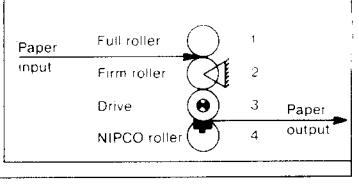

Figure 2. Extract from the requirements list for the NIPCO calendar

It is important that each requirements list should contain the names of the originators with the initiating date as well as the name of the person approving. For each project which exceeds an expenditure of more than 1 man-month, there should be a requirement list and this should be kept simple. Many fly-by-night schemes die an early death during the preparation of a list, since it forces reflection on the necessity of a development before much money is spent. Experience shows that it is not possible to propose a requirements list completely at the first attempt: during the sequence of a project additions, clarifications and other changes occur. It is important that the changes should be approved through the same office which proposed the initial scheme.

The requirements list is an important document that makes possible, even after some years, the checking of the original objectives. It is possible therefore to describe this as confirmation of the development order.

FINDING SOLUTIONS

Of the numerous solution-finding processes described in the literature as well as in the VDI Guideline we use almost exclusively brainstorming and morphological analysis. The prerequisite for successful application of these known and established methods is basic functional analysis and synthesis.

Without doubt function thinking is one of the most difficult of the concept-finding processes because of its great potential for abstraction, and it is therefore strongly avoided by practical men who refer to 'unnecessary academic exercises' and the expense of time involved. Because of this we have developed a special training course in which such function thinking is exercized. In doing this it has proved necessary to build up the VDI Guideline in this area and formulate it more practically. In particular the introduction of function structure as a hierarchical arrangement of the sub-functions of a technical form proves advantageous where a linear function chain in most cases does not stretch to the development of real objects.

Figure 3 shows the outline of a NIPCO roller. A range of stay-units is actuated within a stationary yoke and their head carries over to the shell a hydraulically-produced force by a four-pocket hydrostatic reservoir.

Figure 4 shows an extract from the relevant function structure in which the sub-function 'provide support force' is broken down into two further sub-functions of lower rank. The sub-function 'produce support force' can be further broken down so that, for example, the chosen working principle 'hydraulic piston' may be split

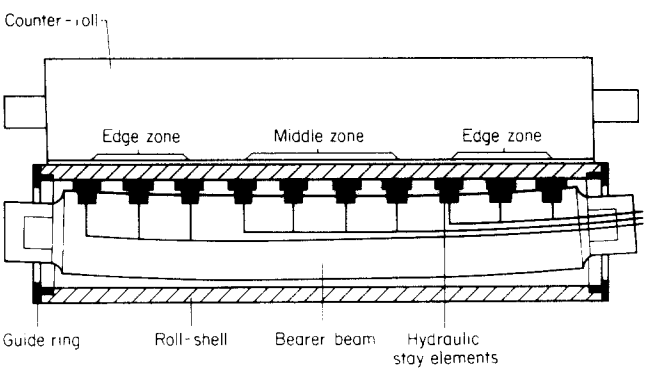

Figure 3. Principle of the NIPCO-roller (Escher Wyss)

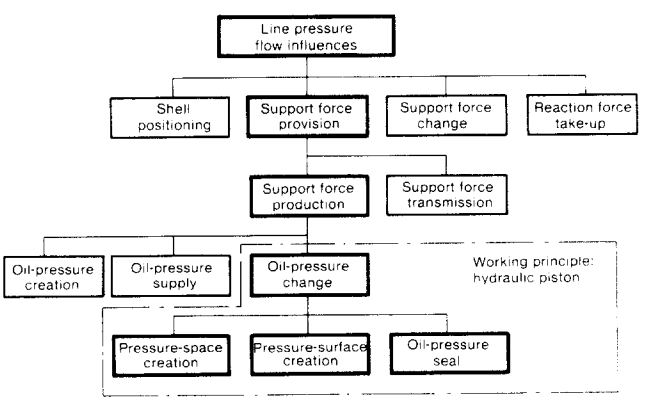

Figure 4. Extract from the function structure of internally-stayed roller (NIPCO roller)

into the sub-function 'change oil pressure' as indicated. If another working principle is chosen the relevant function structure is changed.

The special value of the function structure lies in the fact that it is possible to distinguish the function levels in which new solutions should be sought. The smaller the separation of the overall function from the sub-function of which a solution is sought, the more novel the solution might be. With functions found in this manner the open-ended search for solutions with the help of brainstorming may be much reduced. According to our experience the most interesting ideas come two or three days after the session through the unconscious work of the participants on the problem. There should be a further several days to rank and evaluate the solutions.

The representation of solutions has taken account of morphological analysis; it shows in a particularly comprehensive way all the theoretical choices in a compact manner, as well as the inspected solutions. We make use of the morphological box mainly in the way recommended by the VDI, ie as a matrix built up from sub-functions and their solution principles.

The idea of the morphological box may be varied as shown in Figure 5. The solutions to the requirements list of the polishing plant may handled as in Figure 2. Instead of the functions the positions of roller 1–4 are given on the left from top to bottom. Because of the relatively few solution principles for each sub-function we have set down not only the rigorous function notions but also the practical schemes for subsolutions, eg fixing (of the roller): yes or no; relative roller diameter (taken from a solid roller): small, medium, or large; roller type: NIPCO roller (with moving shell), NIPCO K-roller (with concentric shell fixed to the yoke), and solid roller. Each sub-solution carries a symbol. Through combining sub-solutions for each roller position the main solutions may be shown. The diagram shows an example in which the sub-solutions for each position are specified by letters.

Such a morphological scheme is an important document for each development project and makes possible control for a longer time if a newly emerged idea has already been considered at the time of the original solutions search. The morphological matrix should logically contain all competitors' solutions. Through the direct substitution of one's own and other people's solutions, comparison is possible. The matrix is a central feature of product description and evaluation.

EVALUATION

The euphoric phase of solution finding is followed by the sobering phase of evaluation. This needs the critical weighing

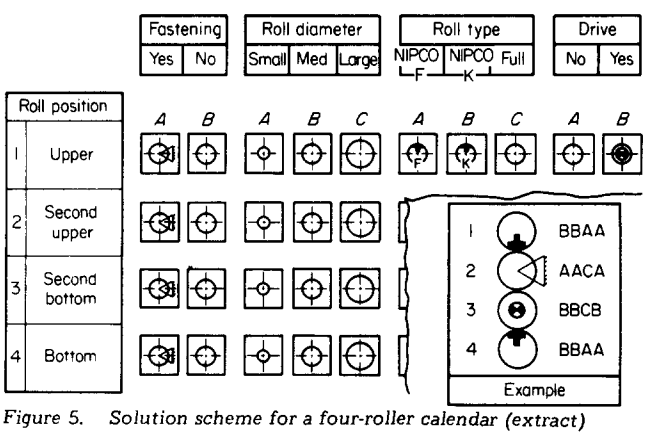

Figure 5. Solution scheme for a four-roller calendar (extract)

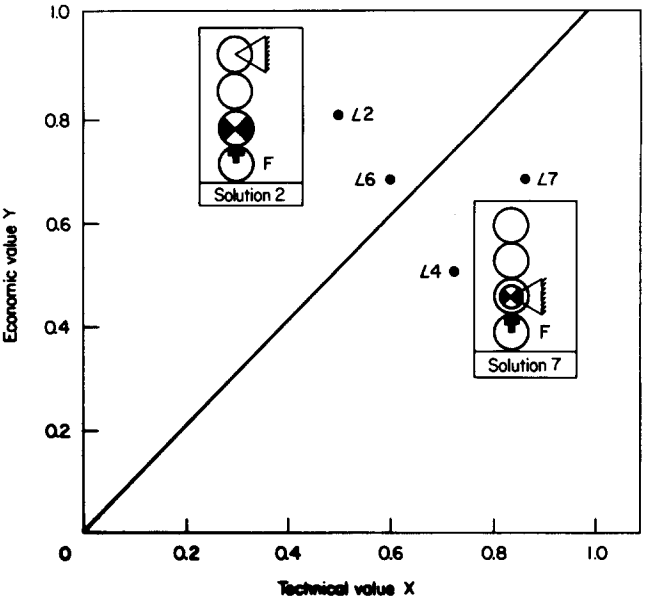

Figure 6. Technoeconomic evaluation of four-roller calendar concept schemes

up of individual solutions in the light of detailed knowledge of relevant characteristics. Also here we use what is applicable of the weighted point evaluation for technical and economic characteristics[4] as in the strength diagram corresponding to VDI Guideline 2222 (Figure 6). The diagram includes the evaluation of the chosen solutions L_2, L_4, L_6, and L_7 which were obtained from the solution display in Figure 5.

The evaluation process is of the greatest importance for the success of a new solution. With assistance from the sales, technical and production departments in this operation there is an opportunity for the first stimulus towards integration. It is easier to reduce the known and unknown resistances against everything new through the active participation of those who will later be involved with the new product.

Our experience shows that the evaluation lists have important side-effects. One is that each participant in the development of the concept favours openly or secretly a particular solution and can be disappointed if his solution does not succeed. The open and regular evaluation process avoids this discouraging effect, or tempers it at least, since it is based upon an overall view and partial views cannot predominate. Another effect is that evaluation lists are a conspicuous cause of argument as much by individual management as later by customers; they were applied by us partly directly for this purpose. It is important to keep one's eyes open so that the evaluation procedure is a help to decision-making and not the decision itself.

CONCEPT PHASE ACTIVITY EXAMPLE

As an example of a larger development project for a sheet-forming unit the concept phase is set out with its method key points within the total activity (Figure 7).

By a sheet-forming unit is understood that part of a paper machine where a strip of desired breadth and thickness is formed from paper fibres suspended in water.[5] For this an adjustable nozzle slit is used which sprays the suspension between two screens with a velocity of up to 2000 m/min. Through filtration the water is removed from the suspension sufficiently to form cohesive fibre mat which is eventually dried further by mechanical pressure.

After forming the project group and before

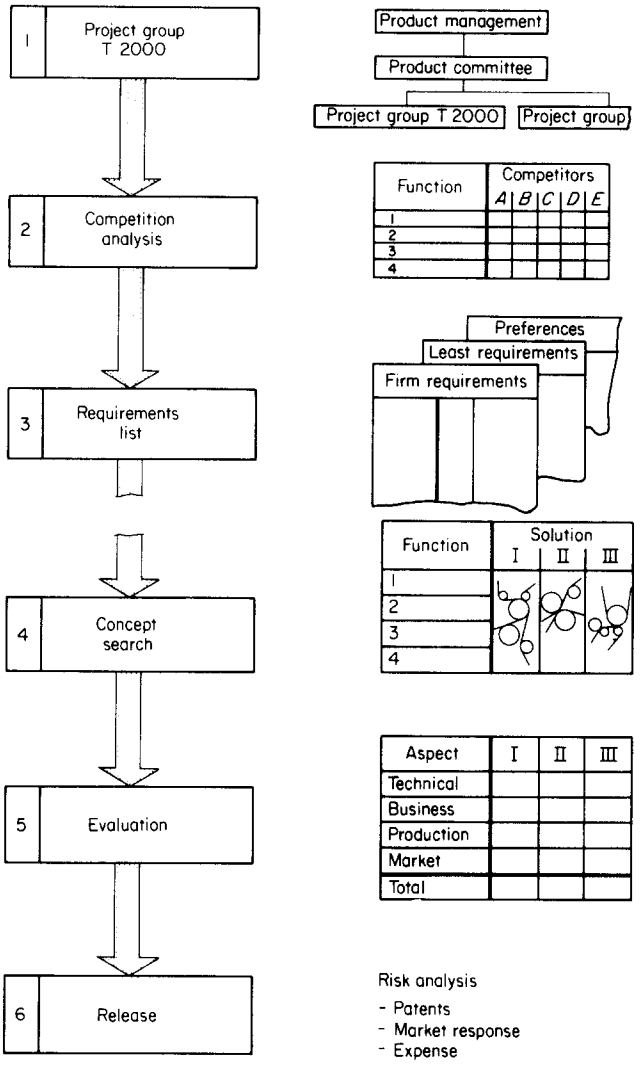

Figure 7. Concept phase of a development project (sheetforming unit example)

discussing any of the proposed ideas we analysed the published solutions of competing businesses. We considered the individual functions of sheetforming such as suspension supply, suspension subdivision, initial suspension dewatering, strip delivery etc and sketched out current industrial versions of selected sub-solutions and then made a partial estimate with reference to the specified performance.

From this basis we drew up the requirements list to which the concept search was attached. From the many solutions found a whole range was separated on differing grounds in order to finish with three solutions in a narrow band of choice. These were evaluated according to four groups of characteristics which arise from 10–15 individual characteristics. The group 'technical' is developed essentially from the quantitative performance and the sheet properties. The group 'business' has a demand index evaluated on a single unit basis. With 'manufacture' are considered the technical requirements for the construction of the unit, referring particularly to the accuracy of the jet outlet-cutter and the surface of the paper-stock contact parts, as well as the manufacturing costs. Under 'market' we have brought together all the characteristics which relate to the expected sales outlets eg the spread of the competition, market volume, extent of novelty, etc.

Because of the great technical and commercial risks involved, it has been necessary to obtain release at board level. Together with the key points in evaluation characteristics three risk characteristics emerged from the discussion: patent evaluation, market response to a new concept, and the expense of testing and market introduction.

After release by the board the bid (order) phase and the scheme phase began in parallel. Between them the concept was successfully introduced to the market.

A frequent criticism of this kind of procedure is that the expense involved might not be feasible in view of the already short recovery time and the high investment of hours. We have separated out 1500 hours which were used for the concept just described and established that the requirements list and its evaluation took up 300 hours or 20 per cent of the concept phase. After this further experience with some 15 similar projects has reduced this expense by 10–15 per cent.

ORGANIZATIONAL SUPPOSITIONS

Procedures of this kind are not sufficient on their own but require accompanying organizational modes of action and personal involvement of the leading managers. Thus, after the first pilot project, we have trained all the qualified development, design and sales engineers in a 4-day in-company course over a period of some three months. Certain colleagues from work preparation, manufacture, erection and commisioning whom we believed would be working with us later in the project also attended the course.

It appeared that it was necessary to have a special committee to bring together the many creative stimuli of the market, competitors, in-house and external patent and licence requests, and review, rank and evaluate within the framework of the company the product and development plans. (Figure 8). This group (called the product committee) decides whether a particular project should be run as a solitary effort, in the form of an internal working party or as a project group with assistance from our central research and development division.

The product committee is an advisory arm of the so-called product manager who is responsible on behalf of the company management for the international coordination of sales, technology and manufacture of his product sector. Goal-setting for the product committee involves coordination of the search for new products, their development and introduction.

Figure 9 shows the organizational arrangement of the product committee and development groups within the company structure. The activity of the product committee in providing a link with the product manager for the sales manager, the technical manager, the manager of technical planning (here located in the sales division) as well as the R and D manager, is demonstrated. The membership represents in a measured way market and technology on

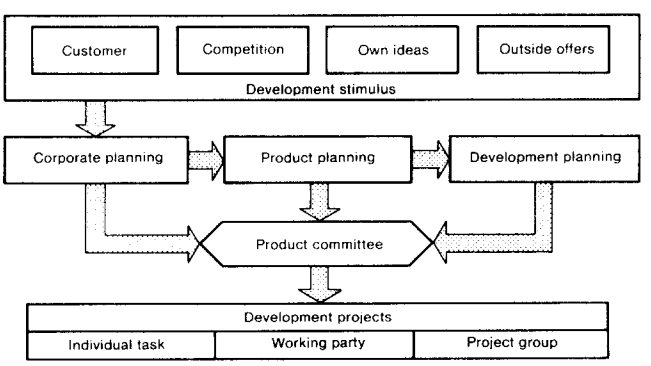

Figure 8. Control of development projects through a product committee

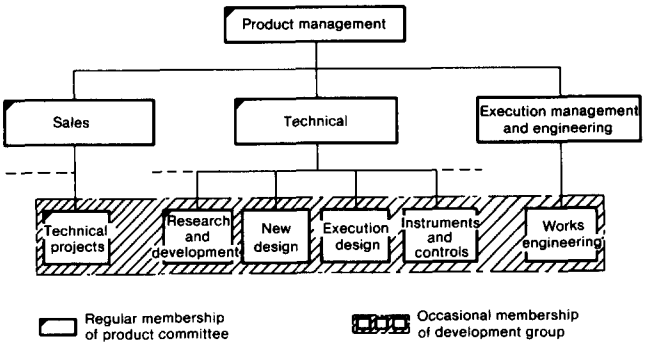

Figure 9. Organizational arrangement of product committee and development group (capital equipment example)

one hand and, on the other, the more general and the more specialized aspects of product development. Participants in the work and project groups derive from the indicated sectors of planning, R and D, new design (as in the diagram), execution design, control technology, services engineering (steam, water, effluents, vacuum, drives) and commissioning.

The project manager gives information about the state of projects on the basis of approximately bi-monthly sessions of the product committee. He makes use of written aids, requirements lists, morphological charts, evaluation schemes and concept sketches, eg scheme diagrams.

The use of these aids for this kind of presentation has promoted their application considerably. Further we have ensured that it is no longer only the concern of an individual specialist or project manager as to whether such aids will be used or not, by issuing an internal instruction in the form of a standard activity plan for development projects.

For the successful running of projects a clear division of responsibility is indispensable. The chance distribution of work in the individual phases of the procedure (Figure 10) shows that participants from technical planning and sales have to furnish the main effort in the form of a requirements list in the planning phase. In the concept phase the work of research lies in a consideration of principles and background study whilst the new design group comes first in the scheme phase. Because of the individual character of the machines no prototype can be built, so that the first introduction is through the ordering of design.

We have arranged the work so that a project manager is responsible for time and cost planning results in the form of a rough draft suitable for tendering. The participants in the task group are responsible for their contributions and are obliged to take account of them in their instructions in specific cases. The transition to execution is so arranged that the execution manager already assisted in the new design and is familiar with the particular job, whereas before he would have begun with the basic scheme. The execution manager is completely responsible both for the technical performance and for the cost and time aspects of manufacturing.

The project manager takes part in the release decisions for this job and uses the opportunity to act against non-permitted changes of the original concept. It is essential that this project group does not produce a 'democratic' design, for which no one feels responsible and that line competence and responsibility should remain undiminished.

A strong point of criticism of the VDI Guideline is that it can only be used for development projects carried through by a development team which can explore the numerous variants in complete calm and without any time-pressure attached. This is not possible with capital equipment products because they are developed in steps from job to job.

It is becoming apparent that new products and designs should appropriately be developed by an execution-independent working party, and that, in the future, companies in the capital plant industry who have not done so will build up a team for this purpose.

Nevertheless our experience shows that it is possible to apply some of the insights from the VDI Guideline to the completion of jobs. In Figure 11 this is set out in a simplified manner. A complete project is presupposed with machine design and engineering, ie foundation plans, pipework, drives, instrumentation and control. In such installations it is difficult for technical management to maintain supervision and to find out where changes contrary to prior instructions are really necessary. Often they arise explicitly because of customer requests, sometimes from local regulations, and sometimes again as the result of new experience. Each installation poses some compromise between what can be improved, but has not yet been tested, and that which has been proven but is no longer fully relevant to demands.

As a first milestone in the completion of execution of a project we have something which is analogous to the requirements list for the technical clarification of the job, in the form of an internally defined job specification. This is followed by an internal decision among the staff who have dealt with the job technically and those who have to carry it out.

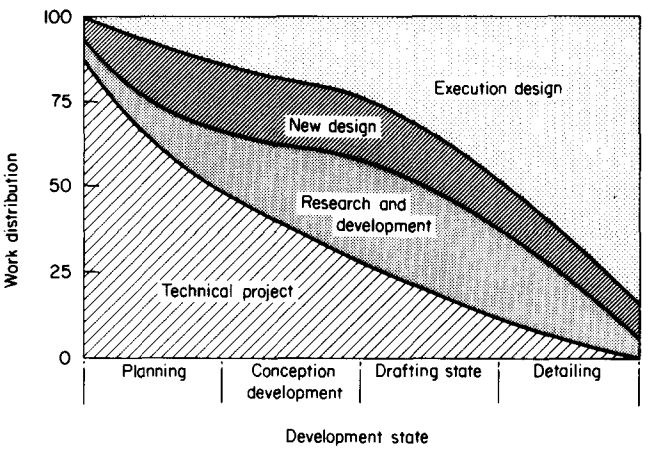

Figure 10. Work distribution in development groups of the specialist divisions

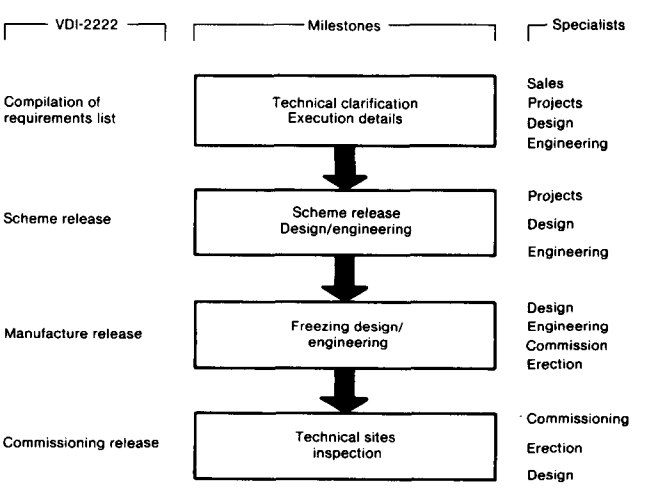

Figure 11. Milestones in project development

The specification, when resolved, is the basis of the scheme which is released to the execution department in the release session (second milestone). In this meeting there is a vote on the proposed schemes of the design/engineering division. In the case of a new concept, the R and D and new design departments also take part.

If all the important individual part drawings are ready and the arrangement drawings are available to the key group then there follows a 'dry run' on paper (third milestone). For this the installation is divided up and gone through on the basis of design, pipework, and control drawings, and the phases of erection, commissioning, operation, programme-changing and takeover are played through, as well as maintenance and inspection.

Finally there comes the technical site inspection (fourth milestone) about two or three weeks before commissioning: In this the erection and commissioning people have the opportunity to bring out any deficiencies and improvement proposals on the spot. In this way direct feedback into design is assured.

The linking of jobs through these milestones provides a guarantee of speedy information exchange, particularly in times of rapid technical development.

SUMMARY

Practical experience with the VDI Guideline 2222 can be summarized in the following points:

- The procedure is a practicable sequence of individual steps which should be applied flexibly.
- Requirements lists, function thinking, morphological methods, and technoeconomic evaluation are recommended.
- The 'identification' process set free by group working eases the introduction of new ideas.
- The company management must give wholehearted support to its introduction.
- With the introduction of the procedure the boundaries of line-competence and responsibility must be explicit and remain guaranteed.
- The principles of the procedure are transferable to job execution.
- Methods and the procedure are no substitute for creativity and market identification but are a sensible complement.

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