8 Detail design

8.1 Steps of detail design

Detail design is that part of the design process which completes the embodiment of technical products with final instructions about the layout, form, dimensions and surface properties of all individual components, the definitive selection of materials and a final scrutiny of the manufacturing methods and costs.

Another, and perhaps the most important, aspect of the detail design phase is the elaboration of production documents and especially of detailed component drawings (incuding workshop drawings), of assembly drawings and of appropriate parts lists. Depending on the type of product and manufacture (one-off, small batch, mass production), the design department must also provide the production department with assembly, transport and quality control documentation and the user with operating, maintenance and repair documentation. The documents drawn up at this stage are the basis for executing orders and for production scheduling, that is for operations planning and control. In practice, the respective contributions of the design and production departments in this area may not be distinct.

The detail design phase involves the following steps (Figure 8.1):

Finalising the definitive layout, comprising the detailed drawing of components, and the detailed optimisation of shapes, materials, surfaces, tolerances and fits. To that end, the designer should refer to the guidelines given in 6.5. Optimisation aims at maximum utilisation of the most suitable materials (uniform strength), at cost-effectiveness and at ease of manufacture, due heed being paid to standards.

The *integration* of individual components into assemblies and through these into the overall product (fully documented with the help of drawings, parts lists and numbering systems) is strongly influenced by production scheduling, delivery dates, and assembly and transport considerations (see 8.2).

The *completion* of production documents with manufacturing, assembly, transport and operating instructions is another crucial aspect of the detail design phase.

Equally important is the *checking* of all documents and especially of detail drawings and parts lists for:

— observance of general and in-house standards;
— accuracy of dimensions and tolerances;
— other essential manufacturing data; and
— ease of acquisition, for instance the availability of standard parts.

Whether such checks are made by the design department itself or by a separate standards department will depend largely on the organisational structure of the company concerned, and plays a subordinate role in the actual execution of the task. In the same way as the steps of the conceptual and embodiment phases often overlap, so do the steps of the embodiment and detail design phases. Long lead-time parts, such as those involving forging and casting,

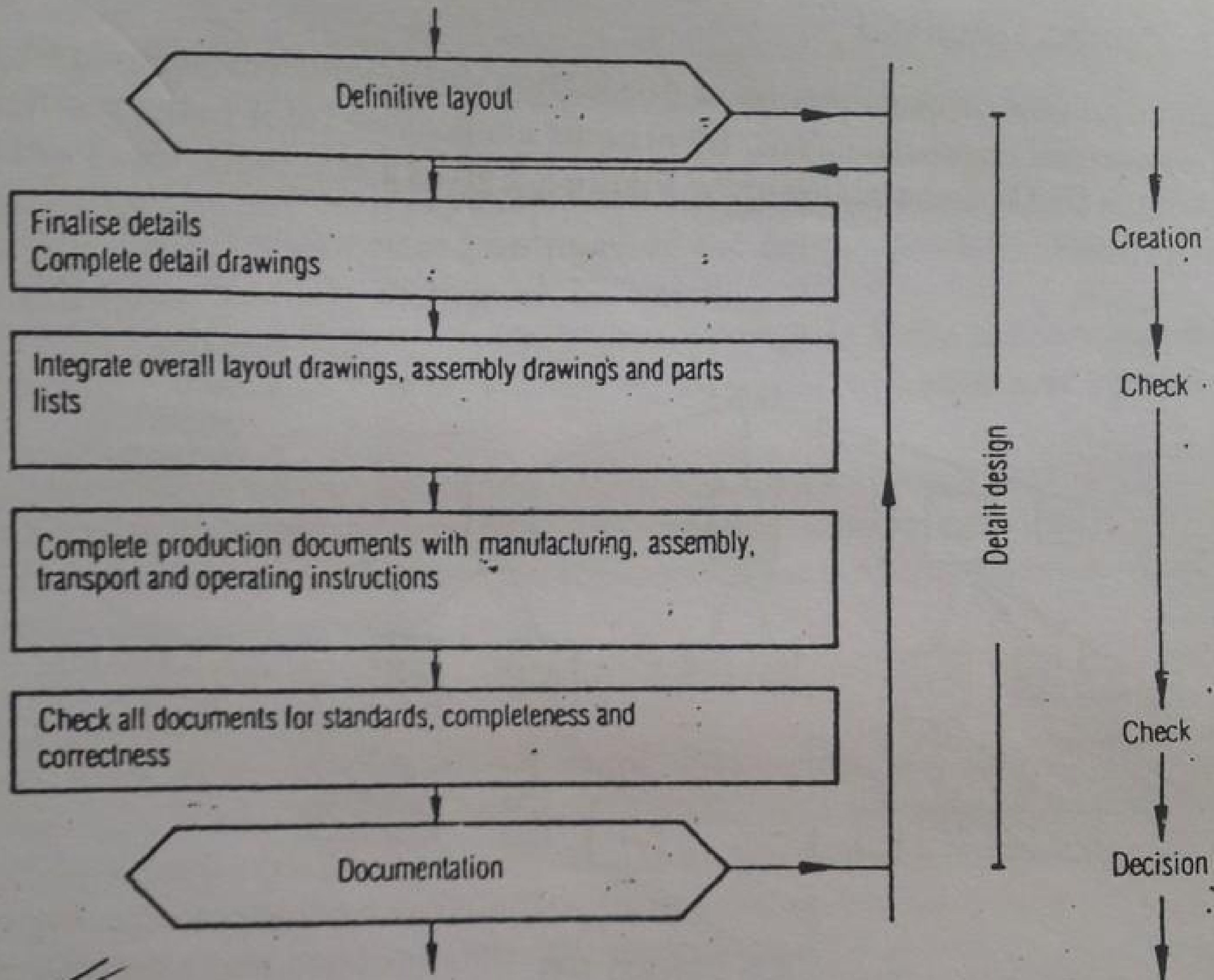


Figure 8.1. Steps of detail design

are dealt with first and their detail design and manufacturing instructions are often completed even before the definitive layout has been fixed. This overlapping of two design phases is particularly common in one-off production and in heavy engineering (Figure 6.118).

The designer must never cut corners during the detail design phase, which has a critical effect on the technical function, on the manufacturing processes and on the elimination of manufacturing errors.

In the following sections we shall be considering aids to the rational execution of orders, paying particular attention to the use of computers. As for such conventional activities as drawing and calculation, we must simply refer the reader to the relevant literature. Aids to, and hints for, detail design will be found in Chapter 6.

8.2 Preparation of production documents

8.2.1 Product analysis

The arrangement or classification of production documents (drawings and parts lists) is based on *product analysis*. By product analysis we refer to the subdivision of a product [8.14] into smaller units. Figure 8.2 gives a schematic representation of this process.

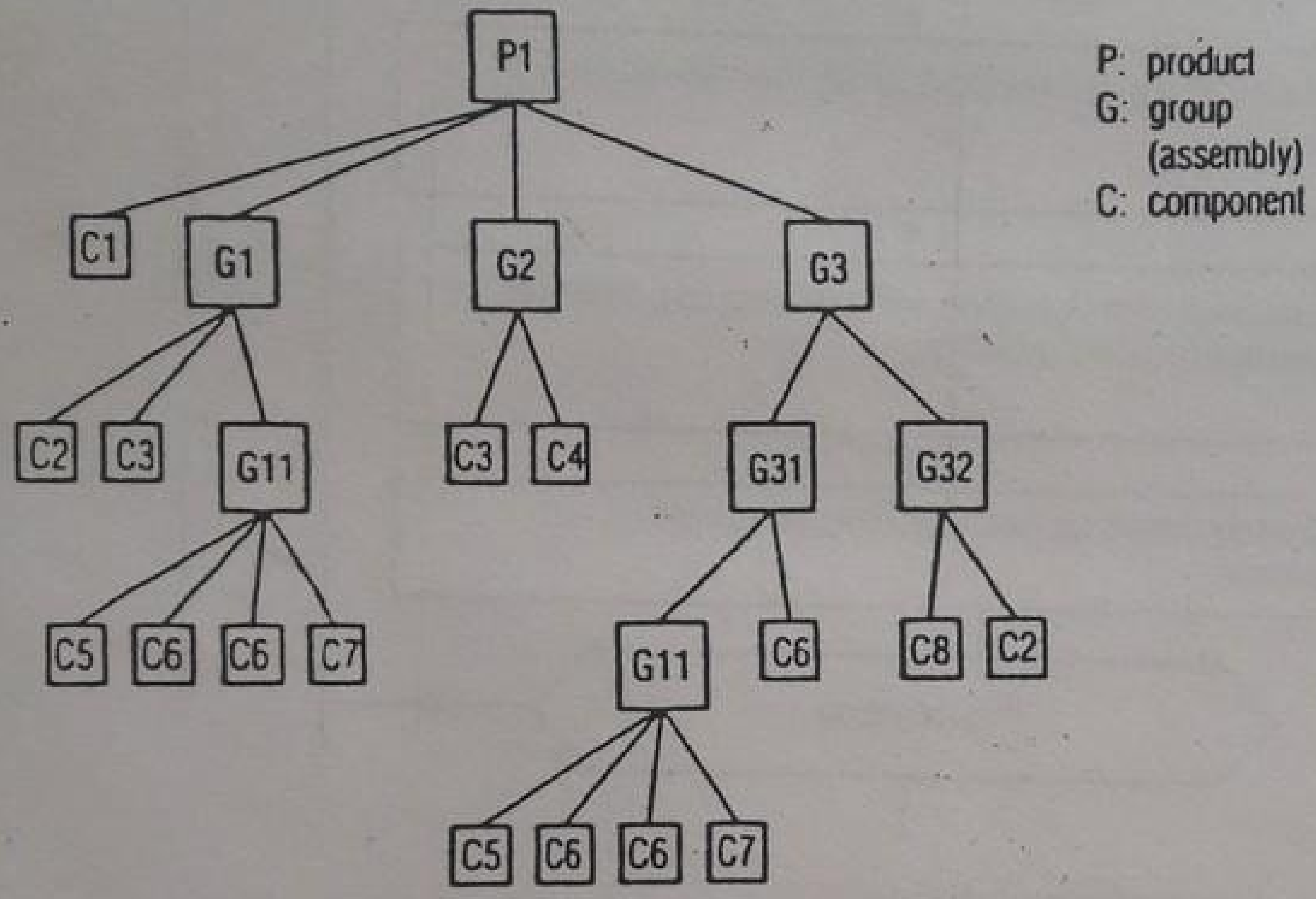


Figure 8.2. Product analysis

Product analysis can lead to a *function-orientated* or to a *production-* or *assembly-orientated* structure. It is also referred to as a family tree, in which the individual components are generally shown as, for example, forged, cast or semi-finished parts [8.14].

Characteristic of this type of structure is the presence of individual components that cannot be subdivided any further, and the combination of such parts and/or groups of a lower order (sub-assemblies) into larger groups (assemblies). It is helpful to arrange such groups and components in hierarchic order, that is, to assign them to a 1st. 2nd . . . *n*th order, the overall product being of the 0th order. Such hierarchic arrangements can be modified to suit particular objectives (function, production, assembly, acquisition).

By way of an example, let us consider the modular bearing system described earlier in 7.2. The family tree shown in Figure 7.23 is function-orientated. In many cases, however. a separate production-orientated analysis must be made. Figure 8.3 does this for the pedestal bearing B_1 of the modular system shown in Figure 7.23. There are two group columns and one column each for finished and unfinished components. Figure 8.4 is a family tree for the same product, in

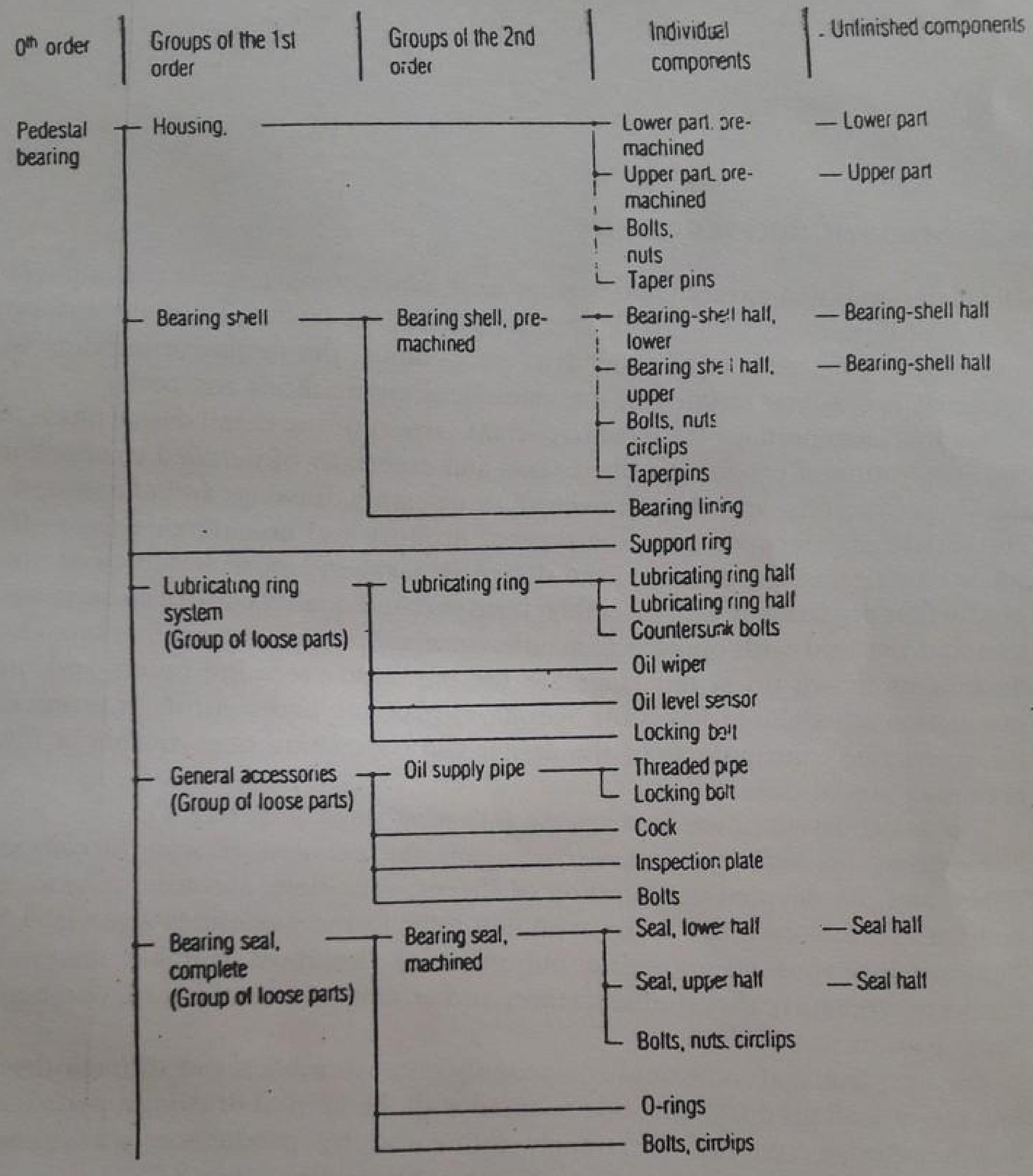


Figure 8.3. Product analysis (production orientated) for the pedestal bearing of a modular bearing system

which the groups and individual components are arranged for assembly purposes.

Since product analysis influences the preparation of the production documents and the production sequence, and vice versa, it is advisable to involve all the departments concerned (design, standards, planning, manufacturing, assembly, purchasing) in its preparation. However, since it depends on the particular product and company involved, hard and fast rules cannot be laid down. Product analysis determines the organisation of all drawings and parts lists and should reflect the appropriate subdivision of the product.

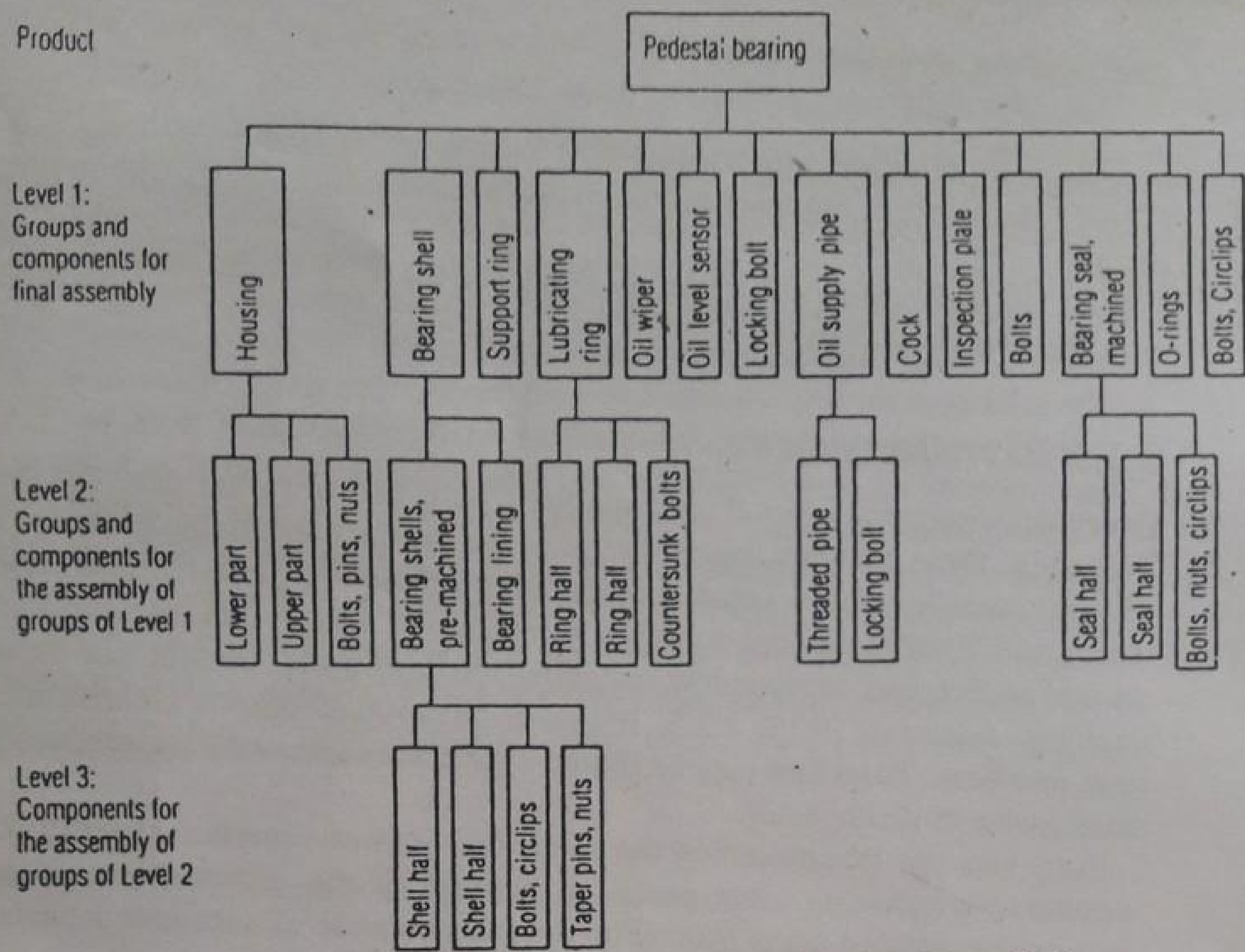


Figure 8.4. Family tree for the assembly of pedestal bearings (see Figure 8.3)

8.2.2 Drawing systems

For the preparation of technical drawings the reader is referred to the comprehensive literature [8.2, 8.6–9, 8.11, 8.12, 8.16, 8.21, 8.28]. Here we shall merely refer to the basic definitions concerning the content and development of drawings and the method of representation, and make recommendations for the organisation of drawing systems.

Technical drawings can be classified by:

—type;
—method of preparation;
—content; and
—purpose [8.9].

In respect of *type*, a distinction is made between:

—sketches, which do not have to be strictly bound to rules, and which are generally freehand and/or approximately dimensioned;
—drawings, which should be as fully dimensioned as possible;
—simplified scale drawings;
—plans, for example, ground plans; and
—graphic representations, for instance of function structures.

Sketches are of particular importance during the conceptual phase, where they provide invaluable help in the search for solutions and the handling of a great deal of information [8.30]. Approximately and fully dimensioned drawings, for their part, are particularly useful in the embodiment phase, and also in the preparation of production documents following the detail design phase.

In respect of *method of preparation*, a distinction is made between:
— original drawings suitable for reproduction; and
— pre-printed drawings that are often not to scale.

It may be useful to build up drawings on a modular basis. To that end, overall drawings are split into 'building blocks' that can be recombined into new overall drawings. For instance, pre-printed stickers can be used to build up electrical and hydraulic circuit drawings.

In respect of *content*, it is possible to distinguish many categories of drawings. One approach is to consider how much of the overall product is represented in the drawings, that is to distinguish between:
— *overall drawings* (layout drawings, representations of the product as a whole);
— *assembly drawings* (representations of separable or inseparable combinations of two or more components);
— *component drawings* (representations of a single component);
— *unfinished-component drawings* (for example, casting drawings);
— *assembly-component drawings* (representations of an assembly and of its individual components);
— *model drawings* (for example, mock-up drawings); and
— *schematic drawings*.

In accordance with [8.31] we must, first of all, distinguish between the technological and the organisational contents of a drawing. The technological content includes the pictorial representation and dimensioning of the object and various representational details (for example intersections), material and quality specifications and handling data. By organisational content we refer to specific data (for example labels and numbers for identification and classification) and also to drawing-specific attributes (for example size, format, date). This subdivision is of great importance in computer-aided draughting [8.31].

Closely connected with its content is the *purpose* of a drawing. We accordingly distinguish between:
— embodiment drawings (drawings of various degrees of embodiment, various methods of representation and various contents); and
— manufacturing drawings.

Manufacturing drawings can be further subdivided into:
— workshop drawings for various stages of manufacture (for example preliminary and final machining, welding drawings etc);
— assembly drawings;
— replacement-part drawings;
— installation drawings (foundation drawings); and
— despatch drawings.

For the rationalisation of drawings, the designer may also have recourse to *collective drawings* which can be built up either as *type drawings* (for design variants) with or without a separate dimension table, or else as *set drawings* (collection of related parts).

Some companies use the recommendations laid down in [8.9] when making drawings for a particular product range or a particular manufacturing method. Thus, one mass-producer of electrical equipment distinguishes drawings by content and purpose as follows [8.29]:

— embodiment sketches for the determination of only such details as are needed for the production of a functional prototype (a prototype on which the solution concept can be tested);
— detailed embodiment sketches with full data for the production of a so-called development prototype (a prototype fulfilling the demands of the specification);
— detailed embodiment drawings as preliminaries to manufacturing drawings and containing all the data needed for a pre-production prototype; and
— manufacturing drawings for mass production of the product.

In one-off manufacture and in heavy engineering, which usually dispense with prototypes, this classification is not needed. Instead, there is a simple distinction between embodiment drawings and manufacturing drawings.

In preparing production documents, the designer must consider the most appropriate *structure of a set of drawings*. For purposes of manufacture and assembly (8.2.1) a set of drawings consists basically of:

— an *overall drawing* showing the layout of the product, from which further drawings (covering transport, installation, assembly etc) can be derived;
— several *assembly drawings* of different complexity showing the combination of individual components into a manufacturing or assembly unit; and also
— *component drawings*, which can be further subdivided into unfinished component drawings, model drawings, pre-machining drawings, final machining drawings etc.

In principle, the subdivision of a set of drawings must fully reflect the family tree of the product (see Figures 8.3 and 8.4). For greater simplicity it may prove useful, for instance in variant design, to combine different drawings (representing different manufacturing stages) or the information contained in them. This can be done by means of *assembly/component drawings* showing the fully dimensioned individual parts and their combination into an assembly. *Collective drawings* cover similar parts of various sizes. In the form of *set drawings* they show parts that belong together (for instance accessories); in the form of *type drawings* they cover the various types or sizes of a particular component. Type drawings are particularly important in the rationalisation of size ranges and modular products. While the combination of several parts or sizes in a single drawing allows the designer to take in the situation at a glance, such combination must not be allowed to impede planning, manufacture, assembly and spare parts delivery.

It is desirable to build up a set of drawings independently of specific orders, so that it can be used for various applications. For that reason, repeat parts and replacement parts should always be shown on separate drawings. An exception may have to be made with overall drawings based on order-specific, once-and-for-all data. Further hints on the construction of sets of drawings will be found in [8.14].

Parts list and numbering systems (see 8.3) should be developed hand in hand with the sets of drawings.

8.2.3 Parts list systems

Every drawing system has a corresponding parts list, or rather parts list system. Together, these systems should describe the product so unambiguously that it can be manufactured without further amplification. A parts list lays down, in words and fixed positional numbers, the quantity, unit of quantity and name of all assemblies and components including standard parts, bought-out parts and auxiliary materials [8.13, 8.32]. It also ensures unambiguous identification by item numbers. Parts lists may be drawn up in accordance with the recommendations given in [8.12, 8.13].

Parts lists can be entered on the actual drawings or compiled separately. The second alternative is often preferred because of the growing importance of computer-compiled parts lists. (For the full potential of automated parts lists, the reader is referred to the literature [8.18, 8.32].)

The *type of parts list* reflects the results of product analysis and the manufacturing processes involved. According to [8.10, 8.18, 8.32], we distinguish between the following types:

— A *quantity survey parts list* simply lists the individual parts with their item numbers and the quantities involved. Frequently recurring individual parts appear just once. However, all the item numbers of a particular product are recorded. There is no step gradation corresponding to product analysis, for instance into function- or production-orientated groups. This is the simplest type of parts list and the amount of useful information it contains is small. It suffices for simple products with only a few manufacturing processes. Figure 8.5 shows this type of parts list, based on the product analysis shown in Figure 8.2, as a computer print-out.

— A *structure parts list* gives the structure of the product with all the assemblies and components, each group being immediately broken down (product-analysis order). The breakdown of groups usually corresponds to the flow of the manufacturing processes (multi-level subdivision). Figure 8.6 shows a section of this type of parts list as a computer print-out, once again based on Figure 8.2. Since computer processing demands the specification of quantities and units of quantity for every location—in contrast to the manual technique, in which the quantitative data of any part are listed just once—these data must be provided for every group. Moreover, the unit 'part (PT)' is printed out each time, because the program demands this information for all locations. Figure 8.7 shows a structure parts list for the family tree of the pedestal bearing (Figure 8.4). The quantities listed refer to the product named in the parts list heading. The advantage of structure parts lists is that

QUANTITY	1		DESIGNATION	P1	QUANTITY SURVEY PARTS LIST
LOC.	**QUANTITY**	**U**	**DESIGNATION**		**ITEM NUMBER**
1	1	PT	C1		
2	2	PT	C2		
3	2	PT	C3		
4	1	PT	C4		
5	2	PT	C5		
6	5	PT	C6		
7	4	KG	C7		
8	9	M	C8		

Figure 8.5. Schematic structure of a parts list giving quantities for the product analysis shown in Figure 8.2 (U = unit of quantity)

QUANTITY	1		DESIGNATION	P1	STRUCTURE PARTS LIST
LOC.	**QUANTITY**	**U**	**LEVEL**	**DESIGNATION**	**ITEM NUMBER**
1	1	PT	.1	C1	
2	1	PT	.1	G1	
3	1	PT	..2	C2	
4	1	PT	..2	C3	
5	1	PT	..2	G11	
6	1	PT	...3	C5	
7	2	PT	...3	C6	
8	2	KG	...3	C7	
9	1	PT	.1	G2	
10	1	PT	..2	C3	
11	1	PT	..2	C4	
12	1	PT	.1	G3	
13	1	PT	..2	G31	
14	1	PT	...3	G11	
15	1	PT	4	C5	
16	2	PT	4	C6	
17	2	KG	4	C7	
18	1	PT	...3	C6	
19	1	PT	..2	G32	
20	9	M	...3	C8	
21	1	PT	...3	C2	

Figure 8.6. Schematic structure of a structure parts list for the product analysis shown in Figure 8.2

they reveal the overall structure of a product or of a sub-assembly. The disadvantage is that a parts list with a large number of locations becomes unwieldly, especially if a series of repeat sub-assemblies recurs in various locations, with consequent encumbrance of the updating service.

— By *variant parts list* we refer to special parts lists covering various products or assemblies with a large number of identical sub-assembies or components. In other words, such lists combine the data of several parts lists, the common parts in them being consigned to a so-called basic parts list, and the variants to a special parts list [8.17]. Variant parts lists are particularly useful in modular systems with a high proportion of common units.

QUANTITY 1 DESIGNATION PEDESTAL BEARING STRUCTURE PARTS LIST

LOC	QUANTITY	U	LEVEL	DESIGNATION	ITEM NUMBER
1	1.0	PT	.1	HOUSING	3202-222 100350
2	1.0	PT	..2	LOWER PART	3200-222 100335
3	1.0	PT	..2	UPPER PART	3200-222 100336
4	4.0	PT	..2	BOLT	9001-222 010674
5	2.0	PT	..2	TAPER PIN	9022-222 011149
6	2.0	PT	..2	NUT	9013-222 012435
7	1.0	PT	.1	BEARING SHELL	3511-222 150379
8	1.0	PT	..2	BEARING SHELL, PRE-MACH	3511-222 150380
9	1.0	PT	...3	SHELL HALF	3511-222 150411
10	1.0	PT	...3	SHELL HALF	3511-222 150410
11	2.0	PT	...3	BOLT	9001-222 010457
12	2.0	PT	...3	CIRCLIP	9022-222 012087
13	2.0	PT	...3	TAPER PIN	9022-222 012437
14	2.0	PT	...3	NUT	9013-222 012433
15	0.3	KG	..2	BEARING LINING	
16	1.0	PT	.1	SUPPORT RING	9271-222 101342
17	1.0	PT	.1	LUBRICATING RING	3901-222 007904
18	2.0	PT	..2	HALF RING	3901-222 150009
19	4.0	PT	..2	COUNTERSUNK BOLT	9009-222 150108
20	1.0	PT	.1	OIL WIPER	3776-222 150581
21	2.0	PT	.1	OIL LEVEL SENSOR	3906-222 000794
22	1.0	PT	.1	LOCKING BOLT	9003-222 011821
23	1.0	PT	.1	OIL SUPPLY PIPE	9448-222 150350
24	140.0	MM	..2	THREADED PIPE	9446-222 150498
25	1.0	PT	..2	LOCKING BOLT	9003-222 011823
26	1.0	PT	.1	COCK	9408-222 021301
27	1.0	PT	.1	INSPECTION PLATE	3904-222 000327
28	4.0	PT	.1	BOLT	9007-222 011316
29	2.0	PT	.1	BEARING SEAL, MACHINED	3020-222 150268
30	4.0	PT	..2	SEAL HALF	3020-222 130105
31	4.0	PT	..2	BOLT	9001-222 010457
32	4.0	PT	..2	NUT	9013-222 012560
33	4.0	PT	..2	CIRCLIP	9065-222 012087
34	2.0	PT	.1	O-RING	9326-222 201793
35	12.0	PT	.1	BOLT	9001-222 010800
36	12.0	PT	.1	CIRCLIP	9065-222 911454

Figure 8.7. Structure parts list of the pedestal bearing, after Figure 8.4

To render the contents of a particular parts list applicable to a variety of products and repeat assemblies, the designer should divide his overall parts list into separate sections, each comparable to a module, as in the following type of parts list:

— *Module parts lists* contain product-independent assemblies and components, the quantitative data simply relating to the module named in the heading. If necessary, several module parts lists must be combined with other parts lists to provide a parts list system for a particular product. Figure 8.8 shows how a product can be broken down to yield several module parts lists in accordance with the product analysis illustrated in Figure 8.2. In Figure 8.9, the structure of such parts lists is shown schematically in the form of a computer print-out. The module parts list of the overall product is also called the main parts list [8.10]. The great advantage of this type of parts list is that a repeat assembly need only be recorded once. As a result, the computer storage requirement is relatively small and the compilation and updating of parts lists relatively simple. A further advantage is that, in the case of computer storage, a structure parts list and a quantity survey parts list can be derived directly. The

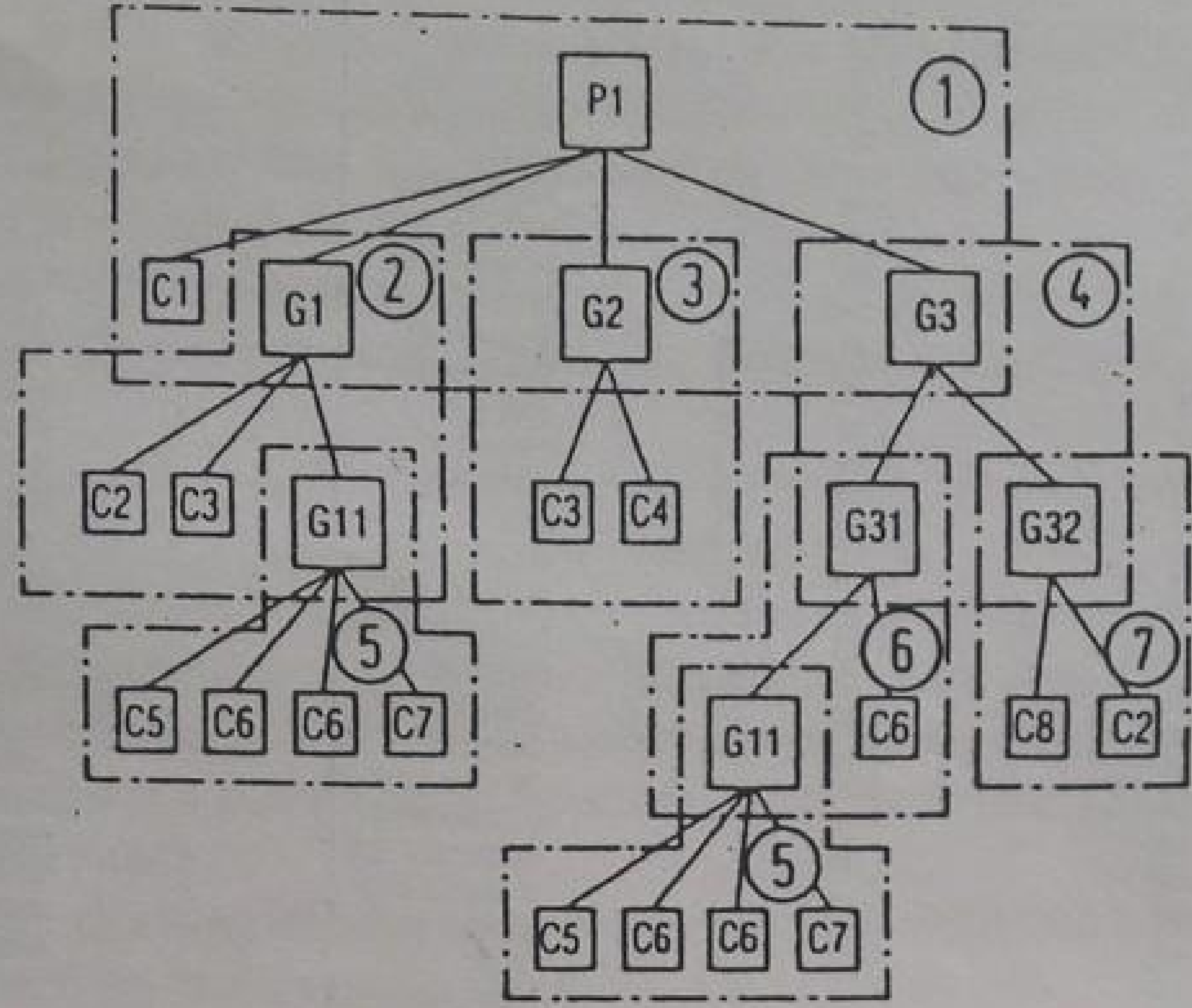


Figure 8.8. Subdivision of a product (Figure 8.2) in the form of module parts lists

use of module parts lists is particularly recommended whenever size-range assemblies are kept in stock or can be manufactured in large batches as repeat assemblies. The disadvantage is that module parts lists yield no definitive information about the overall number of parts required for the product, and that the function- and production-determined overall context can only be recognised once all the module parts lists have been combined into an overall system.

Parts lists can also be distinguished in terms of their applications:

— In *function* or *design parts lists* the combination of components and the corresponding product structure are based on functional considerations. The locations are arranged to reflect the progress of the design work. Design parts lists are often independent of a particular order or of the manufacturing processes and hence very helpful in original and adaptive designs.

— By *manufacture* or *assembly parts lists* we refer to parts lists whose composition and content are based on production considerations. If the design department supplies a design parts list that ignores the production flow, then the production-scheduling department will have to modify that list in due course, which is an unnecessary expense. Manufacture parts lists are order-specific, particularly in the case of one-off products.

— In addition, there may also be *materials parts lists, estimates parts lists* and *spares parts lists*. The designer should, however, try to confine himself to a single parts list.

Because parts lists affect design, standardisation, operations scheduling, production control, estimating, the procurement and storage of materials, assembly, quality control, maintenance, repair and spares, factory costing and documentation, great importance must be attached to their content. The content

QUANTITY 1 DESIGNATION P1 MODULE PARTS LIST 1

LOC	QUANTITY	U	DESIGNATION	ITEM NUMBER
1	1	PT	C1	
2	1	PT	G1	
3	1	PT	G2	
4	1	PT	G3	

QUANTITY 1 DESIGNATION G1 MODULE PARTS LIST 2

LOC.	QUANTITY	U	DESIGNATION	ITEM NUMBER
1	1	PT	C2	
2	1	PT	C3	
3	1	PT	G11	

QUANTITY 1 DESIGNATION G2 MODULE PARTS LIST 3

LOC.	QUANTITY	U	DESIGNATION	ITEM NUMBER
1	1	PT	C3	
2	1	PT	C4	

QUANTITY 1 DESIGNATION G3 MODULE PARTS LIST 4

LOC.	QUANTITY	U	DESIGNATION	ITEM NUMBER
1	1	PT	G31	
2	1	PT	G32	

QUANTITY 1 DESIGNATION G11 MODULE PARTS LIST 5

LOC.	QUANTITY	U	DESIGNATION	ITEM NUMBER
1	1	PT	C5	
2	2	PT	C6	
3	2	KG	C7	

QUANTITY 1 DESIGNATION G31 MODULE PARTS LIST 6

LOC.	QUANTITY	U	DESIGNATION	ITEM NUMBER
1	1	PT	G11	
2	1	PT	C6	

QUANTITY 1 DESIGNATION G32 MODULE PARTS LIST 7

LOC	QUANTITY	U	DESIGNATION	ITEM NUMBER
1	9	M	C8	
2	1	PT	C2	

Figure 8.9. Schematic structure of module parts list based on Figure 8.8

of a parts list is constantly expanded and updated following business rationalisation, and computer processing. Computer processing demands that any one piece of information should only be stored once. To that end, it has been found helpful to divide the information bound to one component into *component source data* (source data for short) and the information bound to certain product structures, for instance the interrelationship of components, into *product structure data* (structure data for short):

— Source data may take the form of drawing or item numbers for the identification of components, materials, units of quantity and component types.
— Structure data may take the form of assembly identification numbers, updating entries, order numbers and code numbers.

Individual companies may also compile *reference data* covering identification numbers and designations used by other companies and suppliers.

The converse of a parts list is the so-called *components usage list*, which shows into what assemblies a particular component could be fitted. (This is helpful for the updating service.)

All in all, the drawing system must be compatible with the parts list system. This is facilitated by the use of a unified numbering system.

8.3 Numbering technique

In accordance with [8.11] we distinguish between numeric characters (for example 3012–13) and alpha-numeric characters (for example AC 400 DI–120 M). In numbering systems, these characters are combined into sets with a strict formal structure. For the detailed construction of numbering systems the reader is referred to [8.4, 8.19, 8.26].

The general requirements of numbering systems are:

— *identification*, that is the unequivocal and unmistakeable designation of objects and of the relationships between them;
— *classification*, that is the arrangement of objects and the relationship between them in accordance with fixed rules. A classification is a description of selected properties. A single classification number thus represents the equality of objects and the relationships between them in respect of these selected properties; not, however, an identity;
— identification and classification must be separable activities;
— a numbering system must be built up in such a way as to permit its subsequent expansion;
— quick retrieval and easy handling must be ensured;
— there must be compatibility with computer techniques;
— comprehensibility, even for outsiders, must be ensured by means of an appropriate logical structure, unequivocal terminology and memorability (try not to exceed eight-figure numbers);

— there must be a design-appropriate structure for the processing and reading of data of various kinds and particularly for the numbering of drawings and components;
— the number of an item must remain unchanged regardless of the product in which it is to be used and regardless of whether it is produced in-house or bought-out.

In his choice of numbering system, the designer must take the nature and objectives of the company into account. Important factors are:
— type and complexity of product programme;
— type of production; one-off, small batch or mass production;
— customer service, spares and distribution control;
— internal organisation, for example, possible use of computers; and
— aim of the numbering system: whether it is to cover every aspect of one or of several product programmes, or merely the classification of individual components for easier location of repeat parts.

To meet these requirements, a great many numbering systems have been proposed. The structure of some of the most important ones will be described in what follows.

8.3.1 Item number systems

By item number systems we refer to such systems as can be used by all departments of a company for numbering items and the relationship between them (see [8.11]). To that end, it is helpful to attach one and the same identification number to the drawing of a component, to its location in the appropriate parts list, to its manufacturing documents and to the component itself.

Item numbers must *identify* items. Beyond that they can also *classify* them. By items we refer to all the:
— objects, for example, newly developed parts, repeat parts, bought-out parts, spare parts, semi-finished parts;
— documents, for example materials documentation, patents, technical drawings and parts lists; and
— procedural rules, for example design codes, manufacturing procedures and assembly instructions involved in the execution of a particular order.

An item number system may be a *parallel number system* or a *combined number system*.

Figure 8.10 shows the basic structure of an item number in the parallel system. In that system, one or several classification characters, independent of the identification, are assigned to an item number. The advantage of this parallel coding system is its great flexibility and expansion potential, both parts of the system being practically independent of each other. This system is therefore suitable for most applications and, moreover, facilitates computer processing.

In *combined number systems*, the overall number consists of two strictly correlated classifying and identifying parts (Figure 8.11). The system demands a

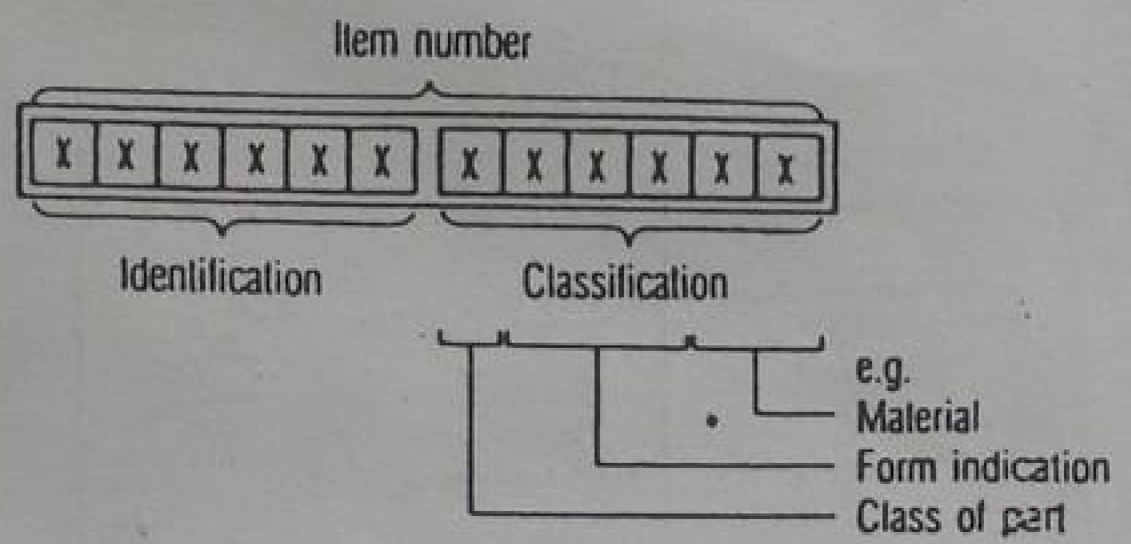


Figure 8.10. Basic structure of an item number in a parallel numbering system [8.4]

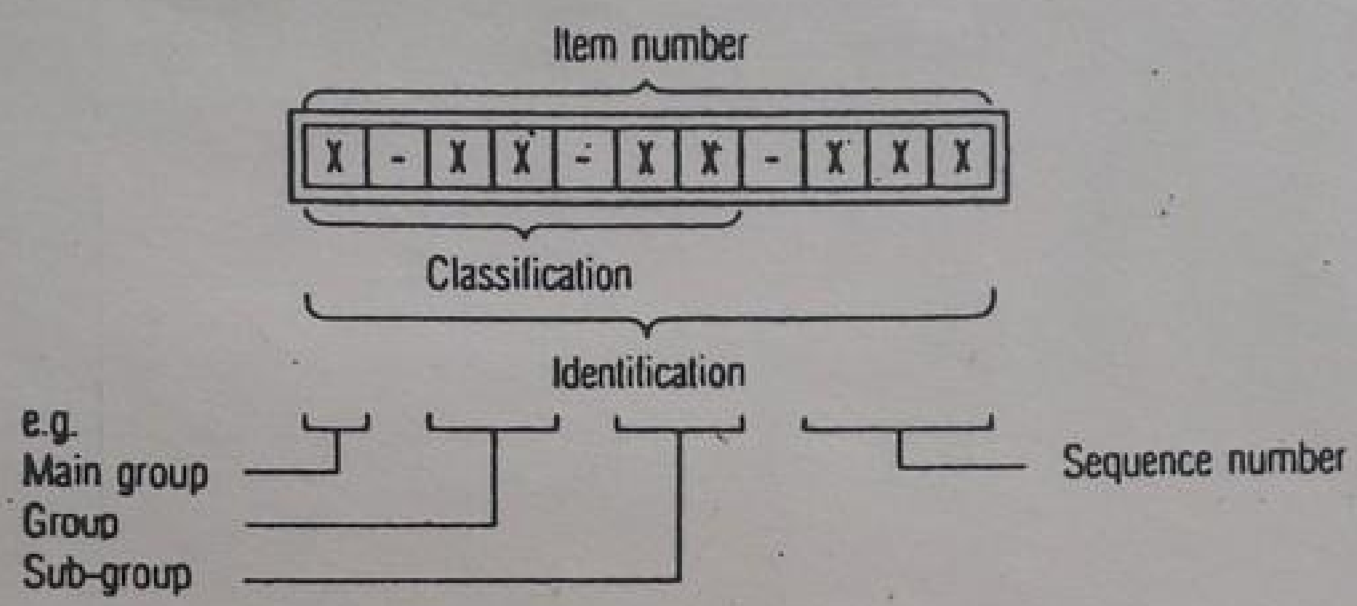


Figure 8.11. Basic structure of an item number in a combined numbering system [8.8]

very fine classification so that the addition of only a short sequence number will provide unequivocal identification. Combined numbering systems are very rigid and hence difficult to expand. They should only be used in exceptional cases.

8.3.2 Classification systems

The classification of items and of their interrelationships, be it by means of an item number or by an independent classification system, is of great importance, especially to the designer.

In general, a coarse classification and a fine classification are made separately. A coarse classification distinguishes between the following areas:

- technical, economic and organisational documents such as guidelines, standards etc;
- raw materials, semi-finished materials etc;
- bought-out items;
- in-house components;
- in-house assemblies;
- finished products;
- auxiliary and operating items;
- equipment and tools; and
- manufacturing methods.

These areas are often denoted by the first character of the classification number. Subsequent positions (2nd, 3rd or 4th) are assigned, for finer classification, to such characteristics as permit the quickest possible retrieval of data in the area concerned.

The link between the different locations depends on the context of the individual groups. If group characteristics can be associated with particular characteristics of the preceding group only, then the classification system must have an appropriate branching (Figure 8.12*a*). If, on the other hand, the group characteristics can be associated with every characteristic of the preceding

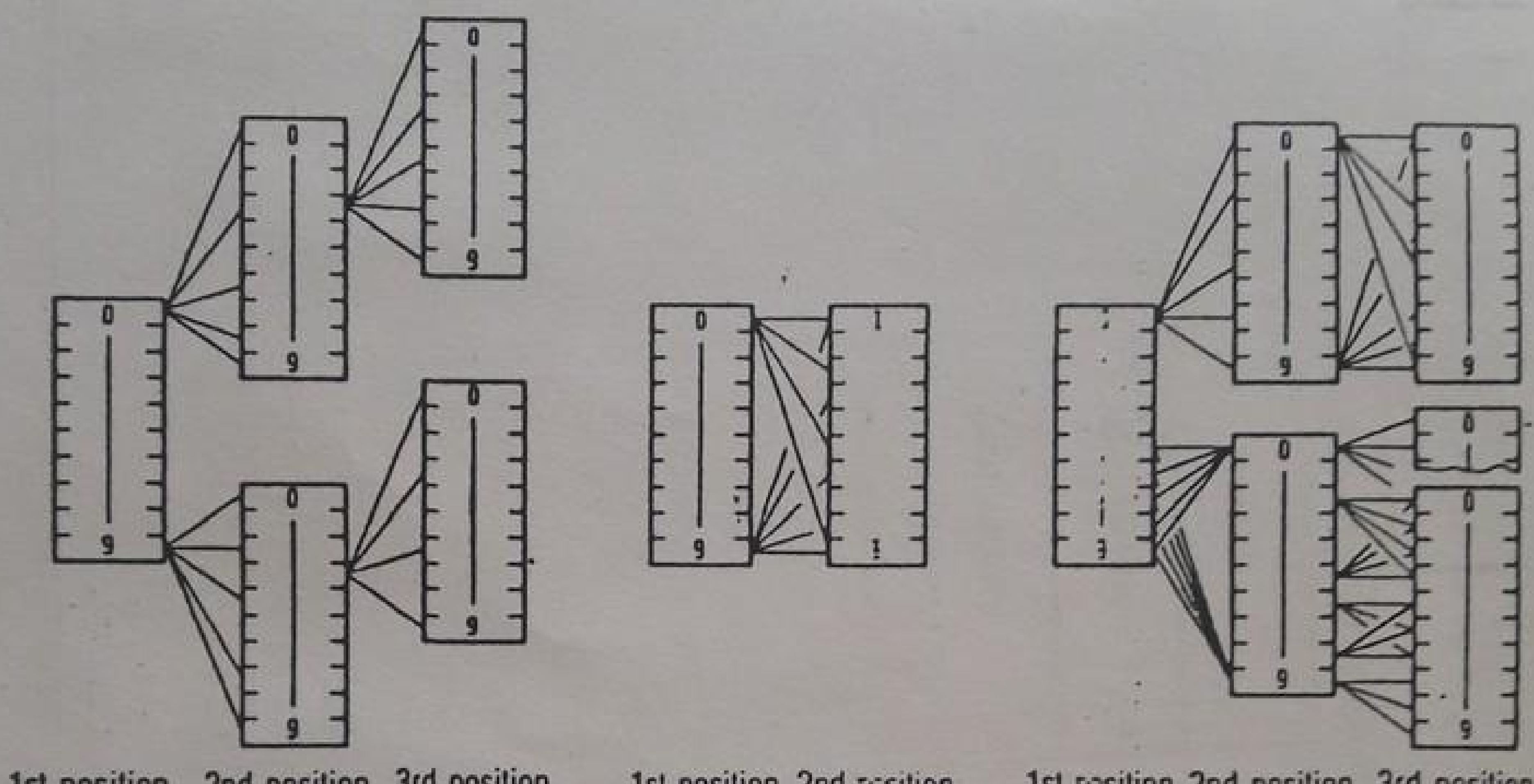


Figure 8.12. Possible correlations of the characteristics of classification systems [8.17, 8.32]

group, then there is a corresponding overlap (Figure 8.12*b*). The advantage of the correlation shown in Figure 8.12*a* is that it provides independent linking of individual branches. The advantage of the correlation shown in Figure 8.12*b*, on the other hand, is a smaller storage requirement. In practice, the two types of linking are often combined into so-called mixed systems (Figure 8.12*c*).

Apart from providing a rationalisation of in-house data exchange during the execution of an order, classification also helps the designer to apprise himself quickly and fully of previously designed parts or parts kept in stock. The use of *repeat parts* in orignal, adaptive and variant designs is one of the most important rationalisation requirements he must meet. How effective a particular system is in the search for repeat parts depends strongly on its content, that is on its classes and classifying characteristics and also on the type of data input and output.

A particularly important feature of classification systems is that they facilitate the search for individual components with the help of so-called *form codes*. Amongst the many proposed systems for the product-independent classification of components with the help of form classifications [8.19], Opitz's system [8.27] has been most widely adopted. Figure 8.13 shows its general structure, which

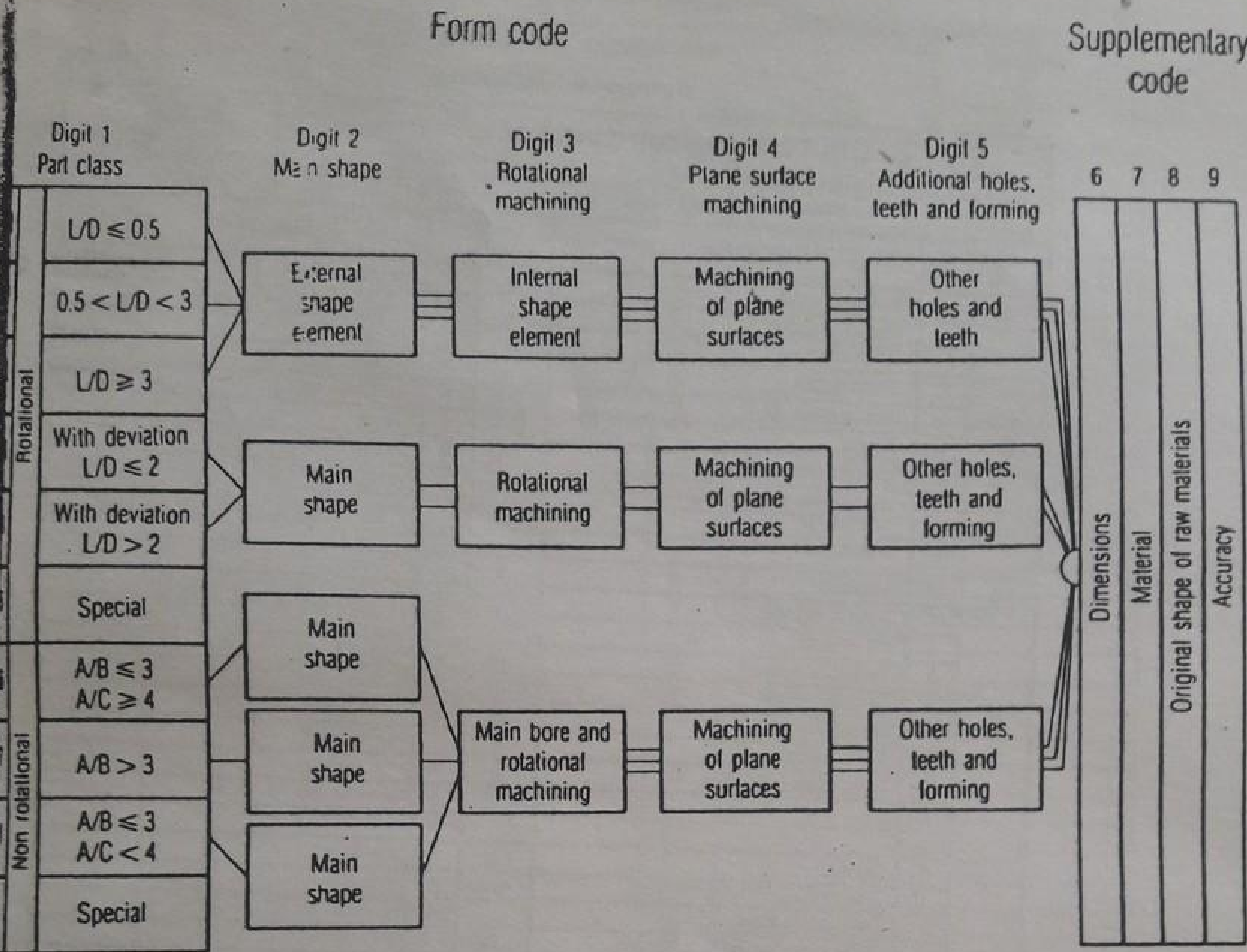


Figure 8.13. Classification system for machine components [8.7]

also provides an example of the mixed system shown in Figure 8.12*c*. Figure 8.14 gives a breakdown of the form code for the upper classification branch. It also contains the classification code for the rotating component shown in Figure 8.15.

The choice of characteristics must above all be based on their fitness as search criteria. They must also permit an even breakdown of the range of items.

There have been several attempts to set up classifications systems for general rather than for company-specific use, for instance in the form of general-standards data banks [8.15, 8.22].

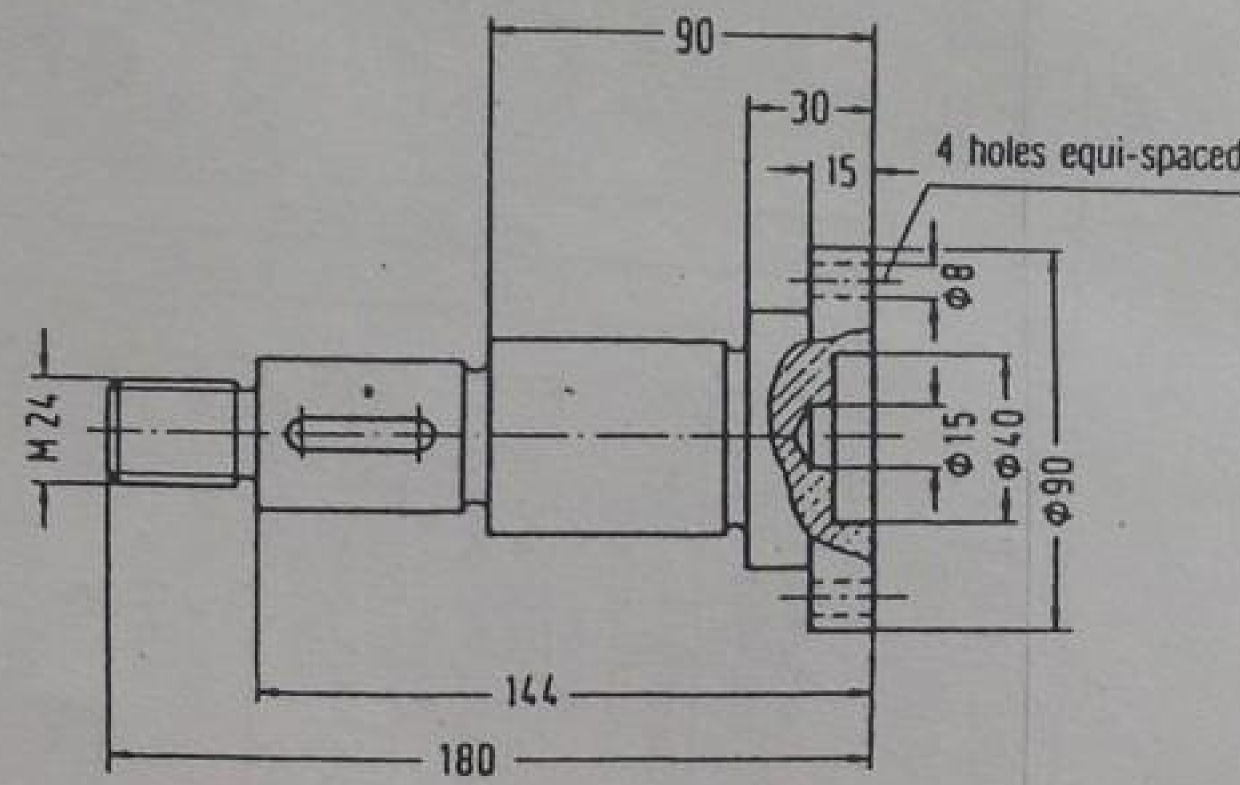
In addition, companies have come to rely increasingly on microfilms [8.5, 8.23], visual display units, and similar equipment [8.3].

8.3.3 Examples

Figures 8.16 to 8.19 are taken from a classification system of items and their interrelationships in a particular sector of a large-scale enterprise. The system is based on the arrangement shown in Figure 8.12*a* [8.1], except that it has an extra decade for so-called supplementary codes applicable to all main groups, Figure 8.16 shows the numbering scheme of this system, and Figure 8.17 the main

	Digit 1	Digit 2	Digit 3	Digit 4	Digit 5
	Part class	External shape, external shape elements	Internal shape, internal shape elements	Plane surface machining	Auxiliary holes and gear teeth
0	Rotational: L/D ≤ 0.5	Smooth, no shape elements	No hole, blind hole	No surface machining	Without gear teeth: No auxiliary hole
1	Rotational: 0.5 < L/D < 3	Stepped to one end or smooth: No shape elements	Smooth or stepped to one end: No shape elements	External surface plane and/or curved in one direction	Without gear teeth: Axial, not regularly spaced
2	Rotational: L/D ≥ 3	Stepped to one end or smooth: Thread	Smooth or stepped to one end: Thread	External plane surfaces dividing each other in a given ratio	Without gear teeth: Axial, regularly spaced
3	Rotational	Stepped to one end or smooth: Functional groove	Smooth or stepped to one end: Functional groove	External groove and/or slot	Without gear teeth: Radial, not regularly spaced
4	Rotational	Stepped to both ends: No shape elements	Stepped to both ends: No shape elements	External spline (polygon)	Without gear teeth: Axial and/or radial and/or other direction
5	Rotational	Stepped to both ends: Thread	Stepped to both ends: Thread	External plane surface and/or slot, external spline	Without gear teeth: Axial and/or radial, regularly spaced, and/or other directions
6	Nonrotational	Stepped to both ends: Functional groove	Stepped to both ends: Functional groove	Internal plane surface and/or slot	With gear teeth: Spur gear teeth
7	Nonrotational	Functional cone	Functional cone	Internal spline (polygon)	With gear teeth: Bevel gear teeth
8	Nonrotational	Operating thread	Operating thread	Internal and external polygon, groove and/or slot	With gear teeth: Other gear teeth
9	Nonrotational	All others	All others	All others	With gear teeth: All others

Figure 8.14. Breakdown of form code for the upper classification branch in Figure 8.13, after [8.27]. The cross-hatched boxes refer to the example in Figure 8.15



Form code: 1 2 1 3 2

Rotational component 0.5 < L D < 3
External shape: stepped to one end
Internal shape: stepped to one end
Plane surface machining: external groove
Auxiliary holes: axial, regularly spaced

Figure 8.15. Classification of rotating component with the help of the form code in [8.27]. (See Figures 8.13 and 8.14)

Standards number 3 4 5 1 , 1 — relates classified objects to standards

Classification number 3 4 5 1 — classifies objects and relationships by use and shape

Sub-group number 3 4 5 — subdivides a group into ten

Group number 3 4 — subdivides a main group into ten

Main group number 3 — subdivides the spectrum of objects and relationships into ten

Gap

Supplementary code — Extension of classification number by one decade
0 = Non-standard part
1 = Company standard part
2 = National standard part
3 = European standard part
4 = International standard part

Figure 8.16. Numbering scheme of AEG classification scheme, after [8.1]. (The numbers refer to the example in Figure 8.19)

groups and group numbers. Figure 8.18 gives an extract for one of the sub-groups showing the succeeding classification numbers.

The properties of, and the data relating to, the components stored under the classification numbers can be listed on special indexing strips based on [8.24, 8.25]. Figure 8.19 shows one such strip for the classification number analysed in Figure 8.16.

Further examples of classification systems will be found in [8.17, 8.32].

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Classification numbers
List of groups
Concepts and applications

N56
0010
Sheet 1

Group no.		Description	Group no.		Description
0 General	0	Numbering system	5 Electrical componenets	0	Resistors
	1	Information system		1	Capacitors, transformers, chokes
	2	Standards system		2	Switches
	3	Design system		3	Protective equipment
	4	Units, symbols, etc		4	Lamps, torches
	5	Threads		5	Valves
	6	Tests and measurements		6	Semiconductors
	7	Manufacturing and manufacturing instructions		7	Integrated switches
	8			8	Electr. measuring devices
	9			9	
0 Materials	0	Materials	6 General equipment	0	
	1	Auxiliary materials		1	
	2	Flat material		2	
	3	Rectangular material		3	
	4	Polygonal material		4	
	5	Profiled material		5	
	6	Round material		6	
	7	Wires, strips, ropes, leads		7	
	8			8	
	9			9	
2 Machine elements	0	Bearings	7 Products and product groups	0	
	1	Drive and guide elements, rollers		1	
	2	Gearboxes, clutches		2	
	3	Hydraulic and pneumatic components		3	
	4	Hydraulic and pneumetic elements		4	
	5			5	
	6	Seals and caps		6	
	7			7	
	8	Mechanical measuring instruments (other than 88)		8	
				9	
3 Mechanical components	0	Bolts	8 Tools, instructions jigs	0	
	1	Nuts		1	
	2	Mechanical safety devices		2	
	3	Other fixing components		3	
	4	Rotationally symmetrical components		4	
	5	Plates, blocks etc.		5	
	6	Springs, chains, belts, ropes		6	
	7	Covers and nameplates		7	
	8	Hooks		8	
	9			9	
4 Electrical connectors and motors	0	Solder and clamp conections	9 Miscellaneous	0	
	1	Plugs		1	
	2	Leads		2	
	3	Leads with plugs		3	
	4	Insulators		4	
	5			5	
	6	Batteries and power supplies		6	
	7	Electric motors		7	
	8			8	
	9			9	

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0010.1

Figure 8.17. Main groups and group numbers of classification system, after [8.1] (see Figure 8.16)

DK 025.46.62-45 Company Standards October 1972

	Classification numbers Rotationally symmetrical Components Group 34				N56 0013 Sheet 5
Classification no.		**Description**	**Classification no.**		**Description**
340 General	0	Descriptions and classifications	345 Round components with holes	0	General
	1	Concepts		1	Outer cyl. inner features
	2	Tolerances, shapes, finishes		2	Outer cyl. other inner shapes
	3			3	Outer cone, inner features
	4			4\	Outer cone, other inner shapes
	5			5	Other external features, inner shapes
	6	Application instructions		6	Other external features, other inner shapes
	7			7	-
	8			8	
	9			9	Miscellaneous
341 Round components Solid Outer features	0	General	346 Polygonal components solid	0	General
	1	Cyl. no features		1	No features
	2	Cyl. one round feature		2	One polygonal feature
	3	Cyl. n-round features		3	n-polygonal features
	4	Cyl. n-round features, threaded		4	n-polygonal features, threaded
	5	Cyl. polygonal features		5	One round feature
	6	Cyl. other features, threaded		6	n-round features
	7	Cyl. conical features, other shapes		7	n-round features, threaded
	8	Conical, no features		8	n-feature, other shapes
	9	Miscellaneous		9	Miscellaneous
342 Round components Hollow Outer features	0	General	347 Polygonal components hollow	0	General
	1	Cyl. no features		1	
	2	Cyl. one round feature		2	
	3	Cyl. n-round features		3	
	4	Cyl. n-round features, threaded		4	
	5	Cyl. polygonal features		5	
	6	Cyl. other features, threaded		6	
	7	Cyl. external cone, other shapes		7	
	8	Conical, no features		8	
	9	Miscellaneous		9	
343 Round components Hollow Inner features	0	General	348 Polygonal components with holes	0	General
	1			1	
	2	Cyl. one round feature		2	
	3	Cyl. n-round feature		3	
	4	Cyl. n-round features, threaded		4	
	5	Cyl. polygonal features		5	
	6	Cyl. other features, threaded		6	
	7	Cyl. internal cone, other shapes		7	
	8	Internal cone, no features		8	
	9	Miscellaneous		9	
344 Round components Hollow Outer and inner features	0	General	349 Miscellaneous	0	
	1	Round features		1	
	2	Round features, threaded		2	
	3	Polygonal features		3	
	4	Polygonal features, threaded		4	
	5	Conical features		5	
	6	Conical features, threaded		6	
	7	Round and polygonal features		7	
	8	Round and polygonal, threaded		8	
	9	Miscellaneous		9	
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Figure 8.18. Extract from classification system (Figure 8.17) for Group Number 34

345	Round components with holes									
3451	Outer cylinder, inner features									
	Key	A	B	C	D	E	F	G	H	J
		Outside diameter	Outside length	Inside diameter 1	Inside length 1	Inside diameter 2	Inside length 2	Additional data	Material	Protective coating
	Unit	mm	mm	mm	mm	mm	mm	—	—	—

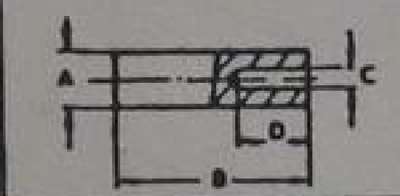
345	Round components with holes		
3451		Pin with hole	—

Figure 8.19. Record card for classification number 3451 of the system shown in Figure 8.16