Handbook for Media Developers

Table of Contents

Handbook for Media Developers.....1

SUMMARY OF QUESTIONS ADDRESSED.....1

0. PREFACE.....2

I.1 OBJECTIVES OF VOCATIONAL TRAINING (Trade standards plus future job requirements).....5

I.2 VAGUE OBJECTIVES VERSUS SPECIFIC TASKS (Bottom−up definition: from tasks to information).....7

I.3 MENTAL REFLECTION OF SKILLS − ROOTING TRADE THEORY (The borderline conflict: workshop versus classroom).....10

I.4 WHAT IS THE POINT OF LECTURES? (The methodology−content−media connection).....13

I.5 CONDITIONS FOR DISCOVERY LEARNING (Appropriate difficulty level).....15

I.6 INFORMATION GENERATING IMAGES AND LINKAGES (Selection aspects to which trade standards provide no clue).....23

I.7 MEASURING LEARNING PROGRESS? (Final trade tests define the real syllabus).....26

I.8 THE DEVELOPMENT CYCLE − MONITORING PROGRESS.....28

I.9 USER FRIENDLINESS (What makes instructors use the package?).....31

II.1 JOB REQUIREMENTS − SKILL SEQUENCES − JOB SEQUENCES.....32

- a) Usefulness and market relevance of training jobs.....32
- b) The skill coverage potential of the training job.....35
- c) Job performance versus product relation.....38
- d) Practice problems leading to relevant trade theory.....39

II.2 SKILL SEQUENCES − JOB SEQUENCES − EXPERIMENTAL SEQUENCES.....39

- a) Distinctive features for skills sequences and jobs sequences.....39
- b) Development and use of skill/job sequences.....40
- c) Differences between skill/job and experimental sequences.....47
- d) Additional hints for the instructor.....48
- e) Illustrative wallcharts conveying a message.....48

II.3 MEASURING THE MASTERY OF SKILLS.....54

- a) Difference between training jobs and testing jobs.....54
- b) Performance marking versus product marking.....55
- c) Testing manual skills versus problem solving strategies.....66
- d) Variety and objectivity of product related marking criteria.....66
- e) Evaluation criteria for marking criteria.....69

II.4 IDENTIFICATION OF TYPICAL CLASSROOM CONTENT.....70

- a) Complexity and problem−orientation of trade theory.....70
- b) Giving top priority to issues with the highest relevance scores.....71

II.5 DISCOVERY LEARNING WITH CAUSE−EFFECT LINKS.....73

- a) Inference questions generating a new concept or rule.....73
- b) Interlinked statements leading to complex logical structures.....74
- c) Features of logical structures.....76
- d) Features of learning with logical structures.....78
- e) Hints for the media developer.....81
- f) Comparisons between conventional information and logic structures.....89
- g) Matching test items/tasks derived from logical structures.....89
- h) The incomplete troubleshooting chart.....90
- i) Comparative tables for discovery learning.....95

II.6 DESIGNING A TASK BANK PRIOR TO WRITING INFORMATION SHEETS.....107

- a) The ambiguity problem with essay questions.....108
- b) Matching tasks for the sake of context and complexity.....110
- c) Multiple−choice items: The pseudo−distractor problem.....117
- d) Item analysis for multiple−choice items and matching items.....119

II.7 CHECKING THE VALIDITY OF TASK BANKS AND TESTS.....124

- a) Slicing the content into roughly equal sections.....125
- b) Classifying test items.....125
- c) Ensuring the variety of types of test items/tasks.....127
- d) Setting the quality marks for test complexity.....127

II.8 INFORMATION SHEETS WITH STRESS ON CONTEXT AND INTERLINKAGE.....130

II.9 A SAMPLE SET OF PACKAGE COMPONENTS.....136

Handbook for Media Developers

CENTRAL INSTRUCTIONAL MEDIA INSTITUTE

MADRAS

INDIA

A GTZ Media Development Project

Dieter Hermanns

1992

This handbook was drafted on behalf of the CIMI media project sponsored by the German Agency for Technical Cooperation (GTZ) in Eschborn, Germany.

SUMMARY OF QUESTIONS ADDRESSED

The development of training software is one of the essential outcomes of GTZ−sponsored vocational training projects. When it comes to the question of what software should look like and what components are needed most, answers differ from project to project. Certain verifiable evaluation criteria may be necessary as a commonly accepted yardstick. Quite a number of suggestions are presented here, to stimulate discussion and perhaps encourage some long overdue clarification.

This handbook addresses the following questions:

- Why does training need to cater for key abilities beyond the skills listed in common trade standards (I.1)?

- Why do trade standards rarely provide the details needed to clarify scope and depth of perception or mastery (I.2, I.7)?

- Why are the customary lists of training objectives no substitute for task banks, although the process works in reverse (I.2)?

- Why should classroom learning concentrate on complex issues, and how are they identified (I.3, II.4)?

- Why is lecturing not an adequate method for training functional understanding (I.4)?

- Why can specialized information be discovered by groups of trainees who use their logical abilities (I.5, II.5)?

- Why does an item of information require interlinkage between text and pictures as well as context among paras (1.6, II.8)?

- Why must tests be valid, and what is a workable procedure for checking validity (I.6, II.7)?

- Why should tasks and test items be developed before the related information subpack−age (I.8, II.9)?

- Why do training jobs and testing jobs need to be adapted to local conditions (II.1)?

- Why does it make sense to distinguish between skill, job, and experimental sequences (II.2)?

– Why should illustrative wallcharts convey a key message with a minimum of text (II.2)?

– Why is performance marking as important as product marking in practice tests (II.3)?

– Why do we need to boost the use of specific, objectively–verifiable marking criteria (II.3)?

– Why do multiple–choice test items need careful screening before being included in task banks (II.6)?

– Why do short–answer questions and matching test items deserve more appreciation in trade theory tests (II.6)?

– Why do validity checks provide valuable clues for improving software packages (II.7)?

0. PREFACE

This handbook is meant as an aid for those whose job it is to develop instructional material for vocational training. As a handout for outsiders and higher–level decision–makers, the manual can also help to promote the layman's understanding of the complexity and difficulty of the developer's work, leading to better appreciation of good results.

The handbook is divided into two parts. Part I explains the underlying philosophy of the approach exemplified in Part II. The first part should be interesting reading for everyone concerned directly or indirectly with instructional material. The second part tells the developer/author in detail what innovations are needed and how they can be developed, using a wide range of examples.

In many cases, the procedures proposed here do not tally with those prescribed in more academic works. They are, however, the result of many years of empirical trial runs aimed at developing a system of training for media developers and instructors who have no academic background in pedagogics or learning psychology. Simplifications have always been made for a reason: they make the system workable and replace more sophisticated approaches which cannot be handled or are too time–consuming. A typical case in point is BLOOM'S taxonomy, quoted in many academic sources. The underlying concept was striking and right and is still valid today, but the system never became workable. Consequently, it failed to generate the changes and improvements it was meant to bring about.

The key points in this handbook with respect to innovation are:

1. OBJECTIVES:

a) There is general agreement that training software must be in line with approved trade standards. It is time we also realized that it takes more than mere coverage of existing trade standards to get good results from a training system. Modernized syllabi incorporate trade standards which describe such key abilities as recognizing how items of information are interconnected, seeing things in context, establishing links between them or planning work steps in a meaningful way before actually doing the job.

b) A key weakness of available training material is the virtual absence of problem–orientation. One gets the impression that, in the imaginary world of some media authors, the tools, machines and processes mentioned in the syllabus always function perfectly. Troubleshooting seems not to have become an integral and mandatory element in all instructional materials simply because it is not yet specifically defined in the respective trade standards. This is especially true of production trades.

2. TASKS FIRST:

Most of the common "lists of objectives" claim to specify the intended outcome of training. In reality, they are often mere vague descriptions providing no clue to the depth of coverage needed and the difficulty level for the trainees.

Accepting MAGER'S definition of objectives as descriptions of the expected result of the training, test items/tasks/assignments/tests appear to express this result more precisely and specifically than many so−called “lists of objectives”.

We should abandon the dubious practice of using vague objectives as a yardstick for the validity of related trade information and tests. It would be better to work from the bottom up, starting from already−developed tasks or tests structured and validated by means of set procedures, and not from the top down.

It is time we saw completeness of subject matter coverage as a vertical aspect, like depth of understanding of selected issues (including problem−solving tasks), and not merely as coverage of a multiplicity of isolated facts (like names and definitions) with which instructors have become familiar.

3. TYPE OF INFORMATION:

a) Complexity and depth

Classroom teaching cannot and is not supposed to compete with a live workshop demonstration. There is typical skill information which directly matches the skill sequences. For trade theory, it is the task of the media developer to look for more complex and highly−interlinked issues which are best covered in the classroom because they require undisturbed concentration over time spans of more than, for example, 10 minutes.

As another rule of thumb, a developer should decide whether a specific item of information can be understood by reading, without explanation from the instructor. Inferring a new rule from, for example, 6 highly−interlinked statements (e.g. describing a process or formulating a new rule or line of reasoning) generally needs the instructor’s assistance, and the classroom is the right place for such training. It is not appropriate to use half the classroom time teaching names and lecturing on definitions.

At present, many typical packages contain too much information because the necessary depth of interlinkage (consuming a lot of time in the learning process) has been ignored. Such packages seem to cover an impressive volume of material, but trainees cannot digest it with the necessary intensity within the given training time.

b) Concreteness of ideas

Few people realize the high ratio of empty word shells in the swollen text information currently presented to trainees. Put to the test by asking trainees to explain the meaning of what they have just read, such packages turn out to contain a high percentage of abstract wording which fails to come across to the reader. In many prevailing systems, no−one minds because trainees cram all information parrot−fashion as verbal chains (verbalism) and are successful in final tests which demand precisely that.

Trial runs for innovative discovery−learning material must prove that an item of textual information is concrete, specific and unambiguous and that it establishes the necessary interlinkage between the given statements. If not, it will merely block the trainees’ flow of ideas.

Harsh quality testing of the media developer’s work in discovery−learning trials also helps him to produce higher−quality information elsewhere in the package. Going through all the stages of preparing a few self−learning exercises is key training for media developers, from which all other components of a package will benefit.

4. ENHANCED ACTIVATION:

a) Methods of teaching

Lecturing is still a common method of training, despite the fact that it turns the trainee into a mere absorber of facts, giving him few chances to train his mind for higher−level activities. It has been aptly described as “the fastest way of transferring information from the chalkboard to the notebook of the trainee without passing through his mind”.

The ability to deduce new rules, to discriminate concepts and to plan working steps in a meaningful sequence is essential in the problem solving situations which confront the skilled worker in the real work environment.

Unless instructors get away from lecturing, one cannot expect trainees to develop the abilities increasingly required by the labour market.

Equally, unless instructional materials offer a wide range of exercises which they find it easy to use, instructors cannot be expected to make the necessary change in teaching habits.

In future, a better−validated final test can apply direct pressure to trainees and indirect pressure to instructors to stop following "beaten tracks". However, unless media authors offer innovative material to the users and the testing authorities, the change is likely to be very slow.

The media developer needs to remember at each stage of his work that a trainee is a human being endowed with intelligence. There must be an end to spoonfeeding and rote−learning. This handbook provides a wide range of sample material illustrating appropriate contexts and difficulty levels which allow trainees to discover new information (distinctions, concepts, rules, interlinkages) for themselves. The basic rules for avoiding lecturing are:

– teach at the highest difficulty level compatible with successful learning;
– provide help only where necessary.

b) Discovery learning as ultimate trainee motivation

Various types of discovery−learning exercise can be used to make trainee groups (not average individuals) discover new insights on their own. Such material will have to be included in packages, to convey two basic messages:

– For media developers, it is a permanent reminder that any item which can be incorporated in "discovery−learning tasks" must not be presented as give−away information. Giving away information the trainee could learn for himself wastes an opportunity for incremental learning which ultimately leads to greater self−reliance. Gradually fading−out guidance or help for the learner is a key feature of well−designed innovative instructional packages.

– For the instructor, such exercises demonstrate that his main role is not to serve as an information machine, but to help only where help is really needed. Restraining his natural desire to "teach" for 15 minutes while the trainee groups work on these exercises shows him that teaching means "making people learn" and not "making people listen to me".

5. THE REAL SYLLABUS:

Final trade tests for certification of skilled workers have enormous potential for influencing a training system. A set of final tests is the real syllabus taken seriously by trainees and instructors alike.

A testing authority which neglects the need for higher−quality test items targeting valid labour market requirements (given in a media package) will eventually lose its real authority. This offers a unique opportunity for media developers to inject innovative elements via trade testing authorities.

Final tests which fail to measure real skills needed on the job (like troubleshooting abilities) generate certificates which fail to describe an applicant's suitability or talent for a specific job.

Although it is a common complaint that approved trade standards do not explicitly define these requirements (as is not infrequently the case), they at least provide ample scope for developers to fill the gaps and are "innovation−neutral", neither helping nor hindering new methods.

6. USER−FRIENDLINESS

Packages must have a certain attraction to the instructor, since he is the key user. What an instructor regards as attractive is, however, very much an individual matter. One type of instructor may be delighted to find the old familiar stories he can chalk out by heart. Another may be grateful for help in responding to new demands he is confronted with (e.g. new final test requirements).

For an instructor, it is usually more difficult to design trade theory exercises than to list related information; so a task bank is more valuable to an instructor looking for innovative material than the information elements of a package.

I.1 OBJECTIVES OF VOCATIONAL TRAINING (Trade standards plus future job requirements)

It is generally agreed that vocational training serves its basic purpose only if it prepares trainees for the labour market and helps them find jobs as skilled workers.

Helping a trainee pass a final exam may be pointless if the trade test is not relevant to the labour market. A test which fails to measure what the labour market needs to know will generate certificates with virtually no value in job terms.

The media developer has to develop his package with one eye firmly fixed on the syllabus and trade standards and the other focused on job requirements.

There have been some essential innovative changes in vocational training in Germany which could provide clues for us to follow.

1. SMALLER VOLUME OF TRAINING CONTENT – MORE PROCEDURAL KNOW–HOW

Less importance is attached to memorizing machine–specific know–how, because design details and handling rules for certain machinery have changed dramatically within a short space of time. Carefully–treasured factual knowledge has become obsolete, while the ability to learn and to interlink new concepts has stayed relevant. Skilled workers should not fill their memories with huge quantities of facts (walking trade–book approach) but learn how to process information for current needs (transferable strategic experience).

Instead of cramming the contents of a table book into their minds, trainees are taught to use the book of tables effectively.

Instead of being offered complete skill sequences and job sequences throughout the course, trainees are first required to complete certain portions of these sequences in full or to write complete work plans step–by–step.

There is now a stronger emphasis on problem orientation, because it is procedural know–how that carries industry through any technological change. New syllabi consequently include problem–oriented objectives extending beyond the scope of single topics.

2. COVERAGE OF KEY EXAMPLES PLUS TRANSFER ABILITY

Self–reliance is the new goal of vocational training. The stress is on the ability to plan actions in a meaningful and effective way, relying on a fundamental understanding of how machines and systems function. All training activities which produce improvements in this direction are seen as desirable.

Example a: Unless he has the ability to select appropriate cutting operations and joining techniques, a trainee cannot plan production of a workpiece from specifications in the drawing.

Example b: Without a troubleshooting strategy for defective machines/equipment, he will be unable to plan the steps in an efficient repair job. Inferring the causes of faults from observable symptoms is a technique he has to develop gradually, through exercises forming an integral part of modern training.

Accordingly, transferring the working principle of one machine/device to another, with instructor guidance gradually faded–out, is a key feature of modern training approaches.

The point is not to apply this methodology to all conceivable fields of technology (many of which may become irrelevant during the trainee's working life), but to give the trainee sufficient experience in dealing with key situations in at least a few specific areas. From this experience he can learn the necessary procedural techniques ("strategy"). The aim is depth of experience using key examples rather than broad but superficial coverage.

New elements of the curriculum (e.g. work–step planning, specifying evaluation criteria, self–management and learning from mistakes how to deal with analogous future situations) mean that the list of items is longer (and the depth of perception deeper). Syllabus coverage therefore has to be cut in other ways. The cut is achieved by a selective approach: by restricting experience to key examples.

Dismantling a commonly−used unit (e.g. a bench vice, a gearbox or a centrifugal pump), spotting fault symptoms, repairing the unit and reassembling it are all techniques which can be learned by handling one of these units. There is a certain equivalence of the training effect in all three cases. Which unit is chosen is therefore of secondary importance, since there is no time to train on all three. Covering essentials through a key example is more important than supposedly "complete" coverage. This all too often derives from an imprecise "should−know" approach. It may mean little more than that the trainee learns to meet the expectations of an "experienced" (too often meaning old) instructor, ensuring that the next generation keeps firmly to the beaten track.

3. MORE MENTAL REFLECTION NOW − MORE ANTICIPATION LATER

Existing trade standards may mention troubleshooting skills, but existing training software usually ignores the fact that knowing how a piece of equipment works does not automatically imply being able to troubleshoot it.

Additional strategy training is needed to familiarize a trainee with the steps leading from recognition of fault symptoms to diagnosis of the underlying cause and thence to remedial measures in a well−planned, effective repair job.

This does not imply that routine skill practice exercises should be discouraged. It means that more mental reflection and analysis of the "why" of job sequences and work rules are needed whenever skill exercises are performed. Skills are not an end in themselves.

Learning how to handle critical steps in one skill sequence is a training for future sequences which cannot be anticipated now. The trainee accumulates know−how enabling him to respond to unfamiliar situations in a future he cannot yet predict.

4. NO SPOONFEEDING

Changes are not confined to content. Innovative methods of training are also long overdue. It would make little sense to give lectures on troubleshooting charts for every topic in the syllabus and then make trainees learn the solutions by heart.

When a trainee is confronted with a new problem situation, the critical factors are his ability to apply known rules and his understanding of working principles. These are not simply a question of memorization. Trainees need to be sensitized gradually to tasks which require them to make intelligent inferences rather than just repeat.

Lecturing is not a suitable tool for achieving these ends.

Since there is no extra cost involved in intensifying trainees' thinking in the classroom, financial arguments cannot be used to justify lecture−style teaching as opposed to interactive learning.

When the instructor is understood as an advisor who provides the minimum guidance needed, trainees are forced to organize their own learning to the utmost possible extent. The tasks or projects they have to handle are correspondingly more complex. Spoonfeeding trainees with lectures and workshop demonstrations is the exact opposite of training for self−reliance.

After basic training under conventional guidance, trainees in modern training systems are exposed to group project work; the spectrum of skills involved in a single project may, for example, range from drilling through taper turning, soldering, quench hardening and hardness testing to assembling. Group planning of work steps includes planning the inspection procedure, so evaluation criteria are needed for self−grading of achievement levels in terms of production and functionality.

No great increase in cost is entailed when the machinery, which already exists in training centres in developing countries is used for more demanding and market−oriented jobs. The change does, however, intensify the trainees' activity level and help to narrow the gap between the real industrial environment and the artificial world of institutionalized training.

Instructors must stop seeing themselves primarily as information machines. What counts is maximizing the trainees' opportunities to think for themselves and not only repeat what has been said and demonstrated by the instructor. This is particularly vital in trade theory. The prevailing practice of cramming irrelevant facts may be justified as a response to the poorly−validated trade tests still in force; but for the media developer the fact that faults exist is no reason to perpetuate them.

Training software for workshop practice should also gradually provide scope for trainee self−planning of working steps in job sequences. Ability to work from instructions in a detailed skill sequence is an improvement on mere repetition of an instructor's demonstration.

I.2 VAGUE OBJECTIVES VERSUS SPECIFIC TASKS (Bottom−up definition: from tasks to information)

1. Starting with trade theory tasks rather than information

Asking a media developer to create test items which measure learning progress will make him think of a concrete test situation with observable activities. Instead of starting from the formulation of vague objectives, it is therefore more productive to go for the tasks and test items straight away.

The lack of precision and concreteness in customary lists of objectives make them unsuitable as a point of reference. They fail to indicate topic coverage. They provide no precise clue to scope and difficulty level. In fact, despite sounding impressive, they may fulfil none of MAGER'S criteria for instructional objectives:

- to indicate specifically what the trainees are expected to do;
- to indicate a specific result of training (behavioral outcome);
- to specify the conditions under which the learners are to perform;
- to determine the standard of performance to be achieved (standard of proficiency)

These criteria are fulfilled far better by trade theory tasks/test items specific to each topic. The marking criteria (performance−related and product−related) indicate the structure and content for the practice tests.

A task bank will by its nature assure proper attention to these aspects, provided that it meets an essential precondition: a trade theory task bank must contain not a few wide−ranging essay questions but a large number of highly specific, unambiguous tasks representing a certain minimum range. Looking at the details of such a task bank will help the media developer to

- select appropriate information;
- anticipate suitable methods of teaching.

One of the main reasons for recommending that the media developer should start designing/compiling/collecting tasks without first formulating objectives is the opportunity this provides for structuring a tasks bank. A media developer who starts in this way has a better chance of ensuring the validity of the task bank in terms of coverage, complexity and testing. In terms of coverage, he can try to ensure that all essential (but no inessential) subject matter is included. In terms of complexity, he can strive for balanced representation of different levels of complexity (including the minimum degree of problem−orientation). In terms of testing, he can attempt to ensure balanced use of different types of test items (impossible with uniform lists of objectives).

There is a further reason for discouraging the formulation of objectives at the expense of carefully designed test items/tasks. A frequent approach of developers and instructors is first to concentrate on the information to be conveyed during training, then think about how to teach it and finally try to develop a tool for measuring results. The result is a bulky compendium containing information of no certain relevance, followed by a few broadly−targeted questions ill−suited as a measuring tool.

The proposal is therefore:

- Step 1: clarify the practice problems.

- Step 2: design test items measuring trade theory know−how that really helps to solve practice problems.

– Step 3: balance these problem–oriented tasks with tasks covering the functional understanding needed to solve the problems.

– Step 4: develop the information covering this task/test item bank.

The present emphasis on large quantities of information must be replaced by closer attention to tasks. Future packages will need to contain a smaller amount of information much better processed, interrelated, and interlinked. Depth of perception rather than breadth of content is required.

In order to create the desired semantic network in the trainees' minds, greater depth of understanding with fewer topics and less factual knowledge is needed. The number of processing exercises (e.g. comparisons, cause–effect linkages and potential defect analysis situations) will need to be increased. Such exercises link newly–learned concepts with trainees' previous knowledge. Current information overkill means there is no time or energy left to achieve this aim.

2. Valid task banks are more important than new lists of objectives

A closer look at the type of questions asked in tests shows that memorizing tasks are sadly over–represented. This is partly understandable as a reaction to current final trade tests. Such tests do not yet demand troubleshooting abilities or the ability to create real applications in new situations. They neither require the writing of work plans nor permit the use of self–evaluation criteria for practice test results.

Trade standards lag behind industrial developments and fail to reflect up–to–date training needs. Lists of objectives are too imprecise to act as a point of reference for validating tests and task banks. Some other design tool is needed to get properly balanced coverage of subject matter *and* depth of understanding.

If it is commonly accepted that a technical topic has not been covered with full depth of perception unless some troubleshooting aspects are included, then media developers will have to present instructors with materials which reduce learning of names and definitions and listing of types to a minimum.

Vocational instructors are not sufficiently aware that by presenting a new machine or piece of equipment and introducing names for 10 new components they are mainly teaching language rather than concepts or relationships. Presenting an excessive number of names and definitions currently absorbs so much time and concentration that trainees have no capacity left to understand the working principles.

It is worth remembering that an ability to reproduce the wording of rules or definitions does not mean the learner has established a mental image and rooted its meaning in existing preknowledge. GAGNE in his CONDITIONS OF LEARNING distinguished between "verbal chains" and "concept learning".

Classroom topics cover 3 main areas:

1. Verbal chains, e.g. names or the wording of rules (verbalism) or isolated facts/figures learned by appropriate cramming. These should be kept to an absolute minimum in the classroom.

2. Discrimination (recognition of differences) and conceptualization (forming mental images with typical attributes or properties) and combination (linking mental images to formulate rules and establish relationships between concepts, e.g. working principles). Constant repetition does not improve depth of perception of such concepts unless it involves transfer to new contexts.

3. Interlinking rules (e.g. applying working principles to new situations, for example in troubleshooting, in many ways the best context for real applications).

All innovative approaches to training, including new German approaches, focus on problem–solving tasks.

The learning cycle should ideally cover all three areas within any session. In practice, this is difficult due to time constraints.

Asking which of the three could be skipped with the least sacrifice may produce an interesting answer:

A trainee can learn the 2 higher levels of complexity without memorizing names. Verbal chains like names can be reduced to labels. For lesson purposes, a “lead screw” becomes part “X” (labelled in a drawing or sketch), the “feed shaft” is “Y” and so on. All interactions between components of, for example, a lathe mechanism can still be understood.

Levels of complexity should not be confused with *levels of difficulty.* When analyzing tests, the *difficulty level* of a test item is measured as the percentage of correct responses. The fewer candidates answer an item successfully, the higher the difficulty level for the target group.

This yardstick is not related to the level of complexity. It can be very difficult to answer a question requiring assorted names for odd types of equipment. Conversely, a short−answer question may cover content at the troubleshooting level without posing special difficulties for trainees who have received appropriate training.

It is possible to analyze and structure task banks to achieve balanced content coverage, but an additional classification scheme is needed to balance the level of complexity.

Levels of complexity:

> **Level I** is used for all isolated facts (names, figures) and verbal chains (wording of definitions and rules) which can be learned by heart without requiring understanding.
>
> **Level II** covers functional understanding of equipment and processes under appropriate working conditions. Test items at this level involve comparing concepts and rules and establishing links between them.
>
> **Level III** differs from level II in that it addresses components and processes which have gone or may go wrong. Test items at this level deal with fault symptoms and require trainees to link them with causes or to plan remedial measures.

The main purpose of the above taxonomy is to provide a simple validation tool for the developer who wishes to ensure balanced problem−orientation in his package. The chapter on validity checks shows how it can be used to analyze task banks.

3. Tasks derived from workshop problems

A marked improvement has already been achieved if related job sequences and skill sequences can be identified by reference to relevant workshop jobs.

Skill sequences ideally lead to the clarification of critical steps (steps involving risks to the trainee, potential risks to tools or equipment or a risk of defective products or services). This recognition of potential difficulties in a skill sequence is a good basis for developing relevant trade theory content with high problem−orientation. The list of problems compiled during writing of the skill/job sequences will serve as a reference for designing trade theory tasks which address just these critical steps.

By proceeding in this way, the media developer automatically builds practice−relevance into tasks and trade theory content.

Instead of leafing through the syllabus to find keywords around which he can compile information clusters, the media developer consults the skill/job sequences and asks what relevant theoretical know−how is needed to solve practical problems and faults or prevent them occurring. Starting from this point, he drafts tasks and test items first.

Step a)	Jobs and project work are designed to cover the main skills mentioned in the curriculum.
Step b)	But before any work starts on trade theory information, skill sequences must be completed, identifying key critical steps together with core skill information which must be included in the demonstration and shop talk.

Step c) Critical skill performance areas are then translated into trade theory tasks.

Step d) The tasks define the objectives. Related trade theory content can then be derived easily from the objectives.

4. The obsession with “completeness”

When media developers are asked why they have included a particular item of information in a package, a common response is that the trainees “should know this..”. A frequent concern seems to be to “cover the curriculum completely”.

The resulting packages possess little structure or emphasis on essentials, because information of this kind easily deteriorates into a mass of trivial detail.

If completeness is understood to mean “as much as possible about all topics listed in the syllabus”, it inevitably leads to packages of forbidding size and detail. Trainees condemned to this approach become “walking books”, absorbing facts like overfilled sponges because they may come up in some arbitrary test question. Content is listed, but not interlinked or processed.

In fact, there is no such thing as “completeness”. There is little point in being able to name 10 different types of clutch if one is still vague about how they function. Moreover, there are limits on any trainee’s capacity to absorb facts; it is not feasible to provide encyclopaedic knowledge AND at the same time promote in–depth understanding of complex essentials.

It is impossible to include troubleshooting in most topics of a present–day syllabus *and* stick to the popular practice of using topics as pegs for hundreds of detailed facts.

There is an EITHER–OR option because of time constraints and the limited absorptive capacity of the trainees.

Two types of information need top priority coverage in an instructional package:

I. Shop talk information is needed as part of the skill sequences, so that trainees read through the working steps and obtain minimum basic information while doing the job.

II. Classroom instruction should concentrate on more difficult and complex issues, where help from the instructor and interaction between trainees is indispensible.

The essential purpose of trade theory is better met by deliberately selecting a few complex representative issues for classroom treatment. Presenting ten types of milling cutter and learning their names is a useless exercise unless it leads trainees to discover for themselves what the different types are used for. The process of finding out establishes a transferable technique for discriminating between tools and their uses. Making trainees find information like the RPM for a drilling job, instead of feeding them the information in the skill sequence, prepares them to react in future jobs where there is no skill sequence to list all the working steps.

Instead of striving for encyclopaedic information, it should be a key aim of the media developer to keep back any information that can be found by the trainee himself, and make it a task for him to do so.

This approach will slim down the information component of the package while increasing the number of tasks.

I.3 MENTAL REFLECTION OF SKILLS – ROOTING TRADE THEORY (The borderline conflict: workshop versus classroom)

a) Skill information versus complex trade theory

There are typical workshop training items and typical classroom training items, each with their own identifying features.

In the worst–case scenario, a theory lesson is misused to cover typical skill information. Alternatively, a workshop demonstration showing how to handle a machine becomes a bolt–by–bolt explanation of the working principles of every component, including internal mechanisms which are not even visible.

The workshop is the place for the trainee to practice the skills demonstrated by the instructor.

The classroom provides an environment for thinking about technical "whys and wherefores", with time spans of half an hour or more.

By limiting working–step information in skill sequences to items which tell the trainee what to do and how to do it, one can ensure that no complex trade theory is trained in the workshop. By focusing classroom attention on more complex issues, one can ensure that trivial issues are not covered first.

The more contrast a package provides, by offering complex classroom issues as distinct from performance–related skill information, the more help it will give the inexperienced instructor who is unsure where to draw the borderline.

The procedure outlined below for selecting classroom items awards marks for the appropriateness of theory content. Four criteria, each yielding a maximum of 3 marks, are used to scrutinize the topic or issue or curricular item. The media development team could then decide the minimum score needed to include a topic/issue in classroom trade theory.

Relevance criteria for classroom content:

1. Relevance to practice: The media developer describes up to three workshop/lab situations (preferably critical working steps of a skill sequence) where the item really matters.

2. Internal links: The media developer lists either cause–effect linkages with a minimum of 3 different connections/comparisons and with at least 5 essential differences.

3. Curricular links: The media developer lists other topics in the syllabus which cannot be understood without knowing this item first, or which naturally lead on to it.

4. Example potential: The media developer lists other topics/issues which could be cut out in part or in full under time pressure, because the item under review is transferable to them or because it illustrates them (equivalence aspect).

Rationale for Criterion 1:

In most (but not all) cases, a theory item which cannot be related to specific workshop situations is not relevant and should be omitted from an efficient training course. The mere fact that a particular item is mentioned in the syllabus does not justify covering it in a media package. (After all, reference books are available and can be quoted in the package).

Example for Criterion 1: Skill sequence "soldering" with the following steps:

- clean surface to be soldered;
- preheat workpiece before adding solder;
- fix workpiece parts firmly until solidification is complete.

These workshop situations relate, for example, to the trade theory item "conditions for diffusion of melts into solid surfaces".

Rationale for Criterion 2:

An item with less than the required internal complexity should be checked to see whether it could not be presented more appropriately in the shop talk. As a side–effect, this provides clues to potential cause–effect links for discovery learning in the classroom.

– The second criterion measures the internal complexity of an item in order to exclude isolated factual knowledge which trainees can learn by reading a book.

Example of soldering: Only when surfaces are clean and heated to soldering temperature and when the soldering gap is sufficiently narrow will the solder be melted by the heat stored in the base metal, reaching contact areas for diffusion and forming an alloy with the base metals.

Rationale for Criterion 3:

A topic which provides preknowledge for several other topics is more important than an isolated item. This criterion ensures that key basics get more attention than topics higher in the curricular hierarchy. A solid foundation is built, rather than a pseudo-curricular high-rise which is bound to topple later.

The third criterion clarifies what other related topics exist. For soldering these might be welding, gluing, metal alloys in case-hardening.

Rationale for Criterion 4:

It is important that training theory content should be multi-usable and that the underlying principles should have common features which allow them to be transferred to other topics. The main point is that content should be worth training to a certain depth because of its example potential and transferability. Such items allow similar issues under other headings to be skipped whenever time pressure dictates.

The fourth criterion covers another aspect of transferable learning. Some topics have higher transfer potential than others.

Example: The phenomenon of diffusion can be introduced in various contexts: recrystallization of metals after cold forming, soldering, case-hardening or quench-hardening. Once the concept of “diffusion” has been clarified for one of these topics, it can be called on as useful preknowledge for all the rest.

Example: selection/calculation of speeds, feeds and machining time. This item can be introduced equally well when dealing with either turning or milling, so that it also has substitution potential.

Example: Work clamping and tool holding. This involves similar geometry defects due to elasticity of the materials and shapes (e.g. cylindricity, roundness etc.) in a wide range of operations. Whether it is mentioned under the headline “drilling”, “turning” or “milling” is of secondary importance, but it needs to be taught in depth once to make the knowledge transferable.

2. Time linkage between trade practice and trade theory training

A well-trained skill sequence or well-rooted learning are not forgotten quickly. A time lag between practice training and trade theory training is therefore quite acceptable.

Prior knowledge of related theory is not a precondition for skill sequences which stress motor skills (e.g. filing, welding or soldering). Of course, this is not true of skill sequences which stress the order in which activities are performed or have strong interlinkages with theoretical aspects (e.g. many repair and adjustment or machining jobs).

Basically, certain skill sequences are learnt faster and the number of exercises is reduced if related trade theory has been learnt well in advance. Trade theory know-how improves self-reflection and self-correction in skill learning.

Conversely, prior handling of tools, equipment and processes familiarizes the trainee with real objects and phenomena; resulting mental images can be called on when needed in concept formation and rule learning. This helps trainees grasp concepts and rules faster in theory work, though there are many ways of compensating lack of direct experience through illustrations or effective verbal descriptions. Engineering students often have to understand the principles of complex processes they have never experienced in reality.

Summing up, one can say that a trainee who has never drilled a hole in steel can still understand the effect of drill helix on rake and its use with certain metals. The reverse is equally true: a trainee who has no idea what helix or rake are can still learn to drill expertly. Only a small fraction of trade theory is needed as skill information in a skill sequences text. This is less true for job or experiment sequences where cause-effect links determine the order of working steps (e.g. troubleshooting).

Splitting up trade practice and trade theory timewise does not spell disaster. The better the quality of mental images produced in the learner's mind, the less will theory training depend on prior skill training.

Much more important than time linkage is ensuring that

I. trade theory content relates to real projects/jobs and derives from critical working steps;

II skill training combines critical steps with realistic problem situations and faults;

III trade theory goes beyond fact−listing to interlinking of rules in discovery learning;

IV trade theory includes troubleshooting as a core element and does not present trainees with the illusion of a "no−problem" world.

I.4 WHAT IS THE POINT OF LECTURES? (The methodology−content−media connection)

a) Methodology can enhance or inhibit perception

Instructional material directly promotes or discourages particular teaching methods, especially in the classroom. A package consisting mainly of information sheets and a few broad essay questions gives little help to an instructor willing to activate trainees more effectively. Providing relevant tasks (including discovery learning exercises) and relevant information in equal proportions directly encourages an instructor to use the exercises and refrain from lecturing.

In the lecture situation, the lecturer presents all information. He also supplies guidance and problem−solutions by asking pseudo−questions which he answers himself. Such lecturing ploys often begin with "As we all see...", followed by a pat solution; all that is left for the trainee is to learn the solution by heart. Since the subsequent test question requires no more than word−by−word reproduction of the appropriate passage from the lecture, there is no way of distinguishing real understanding from mere memorization.

A common feature of all experiments with innovative training approaches is that learning group activities centre round a core problem accepted by the trainees as relevant and vital. Problem−oriented content is essential for innovative training; enhanced trainee activity is the key element in methodology.

A group of trainees who realize that a saw blade penetrates deeper into the work if cutting force acts on only a few teeth, but that this makes teeth correspondingly more prone to breakage, can better judge the amount of force to apply when sawing thin−walled sheets. Such trainees do not need the instructor to tell them why reduced hand pressure is required for this job; they can use their own powers of logical deduction.

In other words, an essential quality criterion for instructional material is: "Does a training package offer trainees a wide range of opportunities to do their own thinking?" Packages which meet this test will present trainees with interlinked items but keep back the final link, which trainees must think out for themselves. Lecturing is not compatible with this approach.

The ability to discriminate between differing concepts or roles helps man to order and structure his environment. A trainee cannot develop this ability by learning a random list of features pertaining to different types of tool, machine or process; the basic effect is to lull his mind into inactivity.

Training should help the trainee to detect differences where the untrained eye sees none. Lectures comparing different types of tool or machine are an example of mental underexposure for the trainees. It is demotivating to have to listen to predigested information for too long.

Inclusion of discovery learning exercises in a package helps trainees use their minds more actively.

b) Impact on instructor's attitude

One major reason why instructors stick to lecturing is their own know−how, or more precisely the lack of it. Lecturing gives the instructor full control over content. He can define the boundaries and stay on safe ground. The shrewd trainee accepts what he is given and does not ask questions. Questioning might stimulate trainees to ask something the instructor cannot answer.

Psychologically, one can understand why instructors like to stay behind the protective screen of the lecture, but the practice makes the entire training system pointless. An unpleasant surprise is in store for trainees who have developed a pride in learning book knowledge (the key to passing the final test), when they discover that the resulting certificate does not get them a decent job on the labour market.

More problem−orientation in final tests makes instructors receptive to new methods, provided they receive a certain minimum level of help from new instructional materials.

Discovery learning materials which force trainees to learn certain items without the instructor's help automatically alter the role of the instructor.

Initially, the innovative components proposed here demand no more of the instructor than to let trainee groups work with the available material.

Group−oriented discovery learning material generates motivation and reinforcement, due to the following features:

- Content is relevant.

- The number of statements is limited (usually 5 to 8) and they are logically interlinked; there is a good chance of success within a time−span of 10 − 20 minutes.

- Wording and language are concrete and specific.

- Verbal information relates closely to labelled illustrations, improving understanding.

- The key situation is unambiguous; the instructor can give trainees feedback as soon as they finish the work.

The instructor may realize the advantages of higher trainees activation for himself (pauses in speaking, periods of relative relaxation while trainees are concentrating etc.) and this make him more inclined to try other teaching methods, like questioning by the trainees.

As few as two theory sessions per week in which trainees use these exercises will have an impact on the instructor's perception of his own role.

The less dedicated instructor can be a formidable barrier barring access to innovative material by the trainees. This is an argument forgiving trainees direct access to discovery learning exercises as part of their standard handout material. (The key solutions are naturally omitted).

c) The impact on the developer's work

The drafting of innovative instructional material can be rewarding or frustrating, depending on the talent and stamina the media developers bring to the job. Although drafting can be done by individuals, evaluation must be teamwork.

Evaluation criteria help to improve drafts and show what kind of adaptation is needed.

The ultimate yardstick, however, is trainee learning success. Here again, there is a marked difference in trial run feedback for conventional information sheets and discovery learning exercises respectively. Where the trainee is required to memorize a given catalogue of information, the trial run measures his ability to memorize but gives no clue to the quality of the material, since rote−learning is equally applicable to meaningful and meaningless texts.

By contrast, it can be a sobering experience to put a set of discovery learning statement to the test and find that they do not work, perhaps because a tiny section of the text is confusing or because there is a logical gap between two statements. After careful self−evaluation by the team, the author may find that trainees on the trial run point out text passages or details in the drawings which arc still clearly wrong, ambiguous or imprecise (and which the development team failed to pick up). Directly observed trial runs with a few trainees arc indispensible for producing top quality material.

Discovery learning exercises offer the inexperienced developer a unique chance to:

- learn what language is understood by the target group;
- weed out empty introductory statements and word shells;
- use precise wording which generates images;
- limit overall content to digestible items of information.

Writing a conventional information sheet or a page for a trade book is one thing; designing a logical structure which generates discovery of a new high−level rule is quite another.

Making a media developer go through the whole development process for some 5 discovery learning topics acts as an eye−opener. It can generate experience which benefits the drafting of many subsequent pages of information sheets. Media developers need to be exposed to such projects and the ordeal of devising self−learning material, to sensitize them to the value of evaluation criteria. Only then should they be allowed to produce normal information sheets and tasks. There is always a risk of overlength and redundancy in information sheets, because no trial run can show where they need cutting.

I.5 CONDITIONS FOR DISCOVERY LEARNING (Appropriate difficulty level)

1) Learning is more than listening

Human beings have an ability to use logic in order to discover new information for themselves. This basic ability can be anaesthetized by treating trainees as memorizing machines; or it can be revived by frequent exposure to related tasks.

Example: A trainee has learned that plastic material is a poor conductor of heat. He has also learned that an increase in temperature will distort micrometer results. By combining these items, he can deduce why plastic pads are glued to parts of a micrometer in contact with the hand.

So long as it can be agreed that teaching does not mean making trainees listen but making them think, preknowledge can be looked at from a different perspective.

Obviously preknowledge of related information must exist before inferences can be made. As the above example shows, two rules may be known or presented or given, while the third can be inferred as new information.

The key problem of existing instructional material is that it does not encourage inferential thinking to the extent that it could. It too often presents all the information when trainees could in fact jump a small information gap intentionally left unfilled by the media developer.

Repeated use of inferential questions which ask the trainees to link two known facts/phenomena/rules and discover a new one for themselves will accustom trainees to this form of learning. Tasks can gradually become more complex. Discovering a logical structure linking six single statements to a master statement is a complex task which cannot be solved just by memorizing facts.

Too much spoonfed information with frequent memorizing of vast numbers of facts not only entails unacceptable volumes of material and waste of training time on non−essentials. Its major drawback is that it generates the wrong kind of teaching attitudes (lecturing) and learning attitudes (learning verbal chains by heart).

Packages should leave deliberate information gaps wherever there is a good chance that a group of 4 trainees can successfully find the missing link by means of logical deduction.

What matters most is not providing every detail of information about a topic, but well−planned use of gaps that can be filled by the trainees themselves. Such material generates a high level of mental activity and high learning efficiency.

Instead of asking himself: “Have I put everything in?” the media developer should be asking: “Have I left out everything I can?”

This approach differentiates various types of task needed in IMPs:

1. Deductive questions establishing cause–effect links

The simplest version is presenting two rules/phenomena which allow trainees to infer a third.

Example A:

Rule 1: The hardness of metals falls with increasing temperature, making tools dull faster.

Rule 2: 80% of heat generated by chip formation in a turning process accumulates in the turning tool.

Question: Why is cooling needed if you increase the work RPM when turning mild steel?

Missing link: Because the tool heats most, it will lose hardness. Unless cooled to lower temperatures, tool is dulled.

Example B:

1) Electric current generates heat in cables and so heats its environment (insulation, walls, air).

2) The plastic cover for cables acts as an electrical insulator, but lets enough heat seep through to stop the cable getting too hot. Plastic insulators deteriorate above 180 °C.

Question: Why must extension cables be unrolled from the drum before connecting high electrical loads?

Missing link: The heat escaping into the densely packed insulation cannot dissipate to the atmosphere. It accumulates in the insulation, causing dangerously high temperatures.

Such small cause–effect links can be traced quite frequently, and used for logic training. But there are other types as well.

2. Comparative tables

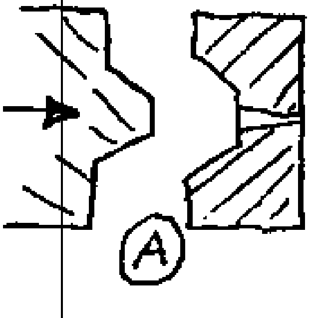
The ability of trainees to recognize differences or similarities can be used to find appropriate positions for statements (features, properties, applications etc.) in relation to different types or classes presented by the instructor.

The learning process is changed from tedious reception of details to a group discussion. Trainees propose solutions and support them with arguments. If the others are not convinced, they make counterproposals with opposing arguments. The trainee’s eye is sharpened for details of the illustrations or the given rules, as he attempts to find knowledge which will prove or disprove the competing propositions.

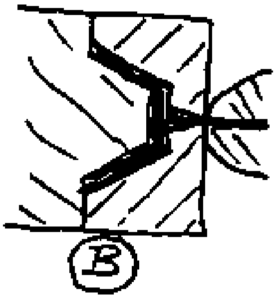
The information belonging to these pictures are mixed up. You are requested to sort them out matching a label number to each of the statements so that they can be listed in correct order!

Task version
(trainee handout)

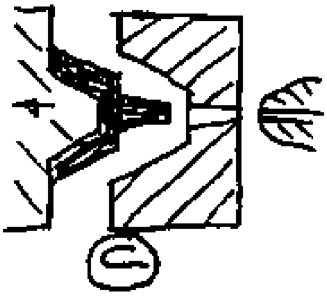
Closing of the mould



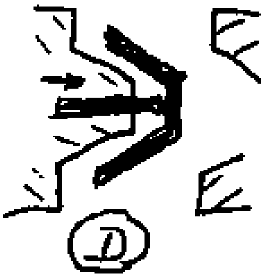
Injection and cooling of mass



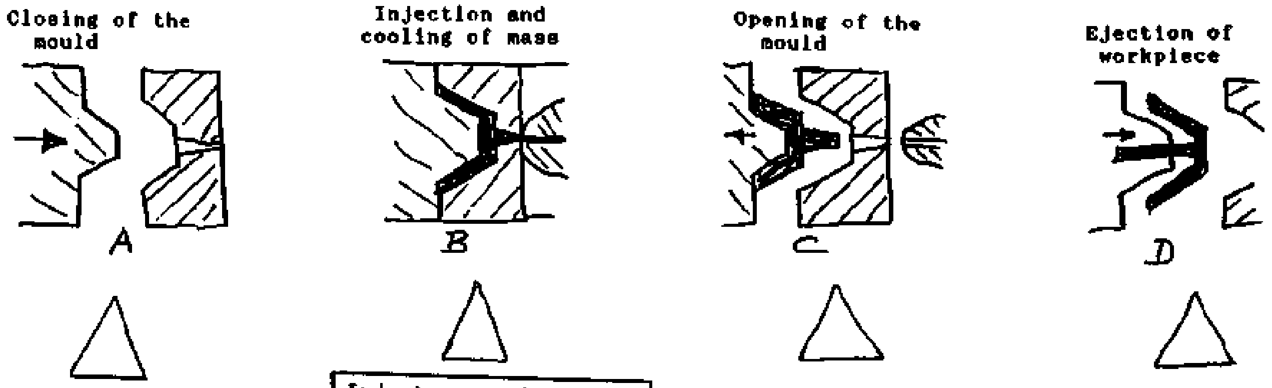
Opening of the mould



Ejection of workpiece



Sprue is pulled out of the sprue bush	Withdrawal of core plate.
Parting line around cavity is sealed.	Injection pressure is increased to compensate shrinkage by additional plastic injection
Prior cleaning is important here	Shrinking workpiece is hanging onto core plate.
Pins push the workpiece off the core plate.	Injector nozzle is withdrawn.
Core plate is pressed against cavity plate.	A water circulation can speed up solidification
Injector nozzle is pressed against back of cavity plate.	Plastic mass is injected into the cavity.



Prior cleaning is important here.

Core plate is pressed against cavity plate.

Parting line around cavity is sealed.

Injector nozzle is pressed against back of cavity plate.

Plastic mass is injected into the cavity.

Injection pressure is increased to compensate shrinkage by additional plastic injection

A water circulation can speed up solidification

Withdrawal of core plate.

Shrinking workpiece is hanging onto core plate.

Injector nozzle is withdrawn.

Sprue is pulled out of the sprue bush

Pins push the workpiece off the core plate.

Key Version

≙ information sheet

Statements can be presented in one of two ways:

The whole class can work in a plenary discussion, using a board with hooks or a mag–netboard. Each statement can be matched to the related picture (using hooks or magnetic pads).

A cheaper and more direct method is to work in 5 or 6 groups per class. The tasks are printed on A4 size assignment sheets (as part of the trainee handout in the package). Each group cuts out the single statements from its sheet. They can now arrange and rearrange the statements on the group table (see example on next page, with a task version on top and missing link below).

Such exercises force the media developer to design statements which contrast clearly with each other.

Lists of types are ideal for discovery learning provided they fulfil certain conditions:

There must be an obvious difference between the types which enhances the trainees' chance of recognition. Contrasting features are stressed to show why different types developed at all.

There are reasons for different types which can be addressed, and which provide the logic for trainee discrimination.

In a conventional lecturing approach, various types are shown as illustrations and names are learnt;(trainees are thought to be incapable of discrimination or independent discovery). Though this may be an appropriate learning situation for a storekeeper who has to hear a name and immediately fetch a piece of equipment from a shelf (while keeping his inventory books in order), it is wholly inadequate for technical training.

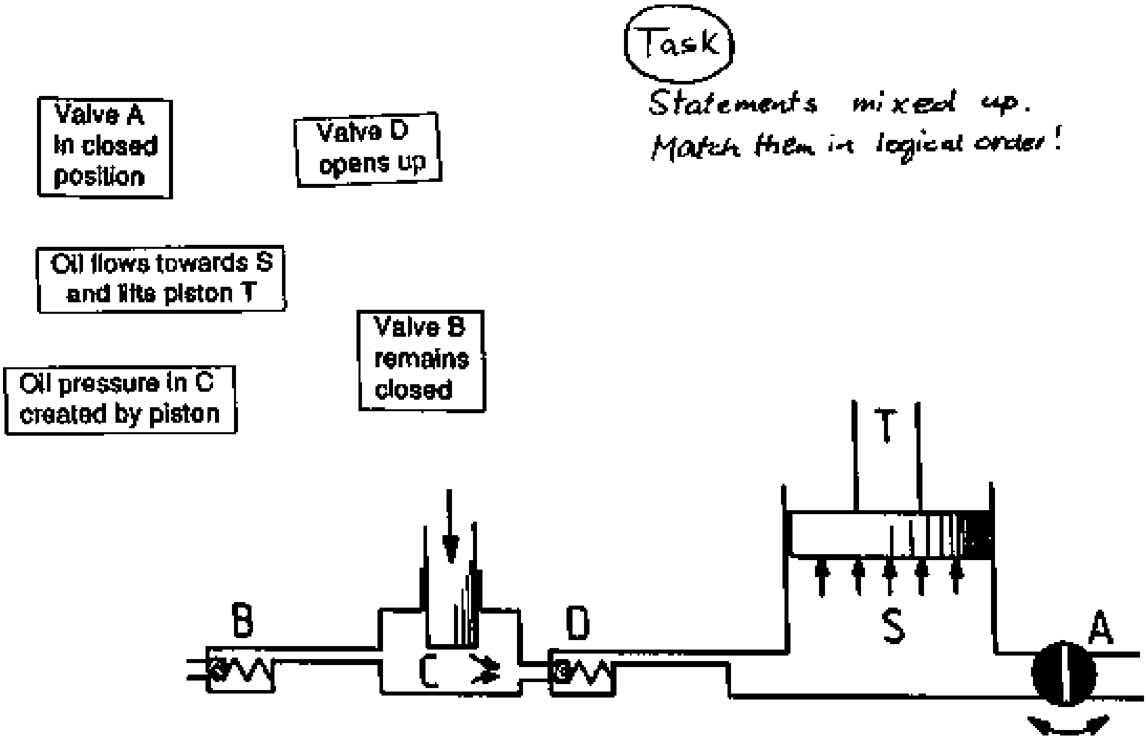
3. Complex logical structures

The third type of discovery learning exercise addresses more complex issues and is the most demanding for group learning. Its difficulty level is such that an average individual will fail to find the solution. Groups are encouraged to develop teamwork, because they will soon realize that critical comments from one group member actually stops the team following false leads. The puzzle–type

task usual begins with a picture establishing a context or topic. The picture can be referred to in asking the question and help to direct trainees' thinking.

The core element is a set of scrambled statements (5 – 8 at skilled worker trainee level). They all belong to a complex cause–effect structure and the trainees have to link them in a strictly logical order leading to an unambiguous key insight.

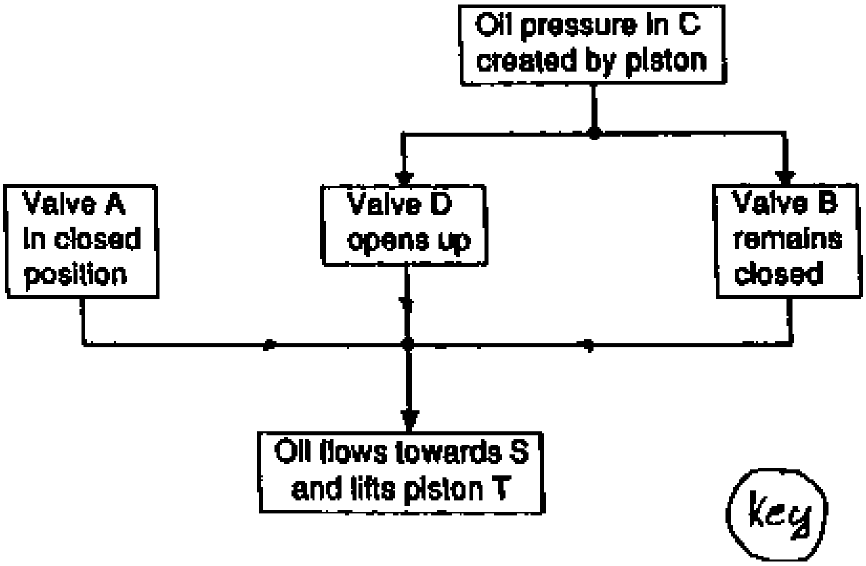
The crux is that interlinkage of the logical structure seldom produces linear vertical logic. Most technical issues require branching because, for example, two or more causes/conditions have to be present before a certain effect can be achieved.



Task

Statements mixed up. Match them in logical order!

Working principle of a hydraulic jack:



Key

Example:

If someone is thirsty he wants to drink. He will drink, for example, a coca–cola provided

a) he is really thirsty
b) he has money and
c) a coca–cola stall is nearby.

This means that three conditions must be satisfied before coca–cola drinking takes place.

Again the result is a new item of considerable complexity which can be discovered only if the information components are given and the number of statements to be combined is limited. The thinking process required to link the statements correctly is totally different from passive reception of a lecture. It provides intensive training for the ability to structure, to link, to relate and to combine. It eventually allows the instructor to confront trainees with complete projects in the final stage of their training (see example below).

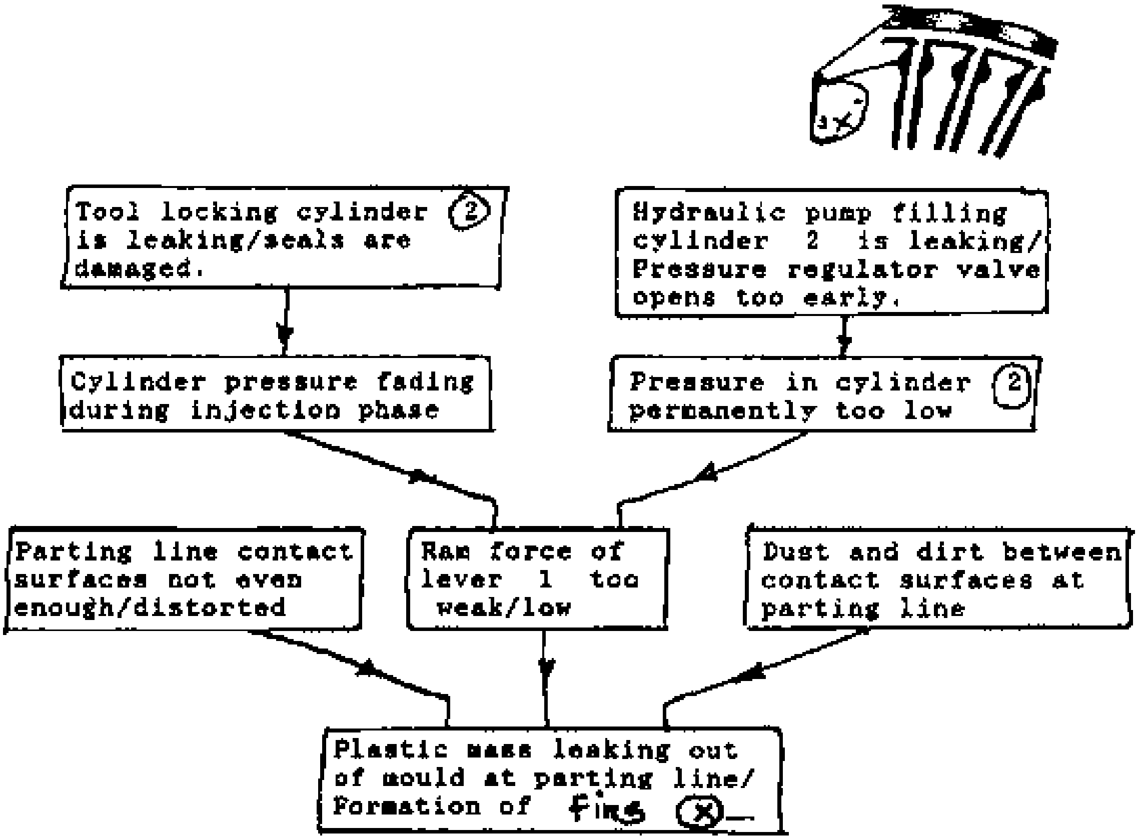
4. Troubleshooting charts

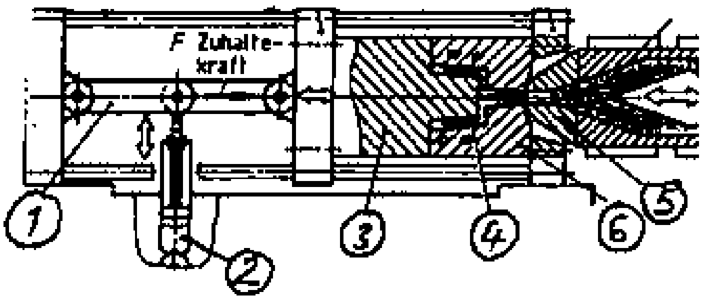
A fourth type of discovery learning exercise, the troubleshooting chart, is very much linked to the third type, but is not necessarily dependent on previous discovery learning

Logical structures can deal with cause–effect links or with fault–cause–remedy links. The more complex problem–related versions of logical structures provide the media developer with a unique chance to design a troubleshooting chart. The only new element is the introduction of observable symptoms (where the faults themselves are not directly visible).

The troubleshooting chart has at most four columns, two of which are sometimes combined. Faults are not always visible, so visible symptoms are used for linkage to cause–diagnosis instead. In the case of visible faults, symptom and fault are identical. The same is true of remedies which simply involve repeating the fault description with inverted wording. The task is to match statements with the incomplete chart (see example below).

Example:





INJECTION MOULDING DEFECTS: Formation of fins

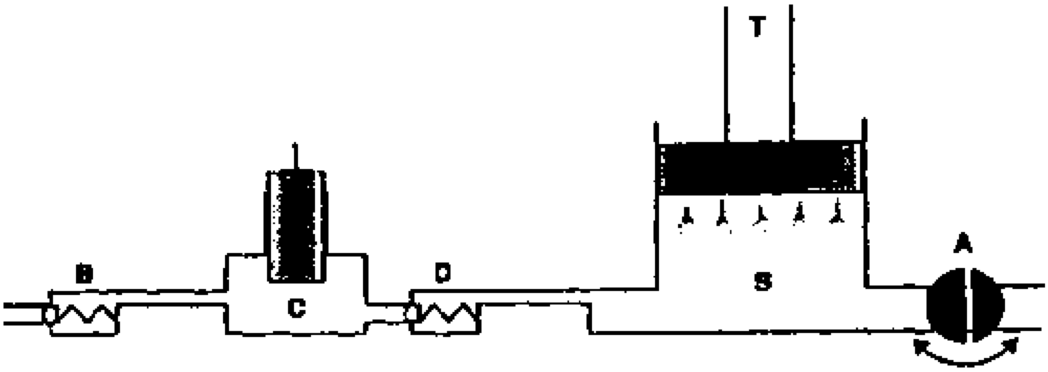
Trouble Shooting Charts

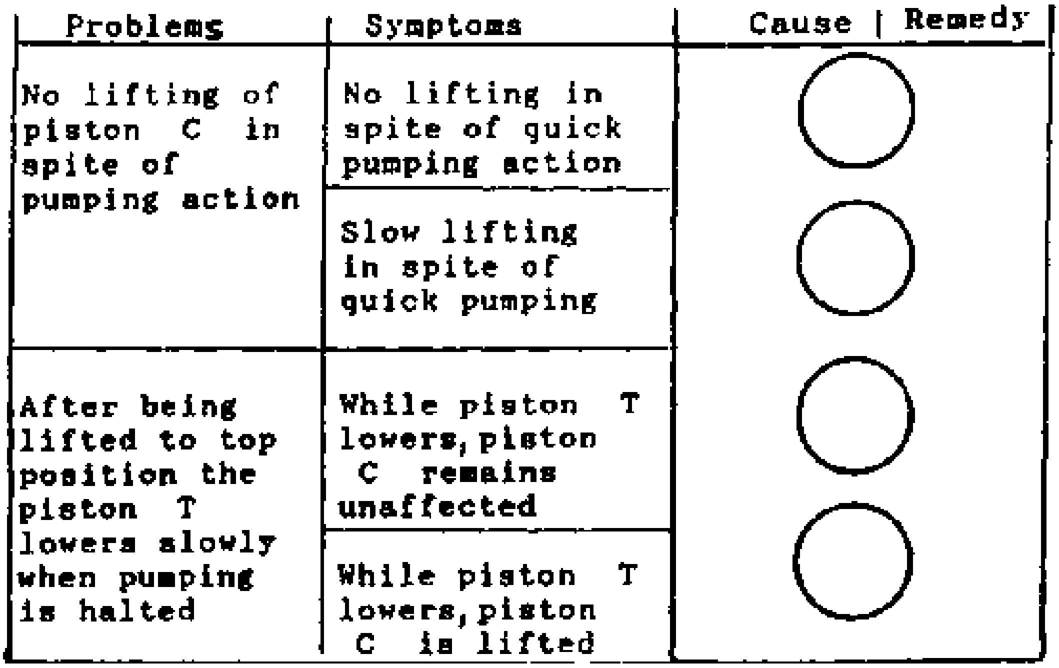
TROUBLE SHOOTING STRATEGY for injection mould defects

Defect	Observable symptoms	Cause of defect	Remedial measures
Thermoplast leaking out at parting line surfaces	a) Pressure from pump too low	Pump worn or RPM of motor too low	Replace pump Replace motor or regulate voltage.
	b) Pump pressure o.k., but cylinder pressure always too low	Pressure valve defect or set wrongly	Renew or adjust valve and tighten pipe joints
	c) Pump pressure o.k. but cylinder pressure is fading during injection phase.	Ram cylinder is leaking	Renew seal of cylinder

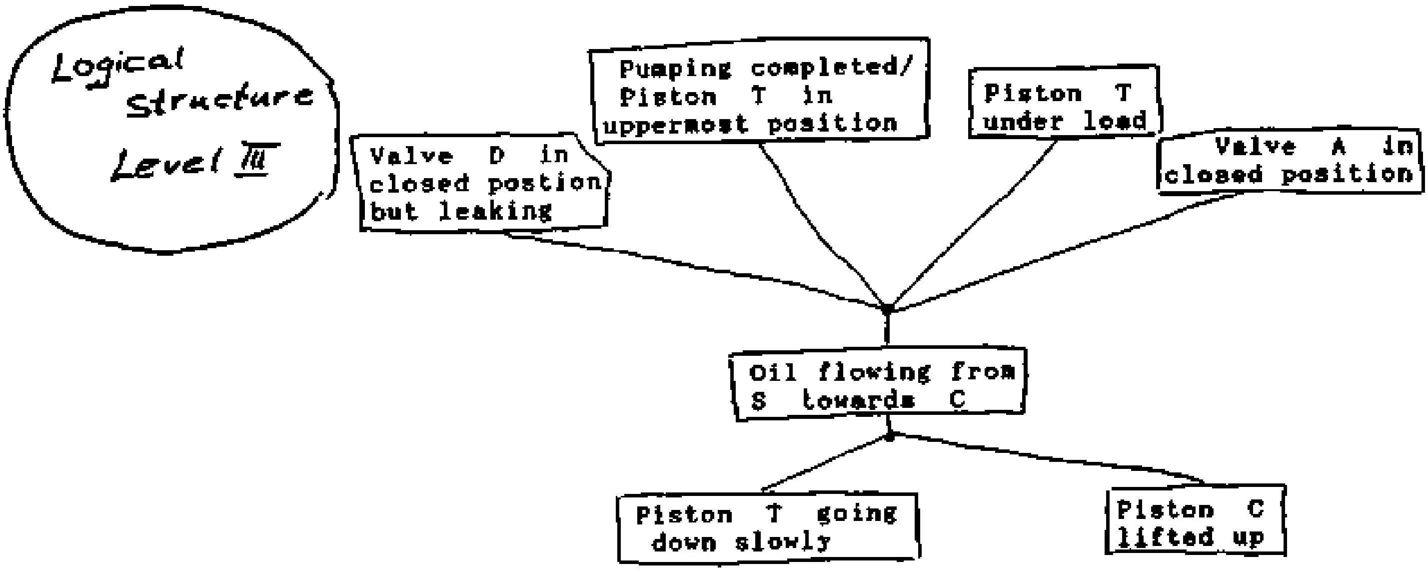
	d) Cylinder pressure o.k., but sufaces at parting line uneven	Contact areas reduced, poor sealing effect	Grind surf. at p. line
	e) Cylinder pressure o.k., but dust and dirt on contact area at parting line	Gap between plates at parting line	Clean area, remove particles

Trouble Shooting chart for HYDRAULIC JACK





Problems	Symptoms	Cause	Remedy
No lifting of piston C in spite of pumping action	No lifting in spite of quick pumping action	○	
	Slow lifting in spite of quick pumping	○	
After being lifted to top position the piston T lowers slowly when pumping is halted	While piston T lowers, piston C remains unaffected	○	
	While piston T lowers, piston C is lifted	○	



Task Match the causes/remedies to the defects/symptoms!

A =

Valve B or valve A are leaking	Clean valves A and B! Renew seals!

B =

Valve A is leaking	Clean valve A and exchange its seal!

C =

Valve A open Oil flows back through A	Close A!

D =

Valve D is leaking	Clean valve D and exchange its seal!

I.6 INFORMATION GENERATING IMAGES AND LINKAGES (Selection aspects to which trade standards provide no clue)

Dispensible items in present packages are often of the following kinds:

a) Trivial content printed as trade theory information

Text information too often contains simple–minded statements like “Threading dies are used to cut threads” or “Drilling is a process for making holes in workpieces”. Such nuggets of information may be interesting to a storekeeper who likes to know what the items he hands to the fitter are used for. But what value do they have for a trainee who drills holes or cuts threads every day?

Verbal descriptions of working steps may be suitable for a job sequence but instead show up in trade theory information sheets, in something like the following form:

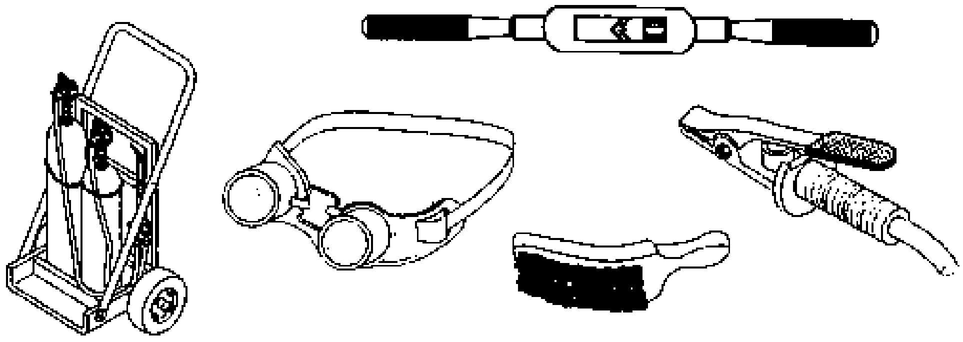
“A taper tap is used to start the threading. A bottoming tap is used to finish the threads”.

Text with illustrations too often describes in broad detail what everyone can see by just looking at the pictures:

“The taper tap has one ring, the intermediate tap has two rings and the bottoming tap has three.”

Such trivialities need to be avoided; the precious space is required for essentials.

The most common flaw in pictorial information is the presentation of equipment the trainee will handle again and again during his workshop/lab practice. A hammer may appear under the headline forging, an earth clamp with cable under arc welding, a scriber under marking etc. Such illustrations impress the layman, who feels that any kind of pictorial information will help the trainee. In fact, however, they take up space which could have been used for illustrations which convey an essential message (see Chapter 2.4). Showing real objects without labels is a sign of redundancy.



The problem is made worse by the fact that objects are shown in full instead of restricting graphics to the most interesting section or components.

b) Vague and abstract wording which does not really put across its message

“Observe safety precautions!” is a typical statement providing no concrete information whatsoever on what the trainee must actually do. Advice to “make sure there is sufficient coolant” is unhelpful unless a demonstration explains what “sufficient” means and what overheating symptoms act as warning signals.

Such repeated statements are too abstract to clarify and specify what the trainee has to do; they may be characterized as pseudo−messages.

c) Lack of interlinkage between verbal and pictorial information

The use of labels (letters or numbers) attached to components or parts of the illustration is an essential aid in connecting a specific text passage to a particular section of a graphic. The picture is not cluttered with designations, and graphics require no modification for different language versions.

Another essential advantage of labelling is the chance to discuss how a mechanism works without even using any names.

d) Poor linkage between text passages

At first glance, certain information sheets create an impression of good layout by avoiding long continuous text passages. A closer look reveals that this has been achieved by splitting one complex interrelated item of information into several sections. The problem is that the subparagraphs are not related to each other. The only connecting element is headlining with the names of the components involved (see example on next page).

This type of inadequately interlinked information is common with authors rooted in a system which stresses memorization of unrelated details. Such authors do not attempt to create a context which can interlink complex information. Attention is focused on the name of a component (and often its definition). The names form the key words or headlines for the subparagraphs. These are then arranged in a pseudo−sequence quite unrelated to any logical sequence explaining the working principle of the mechanism as a whole.

Example: Vernier height gauge

In the original version the description of each part is separate. No interlinkage of the parts 4, 5, 6 and 7 is explained. As an example for a short and interlinked cause−effect related information it is contrasted with a logical structure and a handling sequence. A new picture with changed labels became necessary in order to describe the functions of the screws 7 + 8.

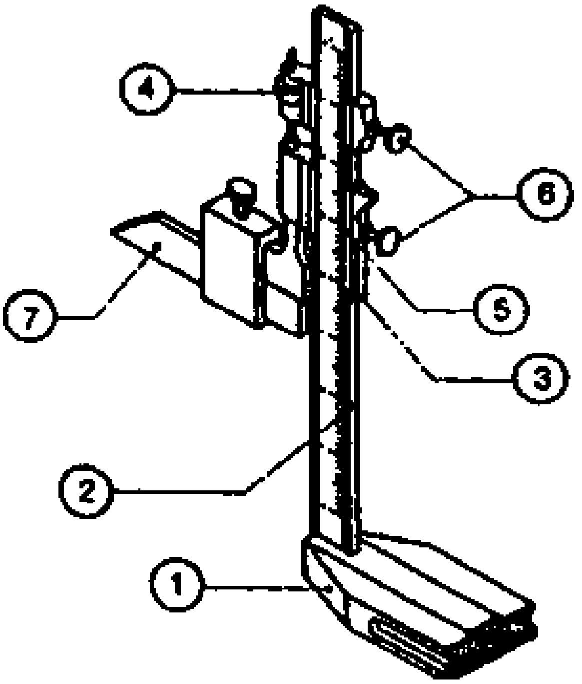


FIGURE 3

Original

Parts and their functions

- The main parts of the Vernier Height Gauge and their functions are: (figure (3))

- Base(1). This is the datum from which measurements and settings are made. The underside of the base Is hardened ground and lapped.

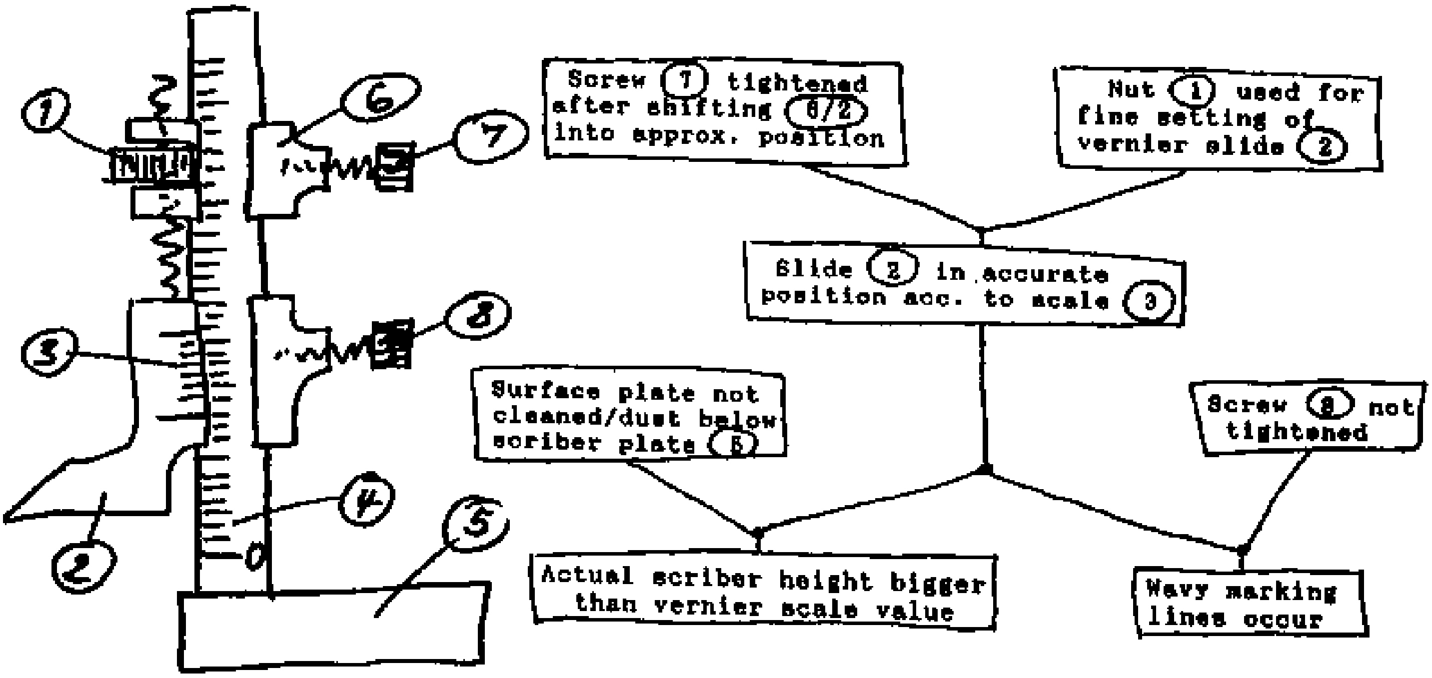
- Beam(2). This Is similar to the beam scale of Vernier Callper and Is attached to the base.

- Vernier Slide (3). This unit slides on the beam and carries the Vernier plate (5), locking screws (6), Fine setting device (4) and Scriber (7)

  Some height gauges are provided with a rack and pinion arrangement for moving the Slide along the Beam.

The description of the height gauge mechanism is shown here as a logical structure as an extremely condensed kind of text information with lines in−between indicating the functional links. This logical structure describes the interaction of slide and fine setting device, but links two typical handling faults to their respective effects on the scribing job. There are 3 AND−links where two conditions coming together generate one effect.

Revised
Version



I.7 MEASURING LEARNING PROGRESS? (Final trade tests define the real syllabus)

a) Test requirements versus approved curriculum

Actual training in training centres is defined far more by test requirements than by officially approved curricula. Instructors everywhere tend to concentrate on the requirements of the final trade test. If the test is highly invalid in terms of coverage and complexity level, the curriculum will be ignored. Trainees want training which qualifies them to pass the test, because they want a certificate.

Trade theory final tests show a dangerous lack of problem−orientation, conveying an impression of “theory for theory’s sake”. Unless test authors remember that theory is not an end in itself, it will not be possible to judge test results for compliance with actual job requirements and workshop problems.

Media developers can demonstrate in their package what valid task banks should look like. A simplified validity checking procedure can be applied to final tests as well as task banks for specific topics.

b) Validity is more than subject matter coverage

The first aspect to be covered in a validity check is the compliance of test items with the syllabus/curriculum/trade standards (width of scope). The range of topics to be covered is divided into sections and the first count reveals sections of the syllabus/topic which are over−or under−represented.

The second, equally important feature is the level of complexity (depth of perception). This step reveals how many of the items deal with problems/defects/causes/remedies. Comparison with the number of items involving memorization of names/definitions/facts indicates the validity of the test in terms of practice relevance.

BLOOM’s taxonomy is not workable because the many levels and concepts it uses are too ambiguous, allowing everyone to interpret it in his own way. Only three levels of complexity are proposed for checking this aspect of test validity:

Level I is used for all isolated facts (names, figures) and verbal chains (wordings of definitions and rules) which can be learned by reading and can be memorized without requiring real understanding. These are needed to a certain extent, and document memorizing abilities, but do not prove functional understanding.

Level II covers functional understanding of equipment and processes in proper working condition, together with rule/concept comparison and interlinkage. A minimum of two related concepts must be involved.

Level III differs from level II in that it addresses components and processes which have gone or might go wrong. These test items deal with fault or problem symptoms, require the trainee to link them to causes or remedial measures.

By making it a rule to compile test question banks comprising, for example, no more than 10 to 15% of Level I test items, between 40 and 65% of Level II items and 25 to 40% of Level III items, the media developer acquires a tool ensuring balanced coverage of syllabus topics at different levels of complexity.

A bolder decision would be to omit Level I from the package completely. Instructors will in any case include self–made questions of this type in their sessional test and the testing authority has ample Level I material for final trade tests already; there is no need for further encouragement.

The third test quality aspect is balance and variety (range of task types). Wide–scoped essay questions are a fine measuring tool for testing the testee's ability to write compositions, but language mastery is probably not the main issue in testing trade know–how. Narrow–scoped questions or short answer questions are a sufficiently good test of the ability to formulate an idea in the testee's own words. Other types of test item, like multiple choice or matching tasks, stress other abilities, so that a mix generates some balance.

Test compilers wrongly assume that the validity of tests can be improved considerably just by using more supposedly objective test items. Names and definitions are now more frequently tested via multiple choice or completion items (requiring the testee to fill in names), but the shallowness of the content remains unchanged.

It is important to note that reading multiple choice items with a minimum discriminative power demands a high level of reading ability, because four contrasting statements have to be checked and compared.

True–false items are very popular because they are easy to design. Since a pass–mark of 50% is used for most tests in most training systems, it is statistically odd to include a test item with a 50% probability of successful guessing.

A final but vital point in the validity check is to scrutinize the use of illustrations in test items. Including more graphics not only allows condensation. It also opens the way to designing new types of test item. Graphics–based items may be more appropriate to a target group with limited ability in handling verbal instructions or information.

The validity check identifies the major gaps and shortcomings in a test. By analyzing the data, the media designer can pinpoint missing and superfluous items, e.g.:

- topics which are under– or over–represented;
- levels of complexity which have already been covered elsewhere or which need to be added.

The analysis concentrates attention on issues within a topic or set of topics which need better coverage.

c) The marking procedure for practice tests

In the workshop, the way in which test results are validated depends largely on the type and quality of marking criteria incorporated in the test job.

The difficulty with the current practice of <u>product marking</u> is that, for example in metal trades, a sophisticated procedure is applied to trivial content. Measuring the accuracy of isolated dimensions with no relation to part functions (metal components, cable layout or welding joint) is not representative for real jobs. Test jobs without assembly equipment, types of fit and geometrical tolerances, including the mating of movable parts, (all of which tell the inspector at a glance if the overall function of a mechanism is flawed) are not valid as a measure of essential abilities.

A mechanism with a minimum of 5 components is needed to obtain the necessary complexity for a test job carried out by the trainees. Marking criteria must have a direct bearing on the functions of the parts being checked, so that defective parts can be traced easily after or during assembly.

Using performance marking criteria (preferably specific enough for self-marking by trainees) right from the beginning improves communication between instructors and trainees about training aims.

Strangely enough, the use of objectively verifiable performance marking criteria is neglected in production trades (less so in the service trades). Including such criteria in the package can promote change in this field, too.

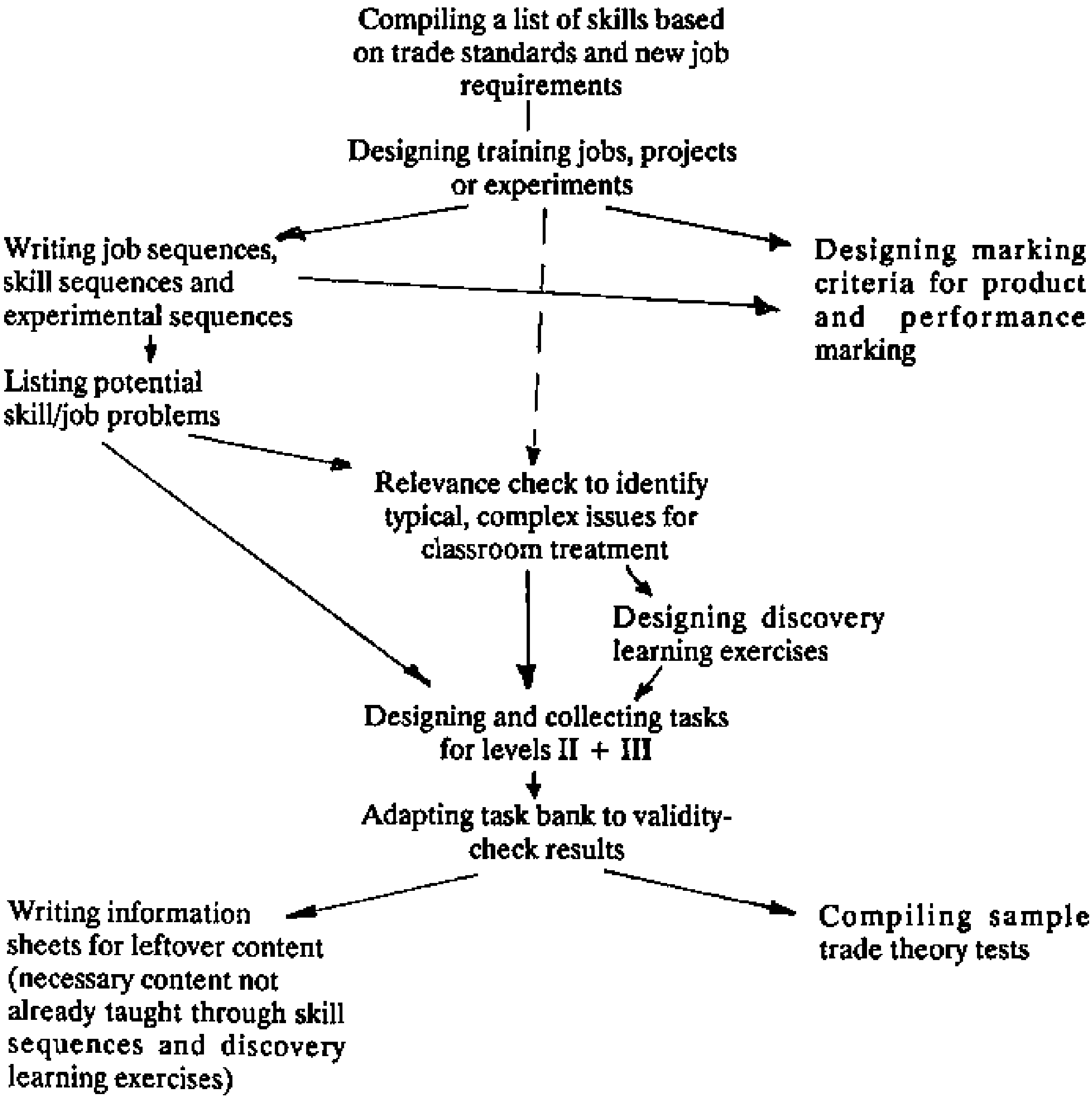
If industry needs self-reliant workers who can be allocated a task and then organize the job themselves in a detailed plan, this ability has to be trained and tested.

Even if time constraints mean that the test requires the testee to do no more than rearrange a scrambled list of working steps in a job sequence, results will allow some judgment of the testees's ability to plan a job before performing the steps.

I.8 THE DEVELOPMENT CYCLE – MONITORING PROGRESS

Many of the proposals made in this handbook are intended to encourage media developers to try out something new. **Perhaps most controversial is the advice to ignore imprecise lists of objectives and to start by structuring a task bank which defines unambiguous training outcomes.**

One consequence of this approach is to stand the conventional media development sequence on its head; tasks are now developed before information sheets and serve as a benchmark for selecting and limiting information content. The flood of information is brought under control. Information is now restricted to items required by the task bank coverage.



SEQUENCE OF DEVELOPMENT FOR THE COMPONENTS OF A PACKAGE

To ensure that trade standards are covered properly, all skills mentioned there should be listed first. Certain skills required on the labour market should also be added. The resulting trade–specific skill profile can then be translated into training jobs covering the whole training period. This work should be performed by committees made up of

– technical specialists with experience in the trade,
– training specialists who know the target group and
– media developers.

The media developer uses the results of this teamwork to draft a skill sequence. He then goes on to draft job sequences covering several skills.

The drafts are evaluated by the committee or by fellow media developers, revised and tried out with a small group of trainees. The revised version goes through a second committee stage, followed by a second tryout (if major changes have been made) or validation in an evaluation cell. The evaluation cell decides whether the draft is suitable for a trial run on a wider scale.

This evaluation procedure is equally valid for trade theory material.

The media developer who prepares, revises and tests the drafts is also responsible for the final printed version. He is the author and puts the final polish on a product which has to pass several quality control stations.

While he is working on job, skill or experimental sequences (workshop practice), the media developer notes any potential problems and difficulties. These are taken up again later as a subject for theoretical explanation and anticipation training. This step ensures that classroom trade theory components are more practice− and problem−oriented.

Only after the workshop training material has been drafted should work on trade theory items commence. The media developer checks the relevance of theory content on the basis of trade standards, common trade book material and the list of problems derived from skill and job sequences. The most typical classroom content is then identified and its discovery learning potential is screened. Appropriate self−learning items are drafted and tested.

The sum of the resulting matching items, together with questions related to the skill/job sequences and additional tasks related to the topic, constitute a task bank. This is validated carefully (content coverage – level coverage – types of task).

This structured and balanced task bank is now the yardstick for any additional information sheets. These are used whenever task−related information is not covered by skill sequences, table books, workshop wallcharts or discovery learning tasks.

The manager monitoring the progress of his media developer team could use the steps in the following chart:

PROGRESS CHART

Status ⤵ Topic no. ?	1	2	3	4	5	6
1. Training jobs designed?						
2. Skill sequences tested and revised?						
3. Job sequences tested and revised?						
4. Experimental sequences tested and revised?						
5. Marking criteria defined and tested?						
6. List of practice problems compiled as base for trade theory items?						
7. Classroom content identified by relevance check?						
8. Discovery learning material tested and revised?						
9. Matching test items tested and revised?						

10. Test items collected from other sources?						
11. Did validity check lead to revised item bank?						
12. Keys for assignments and tasks complete?						
13. Scope of additional information identified?						
14. Information sheets adapted to criteria and revised?						

I.9 USER FRIENDLINESS (What makes instructors use the package?)

More exactly: what is the incentive for the instructor to use the package without being instructed to do so?

The non−experienced instructor will welcome the listing of critical steps in skill sequences. He will also learn a lot from the observation criteria in the trainee practice phase. The greater the extent to which skill sequences resemble a "do−it−yourself" manual, the fewer will be the explanations needed, the greater the workload taken off the instructor's shoulders and the greater his willingness to use them.

In classroom teaching, discovery learning exercises will provide the strongest incentives to refrain from lecturing and to address real problems. The user has no material to prepare. He can relax while trainees organize their own learning.

Discovery learning tasks are included in standard trainee handouts. Each group takes one assignment sheet with the topic−related graphics pictures and statements.

The following table reviews instructor incentives for each component of the package.

INSTRUCTOR INCENTIVES − TRAINEE BENEFITS

a) SKILL SEQUENCES

These not only provide detailed descriptions of working steps, but highlight critical steps (risk to persons, machinery, tools). There are some hints on handling critical steps.

> Performance observation criteria specify what to watch out for during early stages of trainee practice.
>
> Even if the instructor has given a poor demonstration, the trainee has detailed information on what to do.
>
> Critical steps indicate warning signals the trainee must watch out for in his own interest.

b) MARKING CRITERIA

In addition to commonly−used criteria for product− or result−related marking, these offer a number of objective criteria for marking performance. The performance marking criteria replace subjective marking criteria as far as possible, reducing the potential for conflict with the trainees.

> Trainees know the performance marking criteria, enabling them to self−evaluate their work. Performance criteria indicate what is essential and how the instructor will observe the work and mark the degree of perfection achieved.

c) DISCOVERY LEARNING EXERCISES

These activate trainees without demanding sophisticated teaching methods from the instructor. Clear−cut key solutions allow the inexperienced instructor to confront issues he would otherwise shy away from. Discovery learning helps the instructor make training more problem−oriented.

> Discovery learning exercises address the most interesting and most complex topics. They make learning more fun and boost the self−confidence of successful groups. Group work develops teamwork and self−evaluation abilities.

d) TABLE BOOK

Trainees are activated to find out information for themselves instead of expecting the instructor to know all the details.

> Trainees get used to handling books effectively. Much rote−learning of detailed trade know−how is saved.

II.1 JOB REQUIREMENTS – SKILL SEQUENCES – JOB SEQUENCES

a) Usefulness and market relevance of training jobs

The usefulness of the training job is a major factor in inducing trainees to take learning seriously.

In the production trades, the aim should be to make an object of value for the trainee which also covers the training essentials.

In the service trades, it is imperative to master jobs and skills in direct demand on the unofficial labour market, because this will improve trainees' chances of finding part−time jobs during training. In most cases, troubleshooting techniques will be necessary.

In the metal trades, a tool maker's vice is a good example of a product a trainee can take home (paying for the materials) and use there (see further examples below).

One should not, however, expect too much from this approach; the range of products that meet this criterion is very limited.

A more promising line is to produce items which can be sold on the local market without competing against products from small−scale industry. Getting the trainees involved in project work at the advanced stage of training could lead to development of prototype products for training cum production. The bookkeeping problems associated with this approach require a certain minimum flexibility and creativity from management.

Institutionalized full−time practice training implies important constraints on the planning of training jobs. First there is the question of what equipment is available in the workshops and labs. Any training job the media developer devises must be feasible with existing machines.

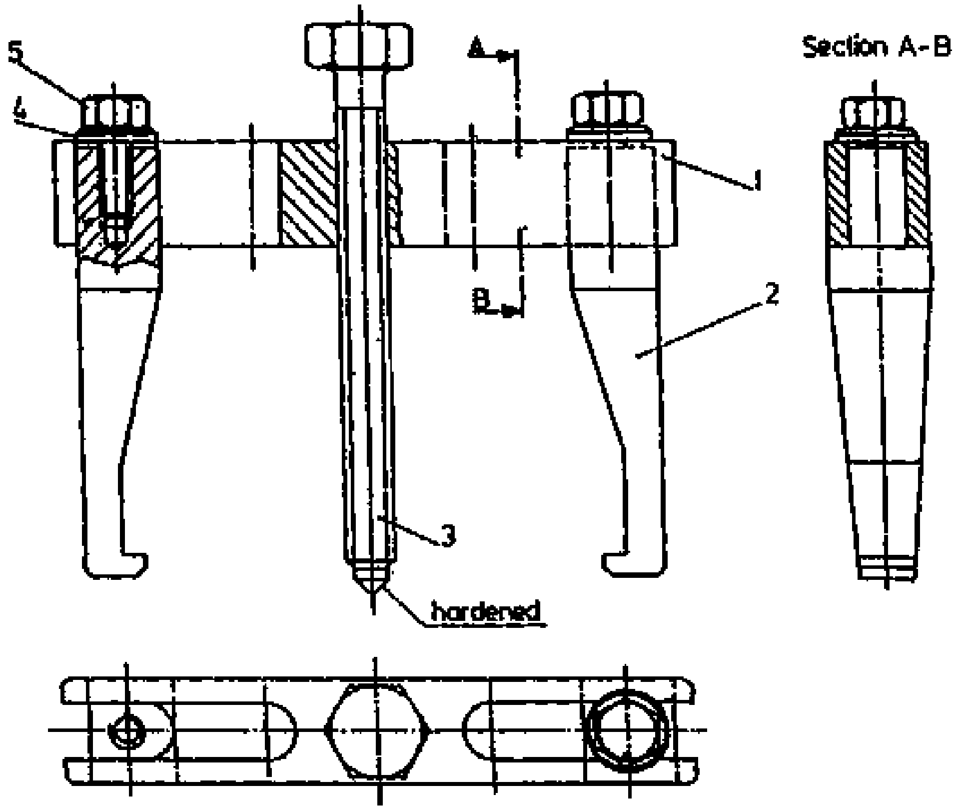
The second constraint is the budget for consumables. Material cost must not exceed actual resources. Jobs that can be taken home by trainees (in return for nominal material costs) are feasible in some cases.

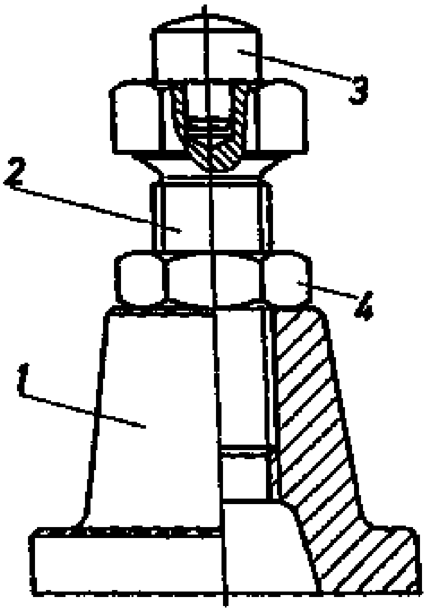
Since, unlike products from the advanced apprenticeship stage, most training job products cannot be sold to a customer, an essential motivating and disciplining factor for producing quality under time pressure is lost in institutionalized training. Quality/time pressure is, however, a vital training objective. It needs attention because it is a general job requirement. Time allocations for training jobs should bear some resemblance to those in industry. Work speed is a skill in itself. It should not be confused with rush and haste. Combining speed with quality requires the ability to organize work and material flows (time study) quickly and efficiently in an optimum cycle.

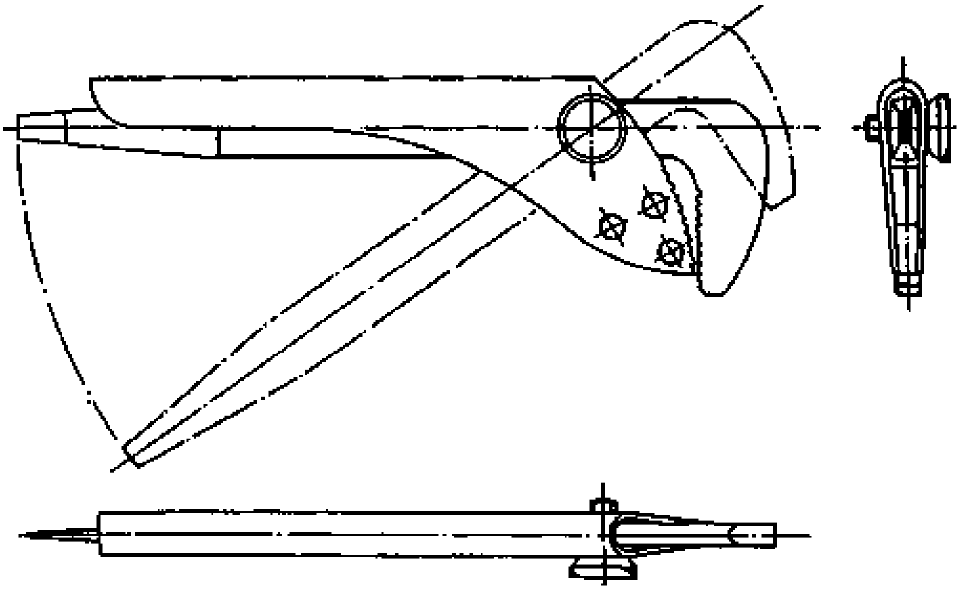
The media developer will get the best ideas by looking at small−scale industry products made for the local market. He can use institutionalized training to simulate jobs usually performed by apprentices (so that desired skills are learned through the job). Ideally, products will attract paying customers.

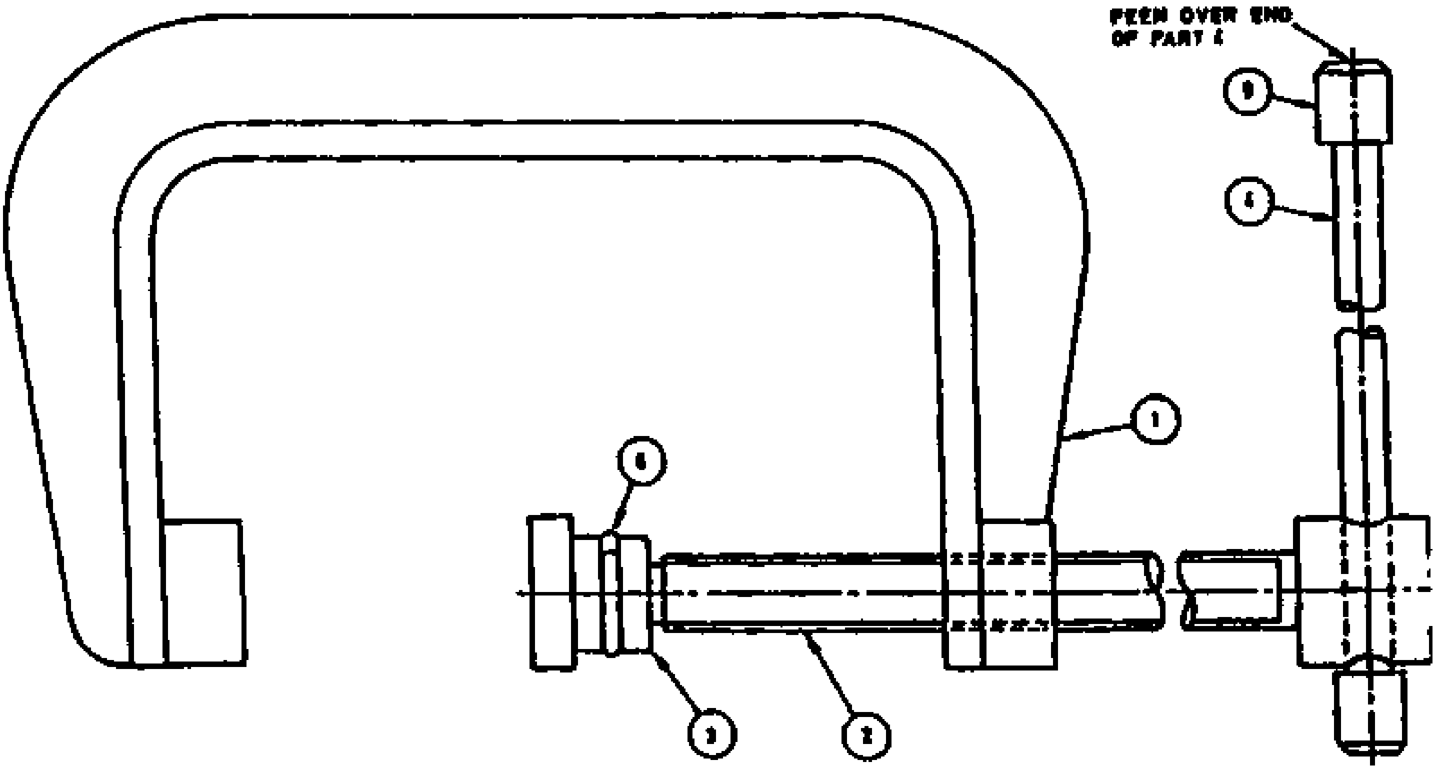
From:

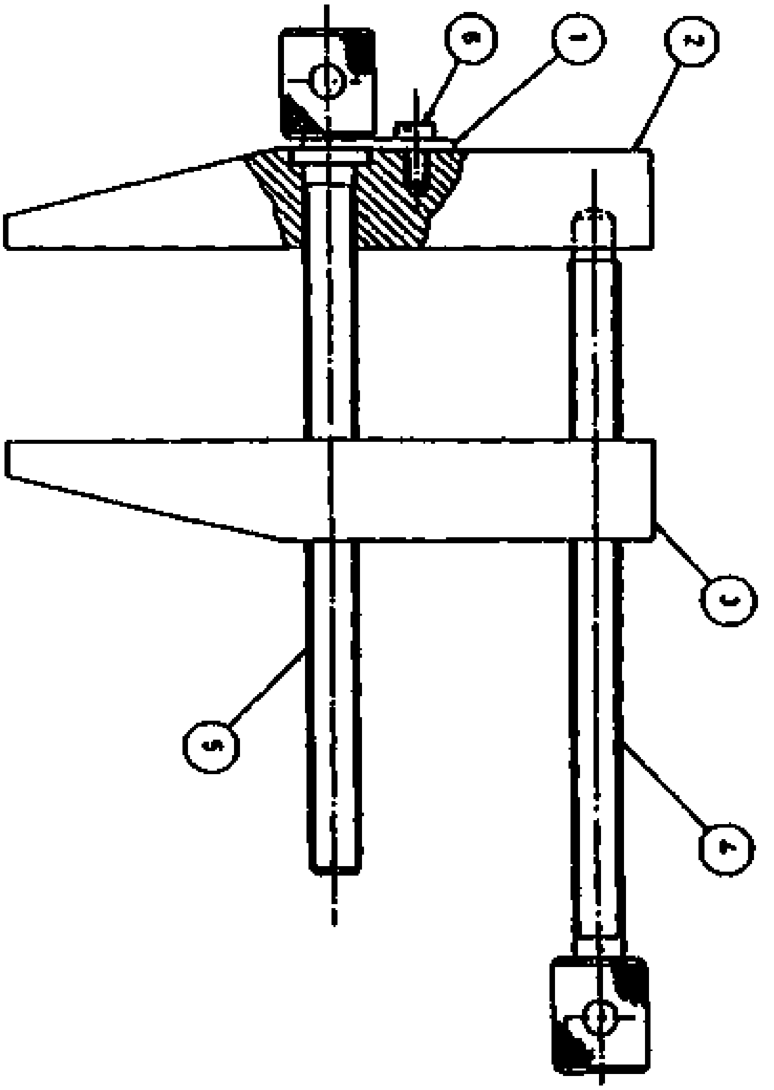
CITY AND GUILDS OF LONDON INSTITUTE:
SUBJECT 820 – BASIC ENGINEERING TRADE SUBJECTS
PRACTICAL COURSEWORK SCHEDULE
PART C – SPECIAL SKILLS (MECHANICAL)








PEEN OVER END OF PART 4
9
4
1
6
3
2


8
1
2
3
5
7

b) The skill coverage potential of the training job

Basic analysis is always needed to match training jobs with desired skills. The vital distinction between job sequence and skill sequence is that a job sequence involves repeated use of several skills like sawing, filing and drilling. The training potential of a job is measured in terms of its suitability for practising skills.

A checking matrix can be quite helpful. First a detailed list of skills is inferred from the syllabus. Major skills like “drilling” are divided into tightly–specified subskills, e.g. “drilling through holes with diameters up to 12 mm in mild steel”, “drilling blind holes with diameters up to 22 **mm in brass” etc.**

In order to limit the length of this list, the subskills must be essential. (It is a mistake to try for a “complete” list.) The number of subskills will depend on the complexity of the major skill. The “measuring” skill will require many more subdivisions than, for example, “reaming”.

The aim is to produce a list of subskills each having roughly the same complexity.

The total list should cover a longer training period (preferably a whole year). Using abbreviations or code numbers to denote the subskills, list them in a vertical column. List training jobs in a horizontal column. The result is a matrix for checking skill coverage.

Related skills for each job are ticked off to analyze its training potential.

The matrix pinpoints any repetition. Skills may of course be repeated intentionally, or because they cannot be avoided. Improving and optimizing the list of training jobs with the help of this matrix is an on–going assignment.

Skills/Jobs	**X**	**Y**	**Z**
Measuring I	○	◐	●
Sawing	●	●	○
Filing I	○	●	●
Measuring II		○	
Chiselling		●	
Filing II			
Drilling I			
Measuring III			
Drilling II			
Reaming			
Tapping			
Threading			
Shearing			
Bending			

Degree of coverage

○ = low
◐ = medium
● = high

The matrix is a useful tool for checking balanced coverage of job or test requirements in the practice stage of training.

EVALUATION CRITERIA FOR POTENTIAL TRAINING JOBS

1) Do jobs progressively cover skills defined by trade standards or by relevant newer job requirements?

2) Do they ensure repeat coverage of the most relevant skills, with an increasing level of difficulty, so that a certain mastery is achieved? (Examples: sawing thin−walled sheets; drilling holes in inclined surfaces; reaming taper holes; turning long, slender shafts liable to geometry errors.)

3) Does the job allow for faulty performance by trainees, with opportunities for rectifying faults and for troubleshooting?

4) Are products attractive for the trainee himself? Alternatively, can the skill be used at home or with friends? Is it immediately marketable, with the chance of a part−time job? Are the products themselves marketable?

5) Can consumable costs be accommodated in the budget? Is there a cheaper alternative with comparable training potential? Can the product be sold (quality and local demand), recouping some of the cost for the training institute?

6) Can jobs be carried out with the available machinery and prescribed tool list? Are the proposed materials and alternatives available on the local market? Are process design alternatives available (e.g. welding instead of casting)?

It is also important to analyze practice training content with respect to training grades: Grade III for semi−skilled (1−year full−time), Grade II for skilled or Grade I for highly skilled. This clarifies the different proficiency levels needed in practice and theory.

The following examples list training contents for practical tests and trade theory at different levels. Comparing items per topic for different levels helps to pinpoint essentials and differences at each level.

Examples for structuring practice training content:

Rulers and vernier calipers are needed from the beginning (Level III); dial gauges and plug gauges may be required later.

Checks on the flatness of surfaces or squareness between two surfaces can initially be made with a try square (Level III); as soon as geometrical tolerances are involved, surface plates and dial gauges will be needed (Levels II and III).

SKILL REQUIREMENTS

FITTER

		Levels		
No.	Module/requirements to be tested	I	II	III
1.	Measuring − Marking			
A	Use ruler, maesuring tape, outside caliper, vernier and bevel protactor for jobs of grade III skill test (see skill test drawings)	x		
	Do measuring and gauging jobs with vernier caliper, micrometer, snap/plug gauges, radius and slip gauges and universal protactor for grade II jobs (see skill test job complexity)		x	
	Measure hidden internal dimensions with inside caliper or vernier caliper depth gauge to an accuracy of 0,1 mm.		x	
	Use dial indicator for measuring true running, eccentricity/run out of spindles or shafts to an accuracy of 0,01 mm		x	
	Check flatness of surfaces and parallelism or squareness to datum surfaces acc. to given			x

	geometr. tolerances			
	Use sine bar/taper gauge for measuring taper sizes			x
	Estimate surface roughness of specimen with the help of surface standards with scratching method			x
A	Do marking jobs using scriber, centre punch, try – square, height gauge and bevel protactor to make datum lines and hole centres	x	(x)	
2.	Material selection – Testing			
	Distinguish steel specimen from brass, cast–iron aluminium pieces using colour, specific weight, hardness or ductility as discriminating features	x		
	Use filing test and/or spark test to tell mild steel (weldable steel) from tool steel	x		
	Identify approximate steel features with the help of workshop tests like filing, spark, bending and welding test		x	
	Relate non–ferrous blank material to given applications (pieces of machine elements)	(x)	x	
	Use hardness tester to detect Rockwell/Vickers/Brinell hardness of broken parts			x
6.	Machine adjustments – Functional checks			
	Tighten the bolts of a bench vice to appropriate pre–load/torque	x		
	Adjust the belt tension of a belt drive	x	x	
	Adjust the gland pressure of a water pump	x		
	Mount the wheel of a pedestal grinder		x	
	Align two shafts holding pulleys or align motor shaft and coupling shaft etc.		x	
	Align the worm wheel position inside a worm gear box		x	
	Detect source of unusual noice in a gear box		x	
	Check proper function of system components like e.g. belts, couplings, bearings, brakes, gears in drives, or valves, gates, steam traps, oil drips, pistons, condensers in hydraulic, steam and pneumatic systems.		x	
	Write a diagnostic report about a broken down unit			x
7.	Repair jobs			
	Replace the belt of a belt driven drilling machine	x		
	Dismantle and re–assemble a bench vice or a simple gear box or a plunger type pump or a hydraulic jack (exchange of gaskets or glands) – equivalents	x		
	Replace a feather or taper key (with guard rings or locking washers) on a belt pulley/gear shaft	x		
	Tight–fit a roller bearing using heat expansion		x	
	Repair hand–operated lifting equipment (mechanical and hydraulic type) or friction type clutches.		x	
	Dismantle and reassemble worm type reduction boxes, or centrifugal/diaphragm type pumps, machine tool spindle bearings, compressors, conveyer rollers etc. –equivalents		x	
	Carry out repair of complete plant machinery			x

Curricular structure for identification of curricular units

A = curricular unit

Levels III, II, I in 1st year
full time training

The existing syllabus may specify use of fits systems at a later stage. However, if multi−component jobs are included from the beginning of practice training, this topic will have to be covered at a very early stage (together with isometric perspectives).

Simple adjustment exercises like rectifying belt tension on a drilling machine drive can be a basic exercise for machinists and fitters (at Levels III or II respectively). Writing a diagnostic report after troubleshooting complex faults is not a basic job element and should be reserved for Level I.

A filing test and a spark test (mild steel/tool steel) to identify what material a broken spare part is made of are at the basic difficulty level. Interpreting the grain structure of the ruptured cross−section is certainly not, and should be kept for Level I.

Specifying practice exercises in this degree of detail helps to decide the appropriate stage of training for various skills under the same broad syllabus heading (e.g. measuring skills, machine adjustments or testing skills).

It is also advisable to correlate the proficiency level and stage of training for each topic in trade theory. It may be enough to quench−harden a chisel without understanding related theory in the iron−carbon−equilibrium diagram (practice at Level II). The topic of heat treatment, involving careful reflection of typical faults, is vital for the tool−and−die maker (Level II) but less so for a millwright fitter (Level I).

c) Job performance versus product relation

Metal trade and civil construction instructors often feel that troubleshooting techniques are needed only in service trades. In fact, many unacknowledged troubleshooting problems exist in production trades. Training in dealing with these problems is needed. Good planning must accommodate relevant exercises in the programme.

It is naturally simpler to construct an artificial problem−free environment in a full−time training institute, using the same machine tools as in industry but keeping to the smooth jobs.

Syllabi for metal trades are usually biased towards production skills, neglecting maintenance and repair. This is especially inappropriate for developing countries, where the repair cannot be done by the specialist around the corner. One should always consider what maintenance and repair exercises need to be included.

Once the most relevant clamping problems and the most common resulting geometry faults have been addressed, the next priority is the ability to perform simple maintenance and repair jobs, e.g. for a machinist training. Simple adjustments to drive systems, replacement of worn machine elements and preventive maintenance are typical training modules for production trades at Level II.

The most interesting aspect here is the way in which the skills−discrepancy between production trades and service trades narrows once troubleshooting receives the necessary attention. The strategies needed for systematic tracing of the cause of a production disturbance are much the same as those needed for fault cause tracing in equipment serviced by electricians and auto−mechanics.

For the apprenticeship scheme, curricular analysis proceeds in the opposite direction. Jobs have to be chosen from a given range of company production work. One reason for the poor showing of apprenticeship schemes is the lack of advice to managers on how to organize efficient in−plant training without disrupting production.

The training potential of the company production jobs is analyzed as above, but the advisor/specialist has to focus on the actual range of jobs in a company's production spectrum. With some experience, he will select workplaces in the factory which promise good training effects. (The matrix is a useful tool for screening the training potential of each job).

The result is a trainee rotation plan defining workplaces selected for training purposes and fixing the order and duration of in−plant training phases (depending on the proficiency achieved by the trainee).

Skills which cannot be covered within the company production spectrum are highlighted and alternative solutions found (either in combined industry association training centres or in government training centres). Company engineers with no experience of dual system training cannot be expected to provide these inputs; apprentices are too often misused as helpers on a single job. Company willingness to participate in the dual system could be boosted by achieving better in–plant training results under realistic working conditions.

For the inexperienced media developer in a production trade, it is a good training exercise to receive a list of skills, to be exposed to a company production cycle and then be asked to identify components of the production cycle which are suitable as training jobs. For media developers in service trades, an equivalent exercise would be to trace relevant skills concealed in complex repair jobs. Experimental sequences are also necessary to speed up training of mental skills.

d) Practice problems leading to relevant trade theory

When compiling a list of skills and subskills, the media developer should note down any

- potential danger for trainees,
- potential risk to equipment and
- common job faults/defects which may occur.

Interviewing experienced specialists in the relevant engineering fields will help. Such notes form the basis for relevant classroom trade theory material. An important by–product of this planning stage are lists of shop floor problems to be used later in developing trade theory material.

II.2 SKILL SEQUENCES – JOB SEQUENCES – EXPERIMENTAL SEQUENCES

Once a training job has been identified, the media developer is faced with another set of decisions.

a) Distinctive features for skills sequences and jobs sequences

The job of making a workpiece may include the skills of sawing (pieces from blanks), filing a rounded shape and drilling holes.

The job of fitting an electric switch includes the skills of cutting wires to length, stripping insulation, drilling holes in walls and securing the switch with screws.

A basic difference between job sequences and skill sequences is that job sequences are composed mainly of previously–learned skills. Consequently, existing complex skills can be invoked by a short statement. There is no need for detailed description as in a skill sequence covering a new set of motor activities.

It makes sense to distinguish between skill and job sequences, because they demand different training methods from the instructor and a different set of evaluation criteria from the developer.

The mastery *of motor skills* is achieved through multiple repetition of muscular conditioning. The mental skill of combining these motor skills in a meaningful sequence can be gained by self–discovery, since it contains elements of logical thinking.

Multiple repetition of job sequences makes sense only if new work step sequences or variants are involved.

Learning “strategies” is a mental skill which requires backup from interactive training methods in the lab or workshop.

This is not true of the muscular conditioning needed to acquire motor skills like welding or filing. In a skill sequence, “feel” does not develop mainly as a result of mental reflection. The approach is different, with multiple repetition leading to mastery. There can be no sudden intellectual insight yielding immediate results (e.g. revealing how to hold the rod during arc welding).

Once a trainee has learned the skill of drilling holes in walls using a hand−held electric drill, he can vary this skill for a wide range of jobs. A skilled worker will repeat the skills (as a sequence of movements) again and again, but interlinkages with other skills will alter from job to job. As a skilled worker, he should not need anyone to tell him the job sequence. So training should cover the technique of planning job sequences with gradually increasing degrees of complexity and variety.

Because he has to go through the necessary set of movements more than 20 times, a trainee may know by heart what working steps are needed to drill a hole long before he has mastered the motor skills required. Competence in planning working steps is developed by using a known skill in new situations. It is dependent not on mastery of motor skills but on planning ability (mental skill).

Skill marking focuses chiefly on perfection in performance (motor skills).

In job sequence grading, marks should also be awarded for the ability to plan the necessary sequence of working steps (a mental skill).

In some training systems, it is already usual to grade auto−mechanics partly on their mental skill in systematic fault tracing (as opposed to trial and error). It is time that mental skill in planning production steps for a specific complex job played a similar role in final grading for production trades.

In−depth coverage of accident prevention is not needed in job sequences. This content will have been covered during preceding training of related skills. For the same reason, the text need not create such concrete mental images as for skill sequences. It may be assumed that certain key words will invoke a chain of mental images internalized during training of the preceding skill sequence.

Instead of continually re−listing the 10 or more steps of a skill sequence, e.g. “aligning a machine vice on the machine table”, the simple instruction “align and fasten machine vice” will be enough. In the job sequence, this instruction then acts as the trigger for the entire related skill sequence. At first, a cross−reference code allowing the trainee to look up the sequence in the skill package can be given in brackets after the instruction. Once the first 5 job sequences after related skill training have been completed, even this reference should be omitted.

Graphics in skill sequences help to create mental images and procedures. Their value is measured in terms of the help they give the trainee in visualizing the manual actions involved. Graphics in job sequences are restricted to more technical aspects. They help to establish unambiguity about what product is expected (e.g. an assembly drawing in a metal trade or a circuit diagram in an electrical trade).

Skill sequences teach the ability “to work according to orders given in a manual”. Job sequences should stress the ability “to self−organize meaningful sequences of working steps” in a discovery learning approach.

Because trainees can infer logically that, for example, marking precedes centre punching and centre punching precedes drilling, there is little point in providing complete job sequences with all the steps given in the correct order.

After trainees have learned all the skills which make up a job sequence, they must be trained to think through the steps before actually doing the job. A good way of activating a group is to ask them to rearrange a set of scrambled working steps. Early assistance with preformulated statements can be faded out gradually, leaving trainees to write the complete work plan themselves. This key ability should be assessed correspondingly in final trade tests.

b) Development and use of skill/job sequences

Two major aspects of media development may be inferred from the above remarks:

a) In skill sequences, it is essential to make clear to the trainee what he must do and how, providing indicators for him to measure the proficiency of his own performance.

b) In job sequences, it is essential to involve the trainee in planning the sequence of skills to be used in the job.

The basic message for the trainee is that systematic planning should precede any manual activity. At the beginning, plans must be written down so that they can be evaluated and discussed.

Close supervision of practice training is most important when a new skill sequence is first tried out. Accident prevention measures during a skill sequence demonstration are the instructor's responsibility. The package should therefore combine skill sequences with "observation criteria" for the instructor, to structure his observation of the group during the early stage of skill training. Observation criteria are less relevant for job sequences.

Skills like filing, sawing and drilling can be trained equally well on a job ending up with a small vice or with a puller. Mastering the skills is what matters.

An ideal skill sequence provides text and graphics enabling groups of 4 to 6 trainees to try out and perform the sequence without assistance from the instructor. In other words, the skill sequence in the media package becomes a "do−it−yourself" manual for the trainees.

To check for this quality, the media developer must stage trial runs under do−it−yourself conditions, testing skill sequences without prior demonstration by an instructor. (An exception must be made for sequences with complex machine tools like lathes, where some initial support short of a demonstration is needed.) Otherwise, the trial run will indicate the quality of the instructor's demonstration rather than the shortcomings of the draft package. Benefits for revision of the drafts will be correspondingly meagre.

Of course, skill sequences are not always meant to replace an instructor demonstration. However, every sequence should have at least some potential for use as a self−learning manual in a group of trainees.

The greater the clarity created by work instructions and skill information, the greater the help offered by the material to the inexperienced instructor (or to the experienced instructor persuaded of the value of self−learning). If self−reliance is trained gradually, the dedicated trainee can learn skills partly or wholly without assistance from the instructor (but under his close supervision and observation).

The goal the trainee is working towards is the ability to work from manuals. The ability to read instructions and carry out production or repair work accordingly is therefore a key qualification. Although the instructor demonstration is indispensible in the early stage of training, this help should gradually give way to group work.

There is also a desirable side−effect. Trainees' progress becomes less dependent on the dedication of the instructor. As a result, the element of self−responsibility is enhanced.

EVALUATION CRITERIA FOR SKILL SEQUENCES

1. Is the sequence free of technical faults?

    a) Is the sequential order of steps correct?
    b) Are details of working instructions technically correct?
    c) Are all working steps needed for clarity included?

2. Are the working steps easy to read?

    a) Is the total step small enough and still consistent and complete?
    b) Are single sentences short enough?
    c) Is the wording clear and unambiguous?

3. Is the wording sufficiently specific?

    a) Is it clear enough to generate mental images (not too imprecise)?
    b) Does it refer directly to labelled details in the graphics?
    c) Are unnecessary details omitted (no redundancy)?

4. Have graphics been simplified as far as possible and do they convey an unambiguous message (non−relevant details excluded)?

5. Are workrules combined with hints on the potential risk of injury to trainees (accident aspect), damage to equipment or negative impacts on the finished product? Are statements still short enough?

6. Has repetition of working steps from previous skill sequences been avoided (short statements plus code reference to previously learnt skills)?

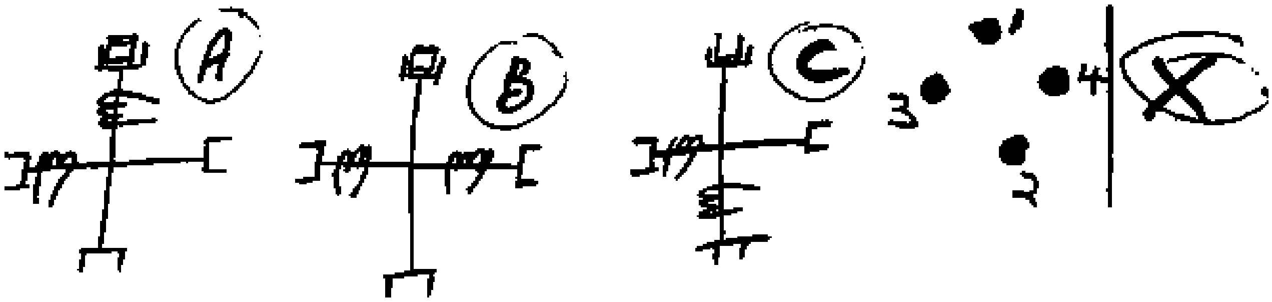
7. Are critical steps highlighted OR marked with a warning symbol?

8. Are observation criteria related to critical steps listed for the instructor’s handout?

CHANGE THE WHEEL

1. Pull hand brake firmly.
2. Wedge wheels on the opposite side tightly.
3. Loosen wheel nuts using correct size spanner (maximum 2 turns).
4. Place a jack in a solid spot of the body frame.
5. Make sure jack is in vertical position.
6. Lift the car slowly.
7. Remove the nuts/bolts and place them safely.
8. Take the wheel off the axle.
9. Fit the other wheel.
10. Fit wheel nuts hand tight.
11. Tighten the wheel nuts cross–wise with spanner until the wheel rotates
12. Lower the jack and remove it
13. Tighten the wheel nuts/bolts firmly now.
14. Remove wedges.

OBSERVATION CRITERIA	Yes	No
– Car cannot be moved?	☐	☐
– Correct spanner size used?	☐	☐
– Spanner correctly used (C+B)?	☐	☐
– Jack placed under solid spot (frame)?	☐	☐
– Jack in a vertical position?	☐	☐
– Bolt thread kept clean after loosening?	☐	☐
– Wheel nuts/bolts fitted by hand?	☐	☐
– Correct sequence (see X) of tightening?	☐	☐
– Wheel nuts/bolts tightened sufficiently?	☐	☐



Example: Grinding of Flat chisel

Original draft:

1. Set the pedestal grinder for grinding.
2. Hold the flat chisel properly.
3. Put on safety goggles.
4. Grind wedge angle.
5. Do not put too much pressure while grinding chisel.

6. Dip in water from time to time.
7. Check with bevel protractor.

Revised version:

1. Take a blunt chisel.

2. Use a grinding wheel with sharp edgges and a protection guard and tiltable shield.

⚠ 3. Check grinding wheel by:

   a) sliding fingertip across to detect glazing.

   b) visual check for cracks.

⚠ 4. Adjust the tool rest (2 mm gap between wheel and rest)

5. While switching on the grinder move to the side for safety and see whether wheel has true run and no excessive vibration. In case of excessive vibration trueing is necessary first. Call instructor for advice!

6. Check level of coolant (max. 20 mm from top level).

⚠ 7. Shield eyes with goggles and lower protection shield near tool rest.

⚠ 8. Hold chisel edge parallel to wheel surface and chisel shaft in appropriate angle for 60 degree wedge angle.

9. Support it by tool rest and press it against wheel slightly.

10. Keep pressure low while grinding for prevention of excessive heating of the cutting edge (avoid blue colour annealing effect!) Dip chisel into coolant every 3 seconds.

11. Move the edge to and fro sideways to

achieve a straight edge.

12. Repeat grinding action on opposite side with same angle.

13. Check wedge angle with bevel protractor.

14. Adjust wedge angle in case wedge is off tolerance by more than 2 degrees.

15. Check straightness of lip with try square for a tolerance of 0,1 mm over 10 mm length.

Observation Criteria

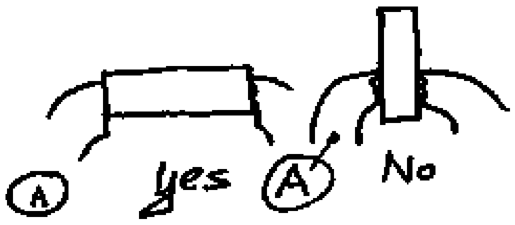
Step 3.	Checked grinding wheel glazing by sliding finger nail across.
Step 4.	Made sure that gap between tool rest an wheel was 2 mm.
Step 5.	Moved to the side while grinder wheel was accelerating. Checked true running and excessive vibration.
Step 7.	Lowered protection shield and used goggles.
Step 8/9	Put chisel on tool rest and moved to and fro with little pressure against wheel. Cutting edge did not become too hot. Dipped chisel into coolant every 3 seconds. Moved chisel to and fro for straight edge.

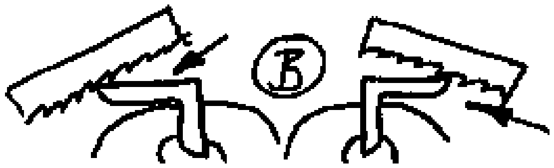
WORKING STEPS AND SKILL INFORMATION

Skill: HACKSAWING

1. Clamp the job in such a way that the flat/long side can be cut rather than the short one (A)

The sawing length is fine between 3 to 10 cm.





2. In case the job has a profile shape, clamp the job so that sawing can be done towards the overhanging end (B)

⚠ 3. Clamp the job as low as possible on the vice and make sure that the marked sawing line is close to the vice jaws side in order to achieve maximum firmness of the job section to be cut. RULE: Whenever the section being cut shows chattering effect or vibrations the clamping needs improvement (ask instructor).

⚠ 4. Tighten the jaws firmly enough to make sure that job does not tilt or shift (see Work Rules for filing No....)

5. Apply work rule for the selection of blade pitch:

a) The shorter the cutting section the finer the blade pitch Make sure that a minimum of 4 teeth are cutting at a time.

b) The harder the material the finer the blade pitch

(For further explanation see Assignm. No.....)

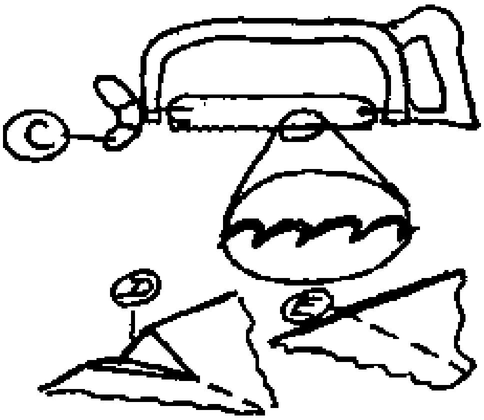
⚠ 6. When fixing the blade in the frame make sure that teeth are pointing towards cutting direction.

Tighten the blade by hand with wing nut (C)

Do not use pliers or bench vice to tighten the nut.

Excessive tension may lead to breakage of blade.

7. On smooth and hard surfaces the blade is prone to slipping sideways. In that case use a triangular file to cut a notch (D) at the starting point (E) of the sawing action.



8. RULES: Apply little downward hand pressure as long as only a few teeth are cutting. Press down only during forward stroke!

Thin−walled jobs need special care (see wallchart No....)

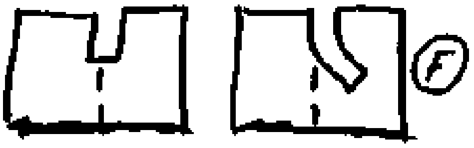
Move saw blade strictly in line with the marked direction.

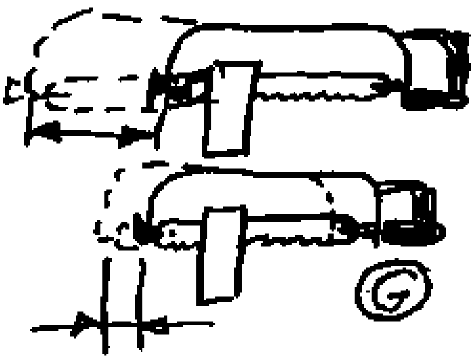
⚠ Do not tilt frame while sawing, because bending of blade can lead to sudden breakage of blade.

9. Increase hand force gradually with deeper penetration into the job. Use steady movements at pace of one double−stroke per second. Keep frame in vertical position and check for deviation of ongoing cut (F) and restart the sawing action at the opposite side in case the deviation from the marked line is excessive.

10. Use the full length of the blade (G) in order to avoid early dulling of the teeth in the centre portion of the blade.

⚠ 11. While approaching the final strokes of the sawing action, reduce the cutting force and slow down (like 8)





EVALUATION CRITERIA FOR JOB SEQUENCES

1. Does the solution key provide the sequence of working steps

a) correctly,
b) in the correct order and
c) without omissions?

2. Does the sequence include planning exercises allowing trainees to plan all or part of the working steps for themselves (in groups)?

3. Are instructions given in brief statements (commands)?

Are related skill sequences invoked in a single sentence (quoting a reference code during the first 5 jobs after the skill sequence has first been learned)?

4. Are graphics clear with respect to technical aspects (technical drawings, circuit diagrams or details from drawings or diagrams)?

5. Is there a checklist for the instructor’s handout listing all critical steps, so that he can countercheck trainees’ drafts?

6. Is there a list of job−specific marking criteria addressing essentials of performance and product marking?

c) Differences between skill/job and experimental sequences

In science lessons, pupils ideally perform experiments themselves. They use apparatus to allow them to observe phenomena directly, and infer general scientific laws and relationships from the phenomena.

This procedure is equally important for experimental work in vocational training, although equipment and purpose are slightly different.

The equipment is trade related. An electrician will, for example, run electric motors under specific conditions in order to reach conclusions about their characteristics. A machinist will operate a machine tool to familiarize himself with the drive system rather than produce a workpiece. For an auto−mechanic, it is not the actual repair job that matters in an experimental exercise but what it shows him about the working principle of a certain system. He will be able to learn the ensuing repair job sequence more quickly because he has already thought about the phenomena involved.

Experimental sequences are meant to draw the attention of the trainees to key phenomena affecting trade−relevant equipment or processes. The main purpose of the experimental sequence is never to make an actual object (product) or complete a repair job (service product).

In contrast to trainees’ work in skill and job sequences, trainee observations must be documented and checked by the instructor. Trainees are expected to draw conclusions from these observations, inferring new rules or working principles.

The intended product of an experimental sequence is mental reflection by the trainee. The essential aspect is the discovery effect, ensuring depth of insight into a newly−identified cause−effect linkage relevant to the trade. Equipment handling is not an end in itself (as it might be in a skill sequence).

EVALUATION CRITERIA FOR EXPERIMENTAL SEQUENCES

1. Are steps technically correct, in the correct order and complete?

2. Are steps easy to read and sufficiently specific (short statements, wording which generates mental images, no redundancy)?

3. Are related graphics labelled, adequately simplified and unambiguous?

4. Are the phenomena to be observed relevant/essential to the working principle of the equipment/process?

5. Does the sequence include documentation of observation results and require inferences leading to or helping in the understanding of working principles?

d) Additional hints for the instructor

A detailed and complete skill sequence is a tremendous help for the junior instructor, provided that critical steps are included and highlighted. As an additional support, the package could include a brief summary of key elements of the skill sequence or the most critical aspects of job or experimental sequences.

Example “Sawing”: Key points for the demonstration

1. Clamping the job

a) Typical differences from clamping for filing jobs (height of jaws and side distance)
b) Reactions to vibrating job ends
c) Firm tightening; risk from tilting work

2. Changing saw blade

a) Rules for pitch selection (wallchart and discovery exercises in classroom)
b) Fixing the blade – direction of teeth, tightening blade

3. Sawing short sections

a) Need to make notches before sawing smooth surfaces
b) Inclined cutting direction for sawing sheets and thin–walled sections
c) Pressure reduction during final stage of sawing

4. Hacksaw movements

a) Pressure variation during forward and return stroke
b) Length and steadiness of motion; holding frame during stroke
c) How to react when the saw wanders off the cutting line

e) Illustrative wallcharts conveying a message

A complementary component for use in the workshop/lab is the workshop wallchart. This provides additional graphic information and is usually associated with skill sequences. Such wallcharts are a special type of information medium, conveying a message (e.g. a workrule or a critical step in the overall sequence) by showing the steps and the various consequences of ignoring a workrule; they tell a story in a series of pictures.

Wallcharts hanging on the walls while related skills are being trained can help to imprint an essential message on the trainee’s long–term memory.

Workshop wallcharts differ considerably from dynamic wallcharts used in discovery learning exercises in classroom. Dynamic wallcharts aim at interactive learning (see Chapter II.5). Workshop wallcharts make use of the time the trainee spends in the workshop; he will look round and see the wallcharts again and again. The model can therefore be the advertising poster or well–designed accident prevention poster.

The message should enter the trainee’s mind without his conscious attention.

Wallcharts should not be wasted on trivial messages. Wallcharts which depict commonly–used tools are a poor use of wall space (the trainee handles the tools as real objects in the workshop). Most typical at present are accident prevention wallcharts showing the effects of sloppy handling or ignorance of workrules. Such posters are provided by work safety associations. But tailormade wallchart material is needed for skill sequence training. It should show critical steps which may not cause accidents but do result in equipment damage or poor work. Wallcharts are worth making for this purpose in particular.

In their least justifiable form, wallcharts contain pictures of machines with each component named. They may help to transfer name learning out of the classroom, but still encourage the human dictionary approach.

Learning the names of essential components may be justified. However, a wallchart depicting a drilling machine with 20 named components documents the media developer's failure to select essential components whose names are really needed during skill training.

The real potential of such wallcharts is tapped when steps in a process are shown or workrules illustrated in a form which needs no translation into local dialects (see below).

Developer resources should be streamlined towards this type of wallchart, conveying a message without using words. The story should be told entirely in pictures. They should catch the trainee's attention sufficiently to make him look at them for some time or come back to them later, so that messages find their way into long−term memory. Typical items which can be presented in this way are:

- **sets of workrules and what happens when they are not observed,**
- critical steps in skill and job sequences.

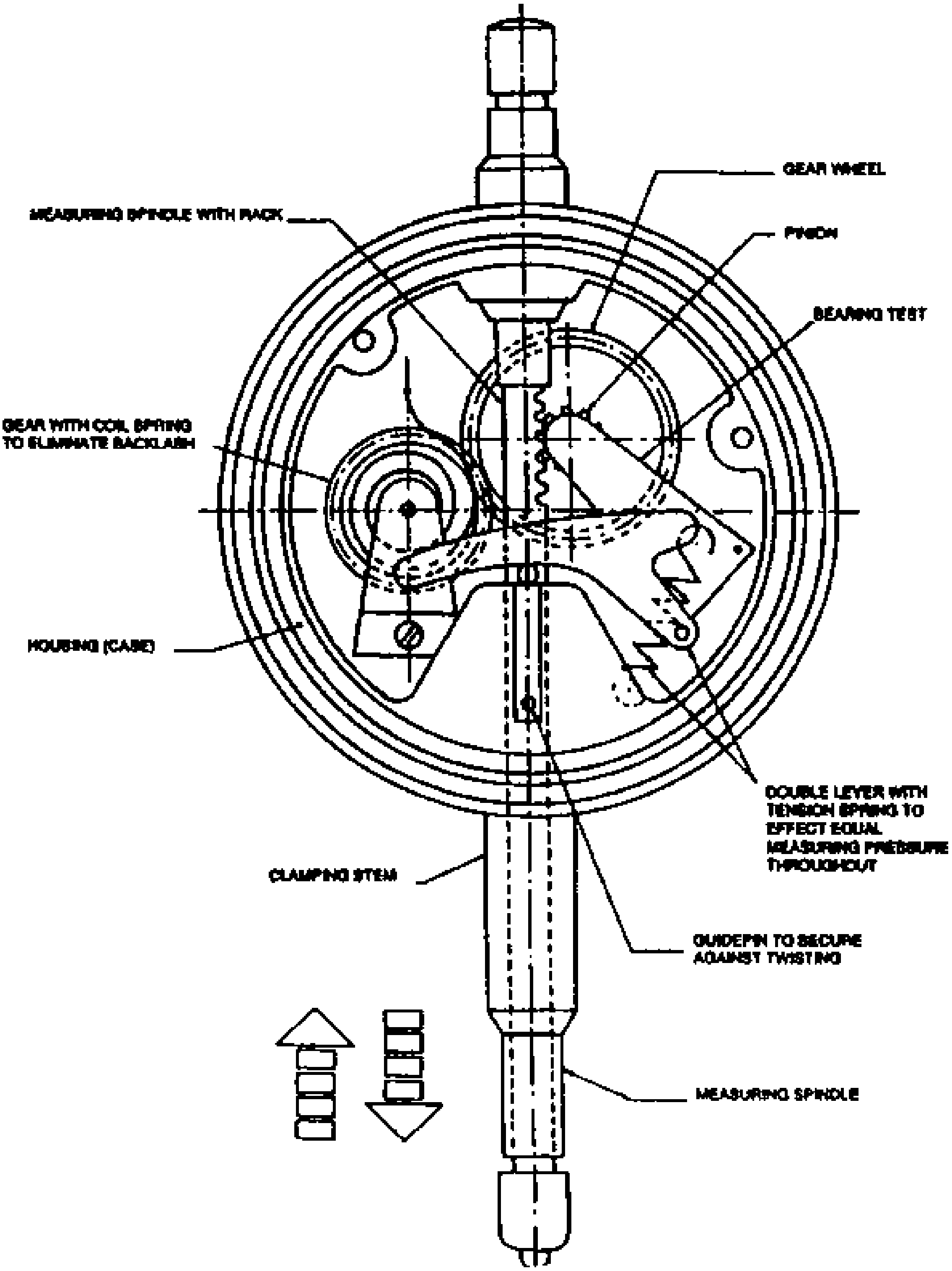
Where media developers feel that they cannot dispense entirely with texts describing the stages of the process, it is essential to use labels. Labels in the pictures link details with the related text, but text and pictures are kept separate. There is a simple justification for separating text and illustrations:

a) Texts overload the illustrations.

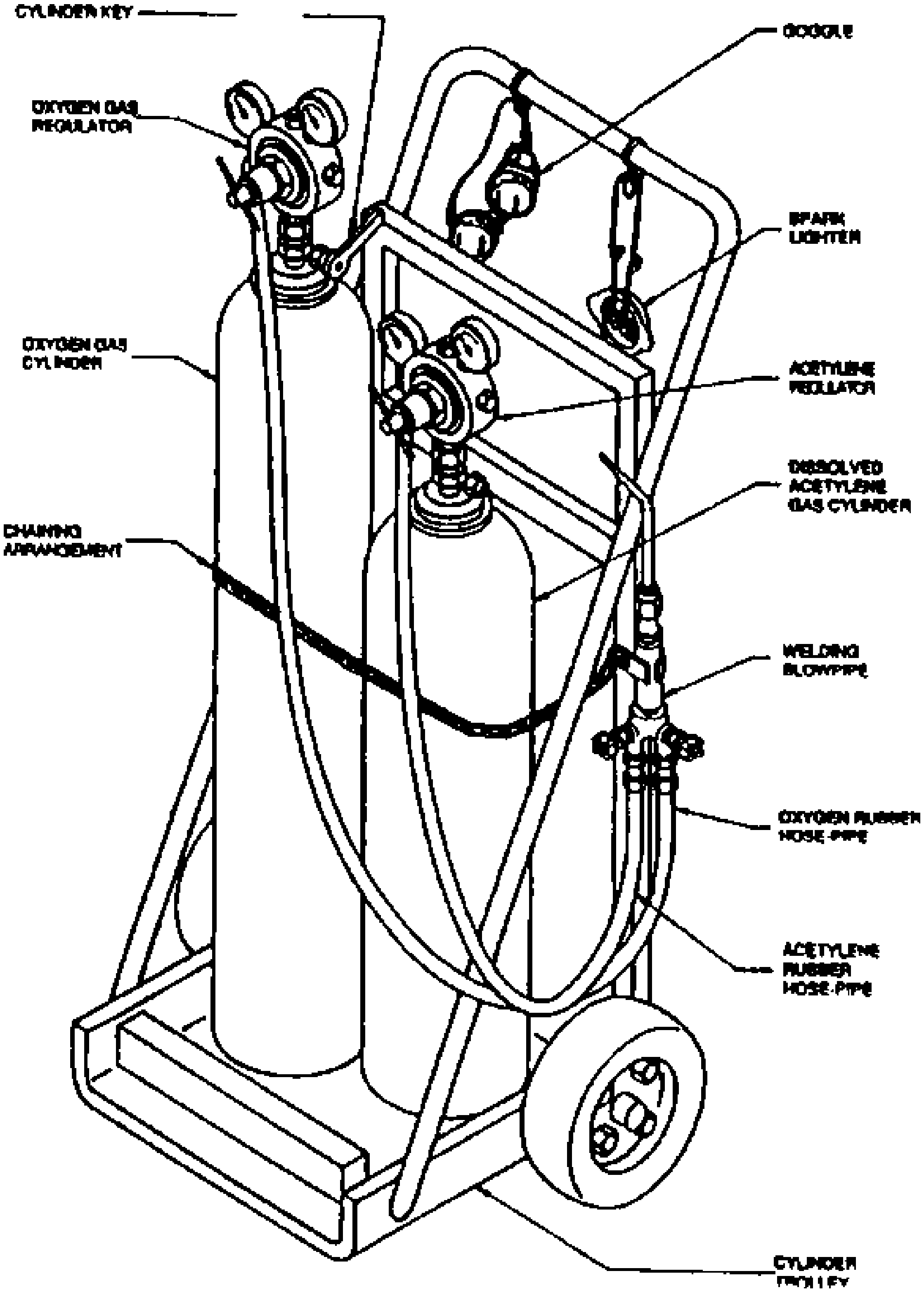
b) Modifying wallcharts for new language versions becomes too difficult.

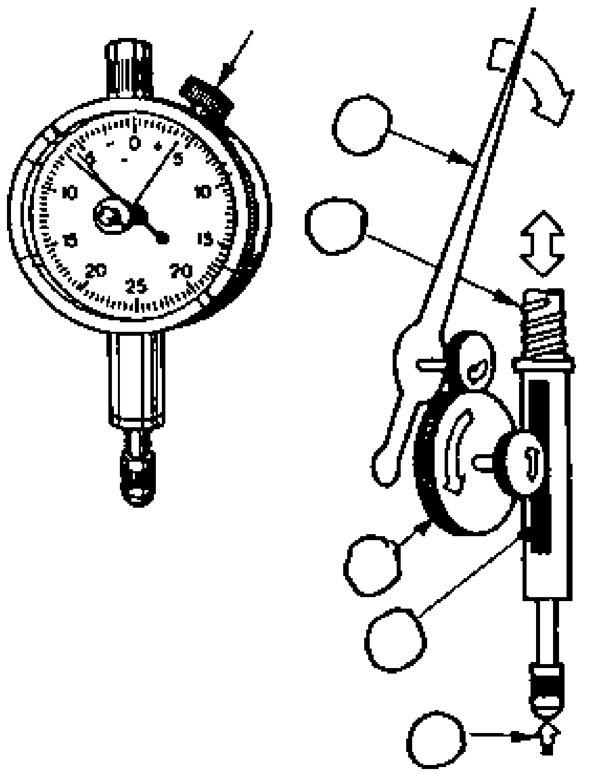
Labels do not disturb the trainee who likes to concentrate on the pictures, because the text is printed separately at the top or bottom of the wallchart.

In multi−language versions, the same label refers to texts in several world languages, or space is left free for handwritten text in local languages.

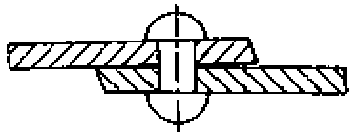

GEAR WHEEL
MEASURING SPINDLE WITH RACK
PINION
BEARING TEST
GEAR WITH COIL SPRING TO ELIMINATE BACKLASH
HOUSING (CASE)
DOUBLE LEVER WITH TENSION SPRING TO EFFECT EQUAL MEASURING PRESSURE THROUGHOUT
CLAMPING STEM
GUIDEPIN TO SECURE AGAINST TWISTING
MEASURING SPINDLE

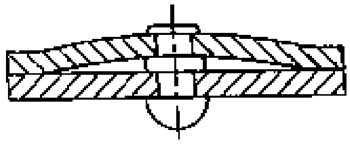
No!

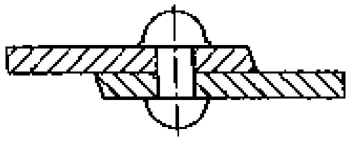

CYLINDER KEY
GOGGLE
OXYGEN GAS REGULATOR
SPARK LIGHTER
OXYGEN GAS CYLINDER
ACETYLENE REGULATOR
DISSOLVED ACETYLENE GAS CYLINDER
CHAINING ARRANGEMENT
WELDING BLOWPIPE
OXYGEN RUBBER HOSE PIPE
ACETYLENE RUBBER HOSE PIPE
CYLINDER TROLLEY

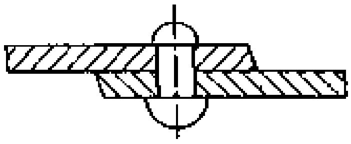


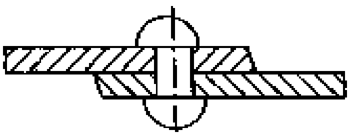
DIAL TYPE INDICATOR

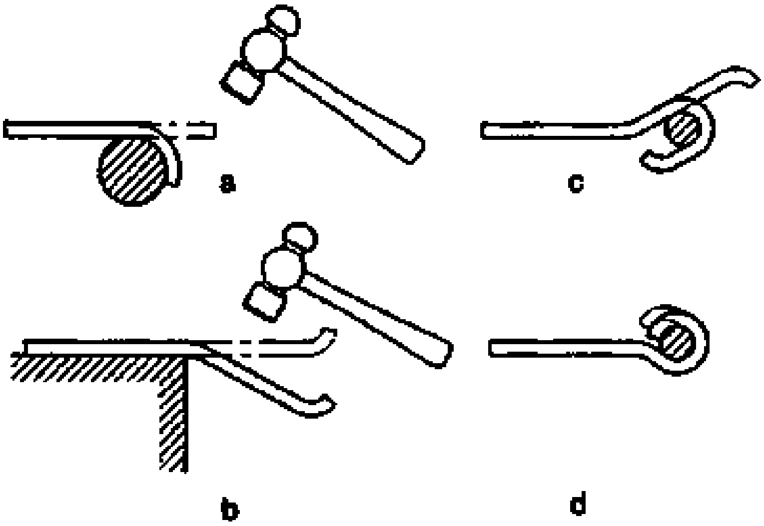




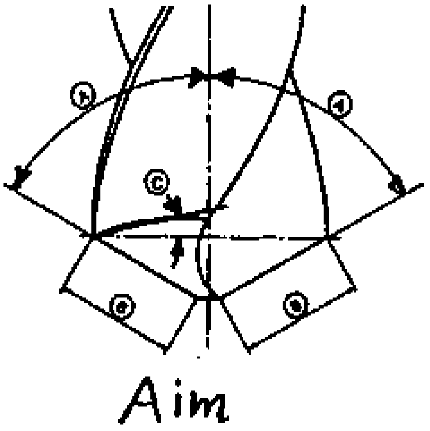


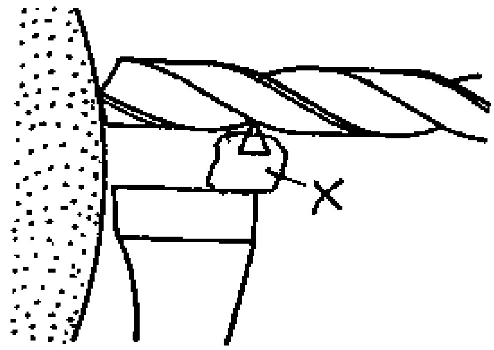


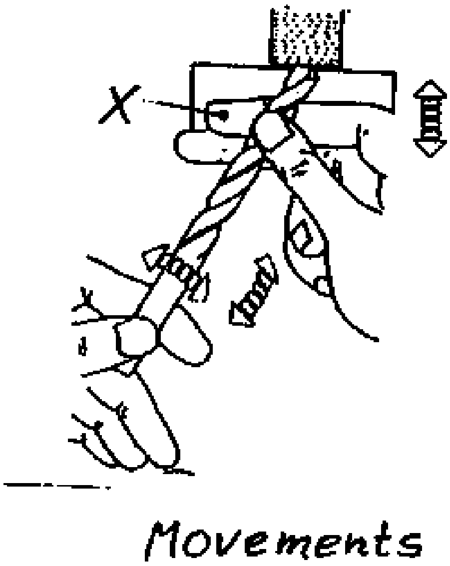


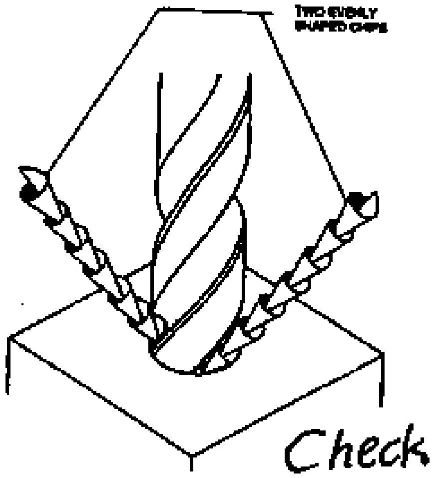


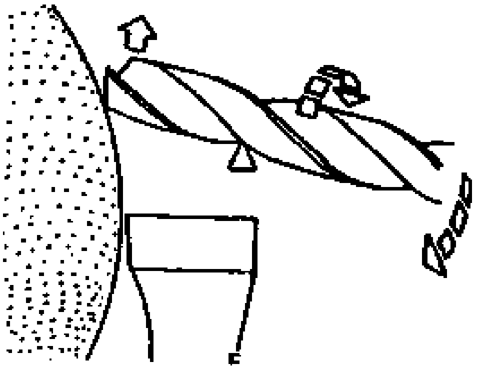
BENDING A HOOK

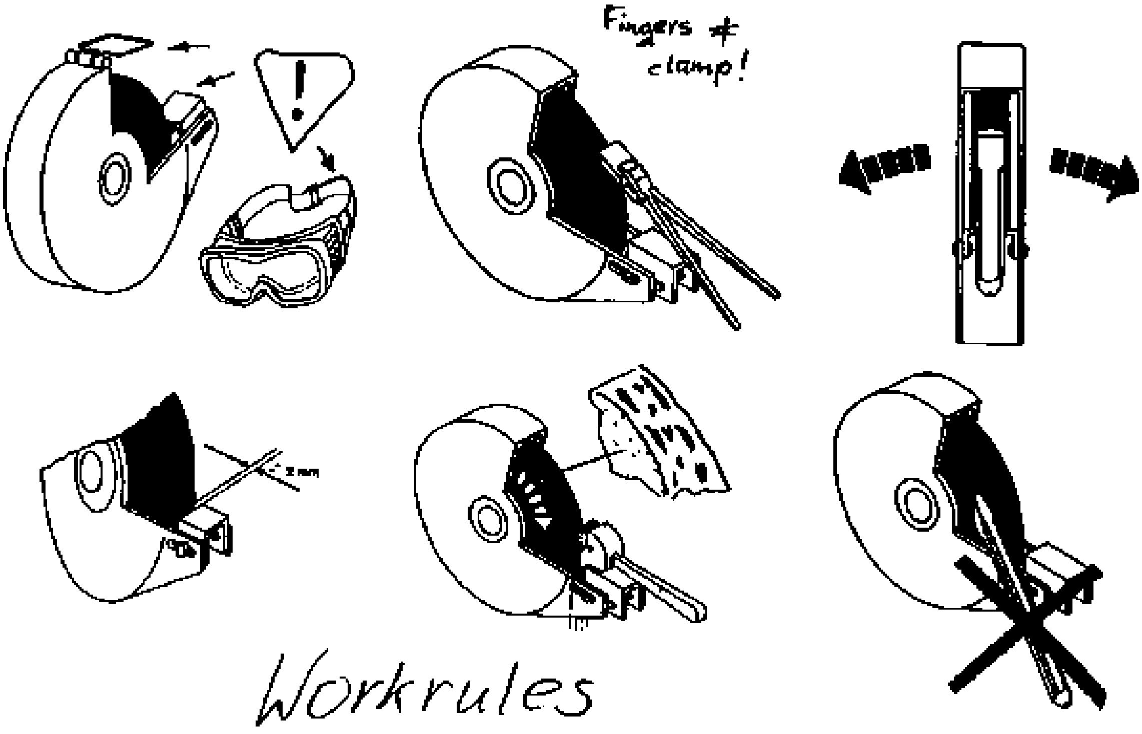












II.3 MEASURING THE MASTERY OF SKILLS

a) Difference between training jobs and testing jobs

A two–day testing period is too short for a trainee to make a bench vice. However, the skills involved in making a vice have to be tested on a mechanism incorporating equivalent movements, fits, accuracy and production techniques, all within the same two–day time–frame. This approach results in special test mechanisms which have little value outside testing.

In current testing, electricians need not work on real machine tools to demonstrate their ability to instal switchgear. Auto–mechanics need not always work on real cars. And metal trade trainees have no time to complete a real job like a normal bench vice.

The main function of testing jobs is to assess key *skills* within a given time. Jobs in a test only simulate certain functions. A simplified bench vice can be constructed by combining mating and movable parts, but the number of parts has to be reduced to an absolute minimum in order to save time. There is little point in a test job where only single parts are made, since no mating fit (the absolutely minimum requirement in metal trades) is possible.

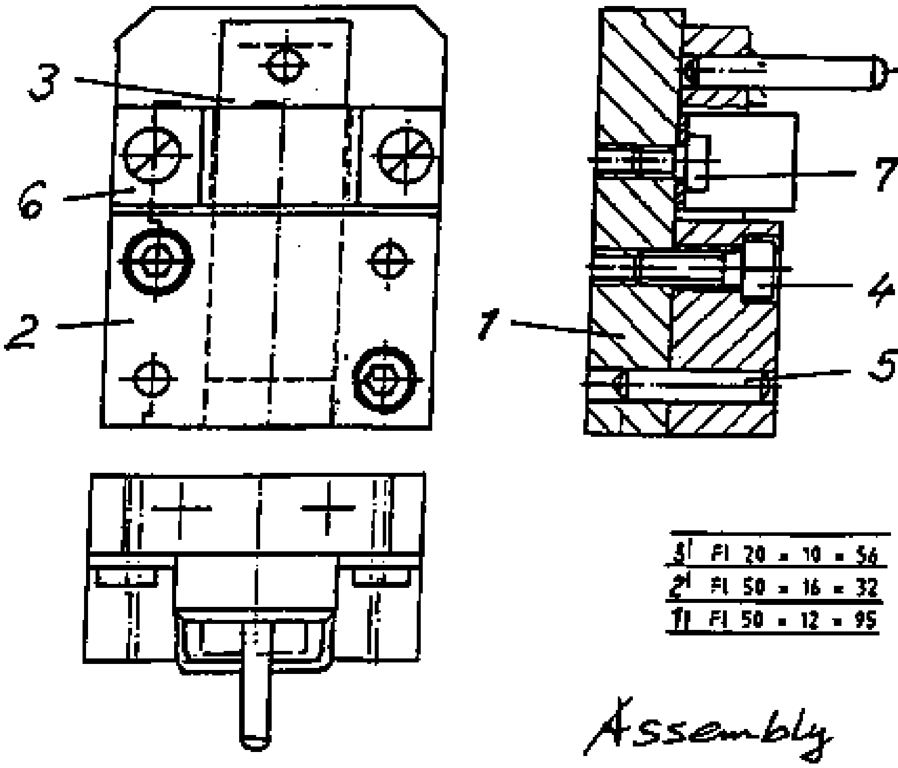
Test jobs checking basic functions like the movement of assembled components require at least 4 parts in the metal trades. The examples below demonstrate possible mechanisms for test purposes. All incorporate fits of various kinds, together with geometrical tolerances. The more sophisticated mechanisms have a drive system simulating a real drive. The difficulty level of such test pieces can be altered by allowing various degrees of component pre–fabrication. Test jobs can be adapted for one–day or two–day tests, depending on the number of components provided as blanks or as semi–finished parts.

The essential feature of such testing jobs in metal trades is the inclusion of several mating parts with a variety of fits and tolerance ranges, geometrical tolerances, surface qualities and materials. It must be clear to trainees that there is a direct link between particular fits/tolerances and the related function. The use of general tolerances (very common in current final trade tests) must be avoided whenever possible.

Movements between parts are necessary so that test results can be assessed visually as soon as the mechanism has been assembled, allowing trainees to evaluate the function of the mechanism for themselves. This form of evaluation is impossible when single components are used for testing.

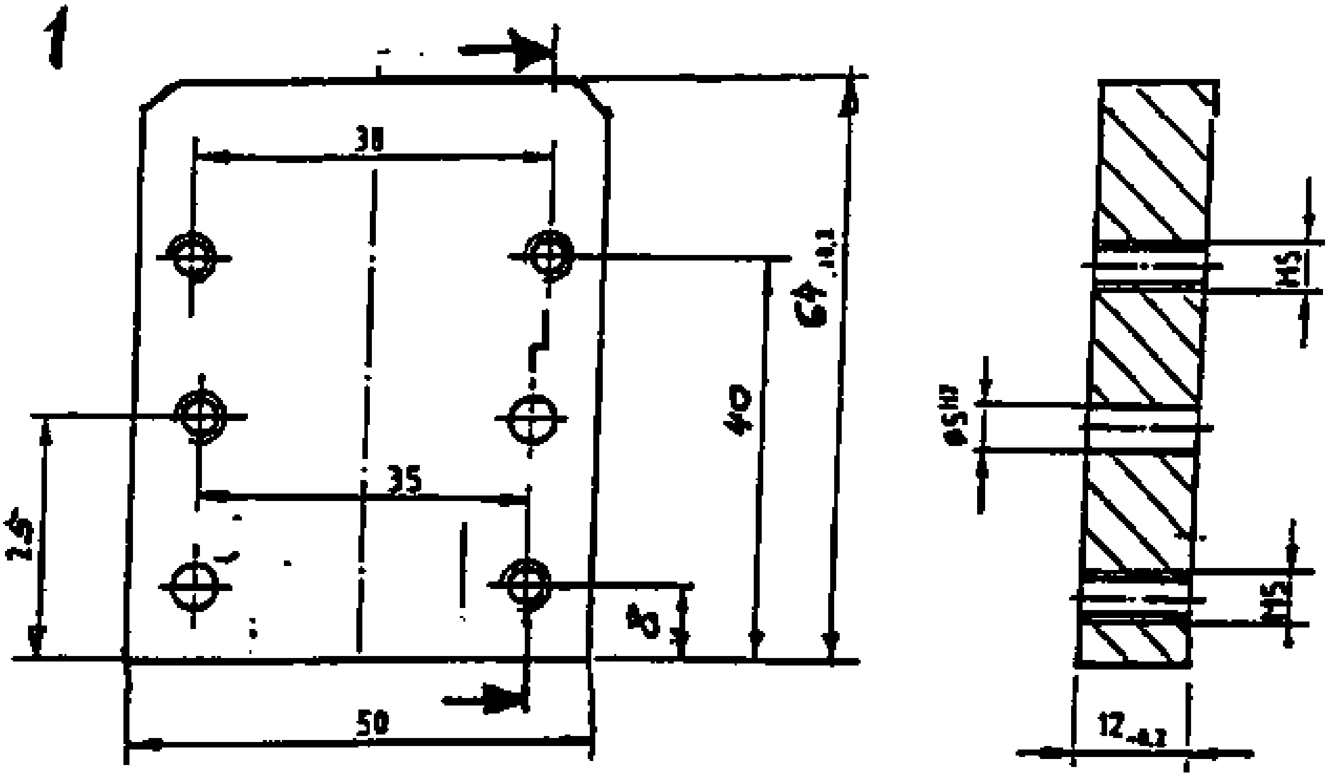
b) Performance marking versus product marking

In the metal and construction trades, assessment is usually confined to examining the workpieces produced during a test. Making trainees write a work plan to be checked by the supervisor before work starts would take only half an hour and would widen the scope of the test.



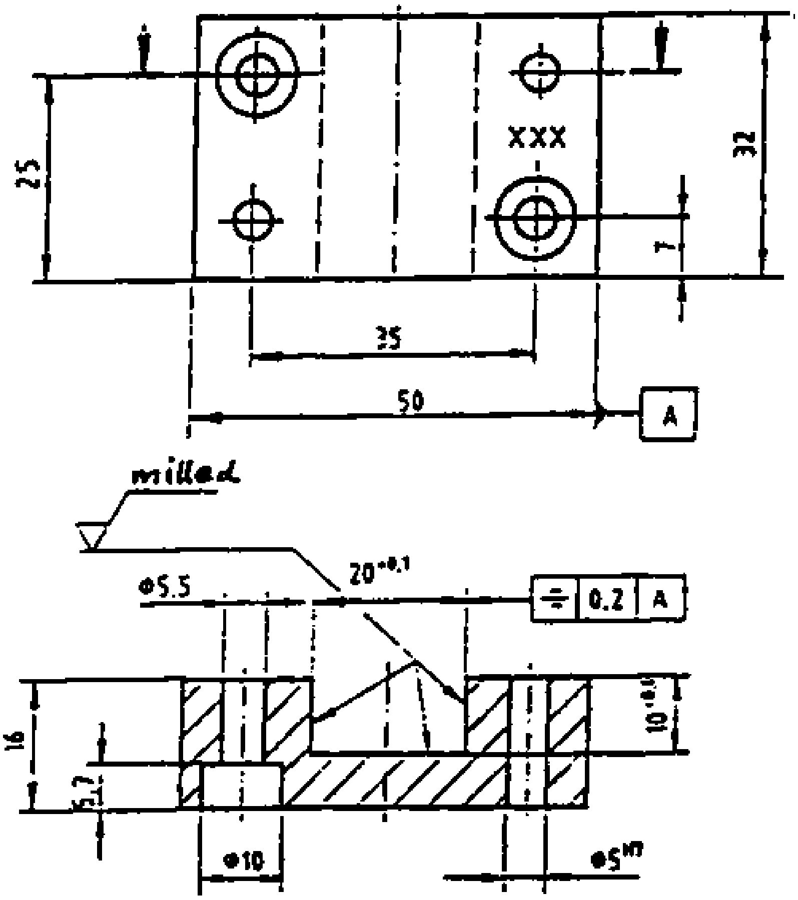
3	Fl 20 × 10 × 56
2	Fl 50 × 16 × 32
1	Fl 50 × 12 × 95

Assembly

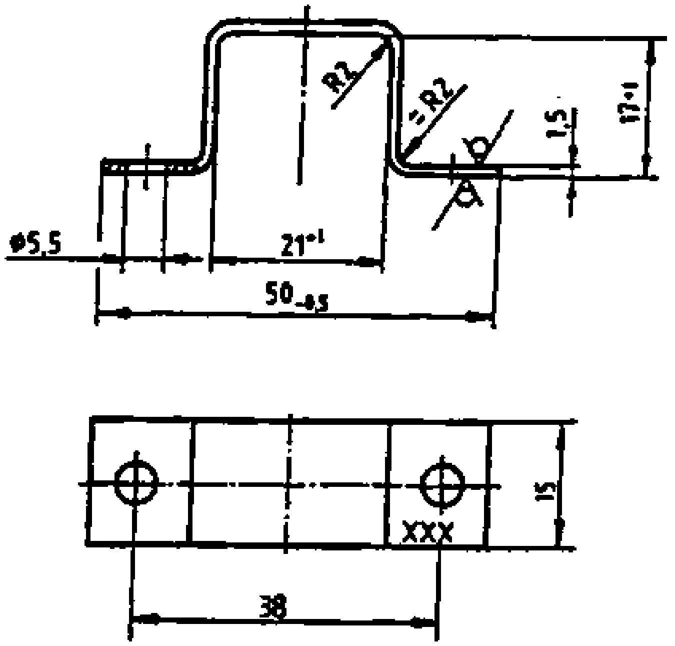


2 √Rz 16 ø5 H7 *drilled with part 1*

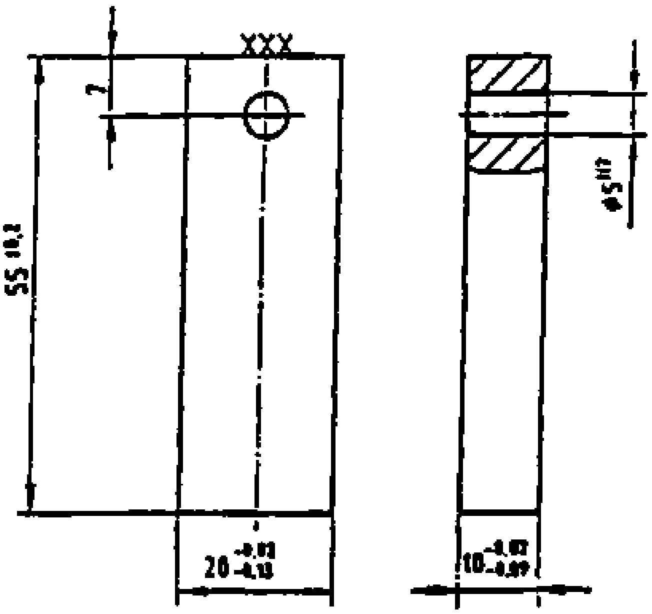
II



6 √Rz 16 (√)

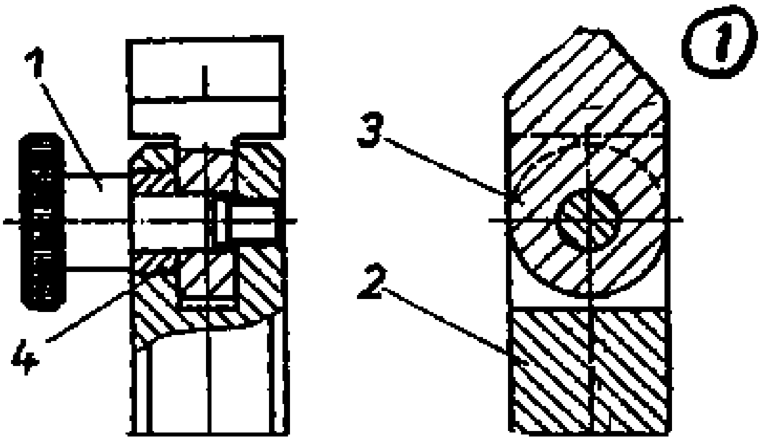


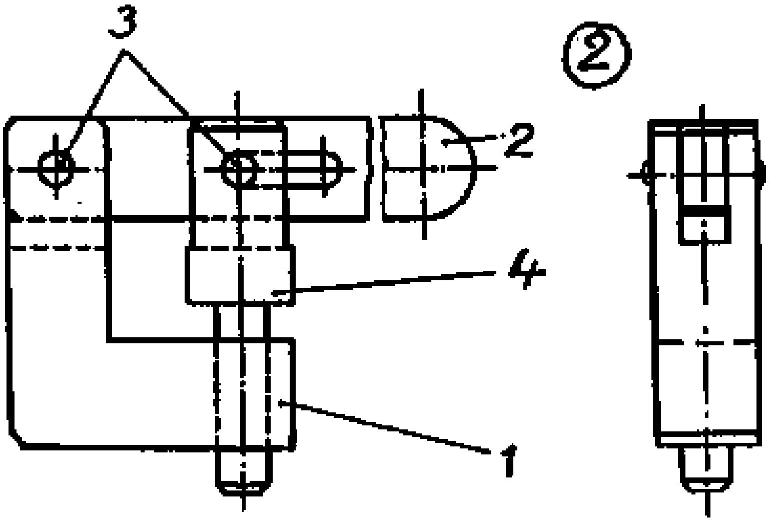
3 √Rz 16

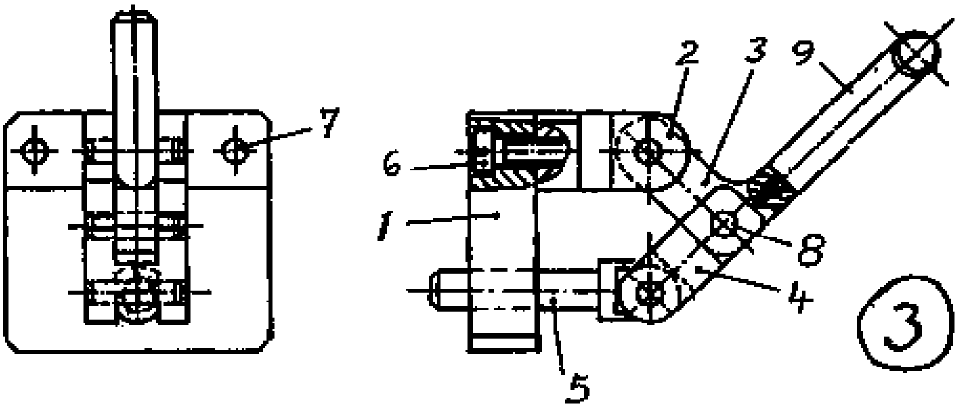


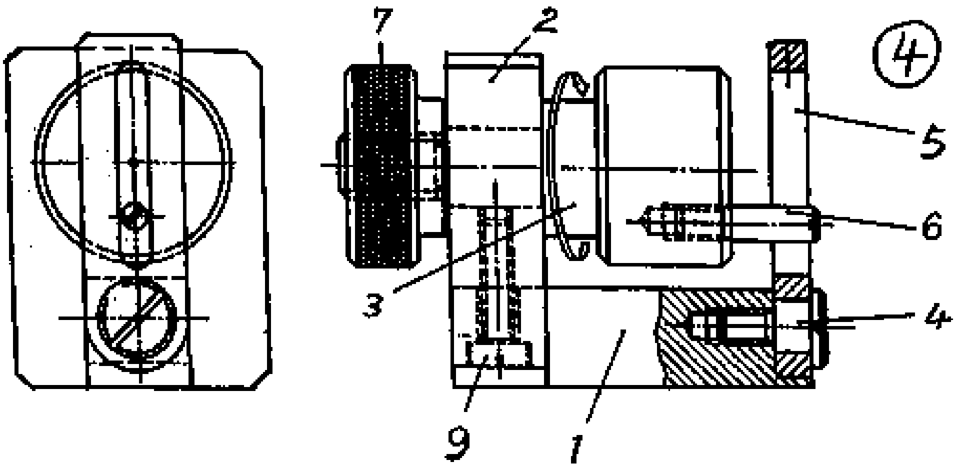
12H7	+0,018 0
5H7	+0,012 0

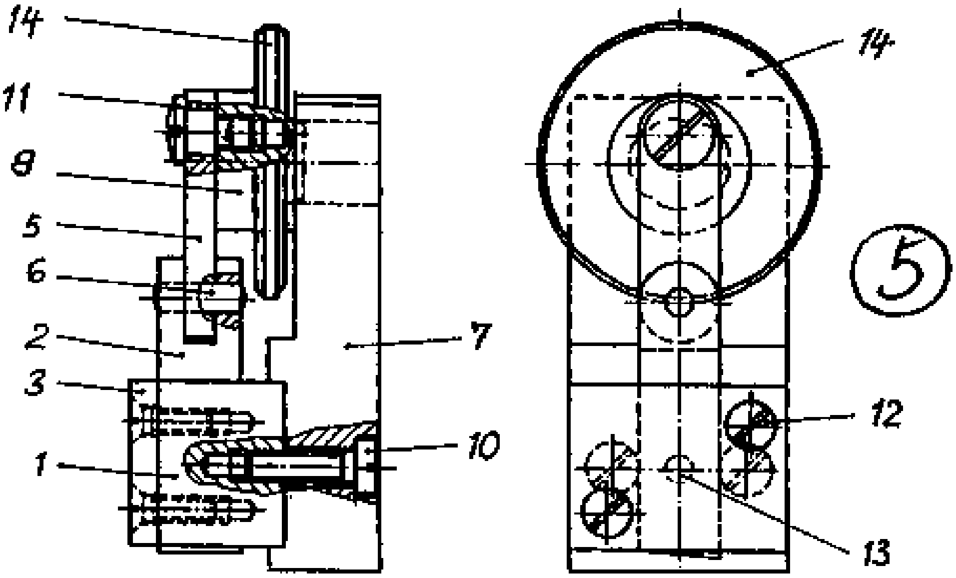
0,5 bis 3	3 bis 6	6 bis 30	30 bis 120	120 bis 400
±0,1	±0,1	±0,2	±0,3	±0,5


①
1
4
3
2


②
3
2
4
1


③
7
2
3
9
6
1
8
4
5


④
7
2
5
6
3
4
9
1



Planning and documentation of working steps in test jobs need to become an integral part of practice tests. They represent a mental skill with a direct bearing on the result of the practice test. The form of planning is of secondary importance. Trainees may be required to describe the steps (advisable for the advanced stage) or may be asked simply to place preformulated steps in the right order (appropriate for the first sessional test).

The absence of performance marking is a major deficiency in production trade tests. Performance marking is an essential component in overall grading. Hitherto, observed criteria have usually been confined to minor aspects like the sequential order of a few steps.

It is far more relevant to observe the handling of machines or the use of complex tools, but this aspect is often omitted.

General formulations like “Proper handling of equipment” or “Correct sequential procedure” or “Systematic approach” frequently figure in checklists. Instead of the generalized criterion “sequential procedure”, the list could include specific details referring directly to a particular test component, e.g.:

“Checked squareness of tap with try square after maximum 2 turns of the tap?”	Yes/No
“Applied countersinking of thread starts before turning in screws?”	Yes/No
“Drilled holes for connecting pins while keeping parts X and Y clamped together in aligned assembly positions?”	Yes/No

Further examples of non–specific observation criteria are:

“Care was taken while centre drilling”

(Did the trainee open the first–aid box and unroll a bandage before he started? What specifically is required from the trainee?)

“Clamped tool with minimum overhang”

(What does “minimum” mean?)

“Set RPM according to drill size”

(For what cutting speed? Why not give a specific RPM range?)

“Drill lifted for removal of chips now and then”

(What is meant by “now and then”? Why not specify time gap in seconds?)

“Turned the tap slowly when starting”

> *(Does "slowly" mean once per second? Is the criterion important enough to be included?)*
>
> "Hacksawing done as per marking"
>
> (What deviation from the marking line is tolerated?)
>
> "Used lubricant while cutting the thread"
>
> *(Continuously? At the beginning? What is the latest possible?)*
>
> "Cleaned threads inside blind hole"
>
> *(With a brush? With an air blow nozzle? By turning work upside down?)*

The advantage of using objectively verifiable criteria is twofold:

For the inexperienced test supervisor or instructor, the package offers immediate help to compensate his lack of experience. For the trainees, it provides the means of self−evaluation. The trainee has only himself to blame for a bad job and poor marking results. He cannot allege that supervisors have assessed results unfairly.

Typical maintenance and repair jobs can be observed and tested via performance criteria in every trade. The examples "Adjusting V−belt tension" and "Aligning V−belt pulleys" indicate how performance marking uses objectively verifiable criteria which can be answered "yes" or "no".

Whenever possible, criteria should be objective rather than subjective. For the media developer, this means that he has to specify in detail what must be observed. Imprecise general criteria are no help (see below).

Packages should include specific observation. Packages need to contain specific observation criteria like:

> "Adjusted the speed of the drilling machine to 700 RPM before drilling the 11 mm diameter holes?"
> "Reversed the tap after turning it a maximum of 3 times?"

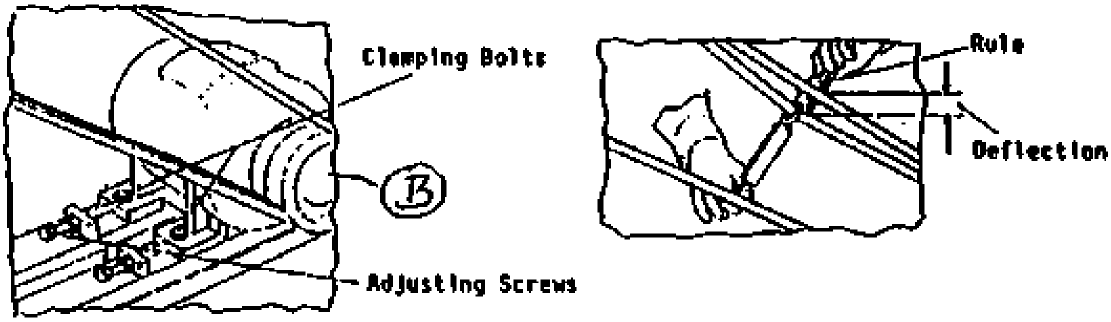
Such handling criteria are to be found in the skill sequences and need only be adapted for the subsequent test job.

Production trades tests can be improved by including a small maintenance or repair job in sessional tests. This may be a simple belt tension adjustment on a drilling machine drive, an alignment job on the belt pulleys, a ball−bearing replacement or dismantling and reassembly of a lathe top slide (for cleaning). The job signals the fact that maintenance and repair are just as essential for a turner or machinist as they are for a fitter.

Since it takes no more than half an hour to test one such ability, there is no reason to exclude it for lack of time. Organizational difficulties cannot justify the media developer in excluding such material. It marks performance not directly linked to a production job but highly typical for maintenance/repair (in demand on the labour market).

SKILL TESTING FITTER TRADE

Marking of performance



Exercise: Adjusting of V−belt tension

Observation criteria

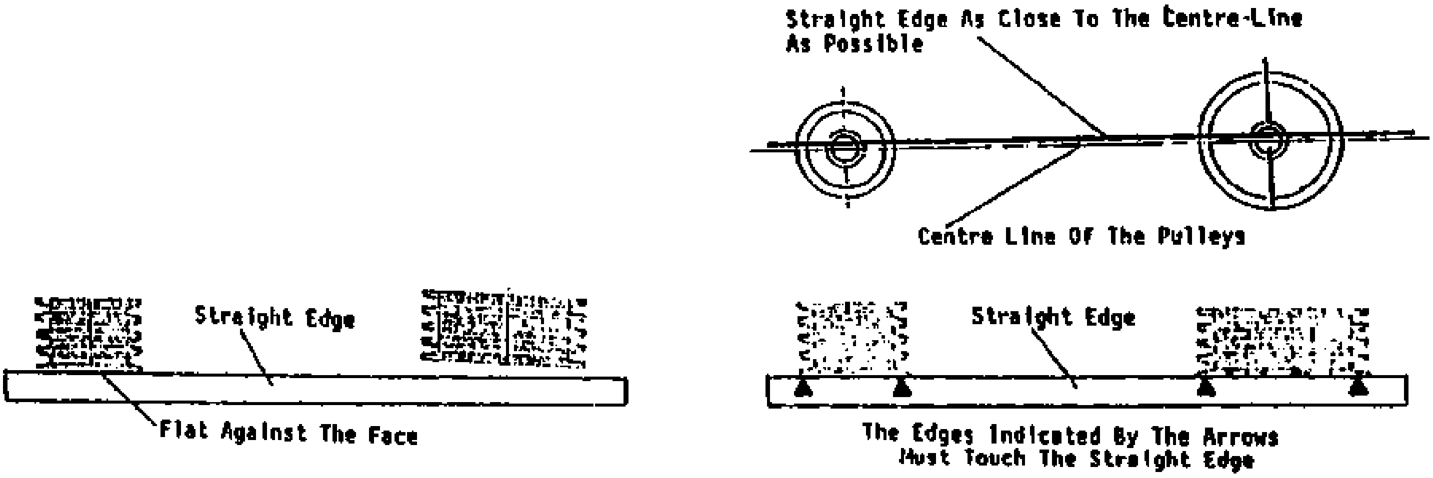
Yes/No

1. Slackened holding bolts on plumber blocks of shaft B and

Adjusted with equal number of turns with tensioning screw until 10 mm belt deflection was attained at centre (Fig. 2). ______

3. Retightened clamping/holding bolts of shaft B? ______

4. Re−checked deflection with spring balance or thumb pressure ______



Exercise: Aligning V−belt pulleys

Yes/No

1. Slackened motor bolts and belt tensioner and

Placed straight edge across centre of fixed pulley, touching its circumference at opposite points

______

3. Moved the motor so that the driving pulley comes into contact with straight edge at 2 points: tolerance +/– 1 mm ______

4. Tighened the motor bolts and re−checked alignment ______

5. Tensioned the belt to a deflection of 2 cm (+/– 1 mm) using adjustment screws with equal turns. Checked deflection with thumb pressure ______

I. INJECTOR TESTING

1. Mount the injector to an injector tester.
2. Bleed the system by pumping the injector tester quickly (approx. 3 strokes/sec) until fuel comes out.

(a) BUZZ TEST

3. With pressure gauge closed pump the tester at a regulator rate and listen and note for buzzing noise of the injector.

(b) SPRAY PATTERN

4. Pump the tester and demonstrate spray pattern to invigilator (Fig 1)

(c) OPENING OR BREAKING PRESSURE

5. Pump the pressure gauge. Operate the tester lever for (5 or 6 times) and note the opening pressure on the gauge.

(d) DRIBBLE (NOZZLE LEAK)

6. Operate the tester lever and build the pressure in the tester to 100 bar and close the gauge. Place a piece of absorbent paper beneath the nozzle for ten seconds and check if the paper is wet.

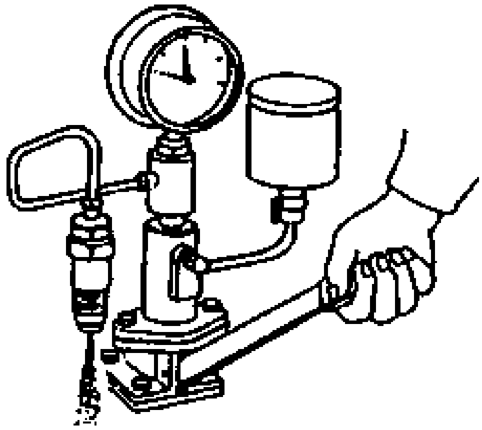


Fig I

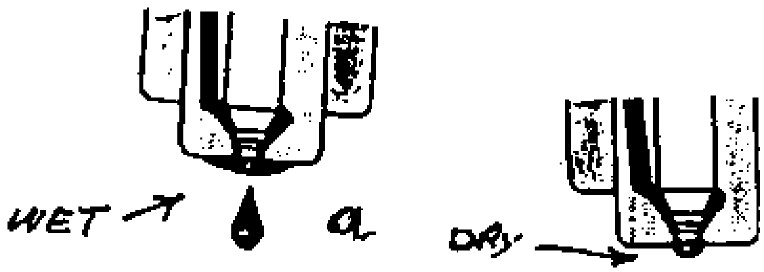


Fig II

(e) INJECTOR BACK LEAKAGE

7. Operate the tester lever to build pressure. Gauge to 100 bar and close the gauge switch on the stop clock and observe how long the pressure drops to 75 bar (SPEC 100–75/10 sec)

II. MARKING OBSERVATION CRITERIA

	Yes	No
1. Was the system bled?	☐	☐
2. Was the pressure gauge closed for buzz test?	☐	☐
3. Was the buzz noted?	☐	☐
4. Was the spray pattern demonstrated or documented	☐	☐
5. Was the pressure gauge used to read opening pressure?	☐	☐
6. Was the pressure set to SPEC (100 bar) and the test done for 10 seconds?	☐	☐
7. Was absorbent paper used and oil traces detected?	☐	☐
8. Was the pressure set to SPEC (100 bar) and the gauge closed for back leakage?	☐	☐
9. Was time recorded how long it takes the pressure to drop from 100 – 75 bars?	☐	☐

<u>Marking Criteria</u>

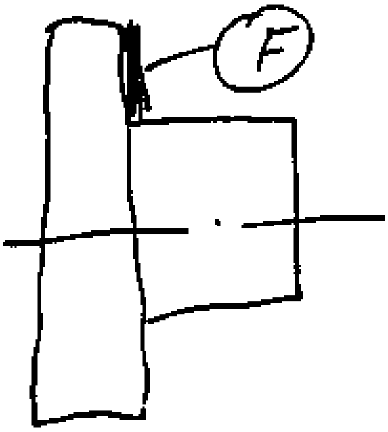
Turning of Component (1)

I Alignment Yes	Yes	No
1. Checked alignment of life and dead centre before clamping the component?	☐	☐
2. Rechecked alignment/cylindricity of work after first turning over the full length of the component?	☐	☐
Adjusted centres, if needed?	☐	☐
II Setting Speed		
3. Set the RPM for diameter 40 according to a cutting speed of 40 m/mm within a speed range ±20% (between 270 and 380)?	☐	☐
III Tapered part		
4. Checked morse taper part angle with drill sleeve using a chalk marking line well before reaching me final diameter?	☐	☐
5. Interpreted chalk mark removal pattern and readjusted taper turning equipment towards right direction?	☐	☐
IV. Thread cutting		
6. Set the compound rest to inclined position (>30°) to cut thread in steps with leading tool edge?	☐	☐
7. Set the threading tool bit square to work using a thread center gauge before starting to cut the thread.	☐	☐
8. Used very low cutting speed and cutting oil for cutting the threads?	☐	☐

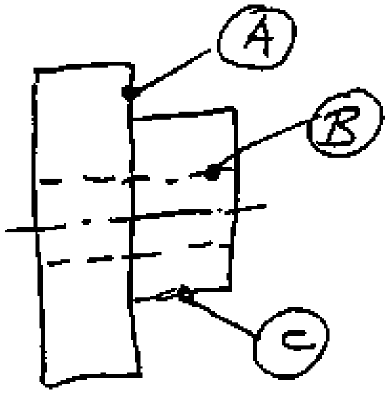
9 When changing gear train at head stock end he set meshing teeth neither too light (X = 0 mm) nor clearance more than 0.1 mm of slip gauge? ☐ ☐

Turning of Component (2)

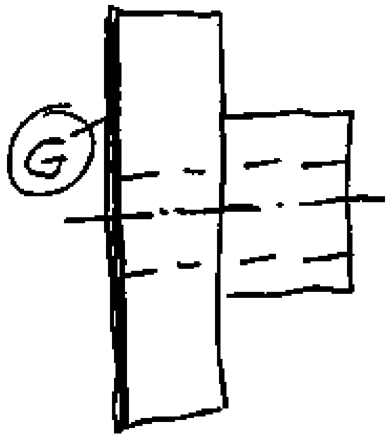
1. Set turning tools to centre height within ±0.2 mm accuracy before turning? ☐ ☐



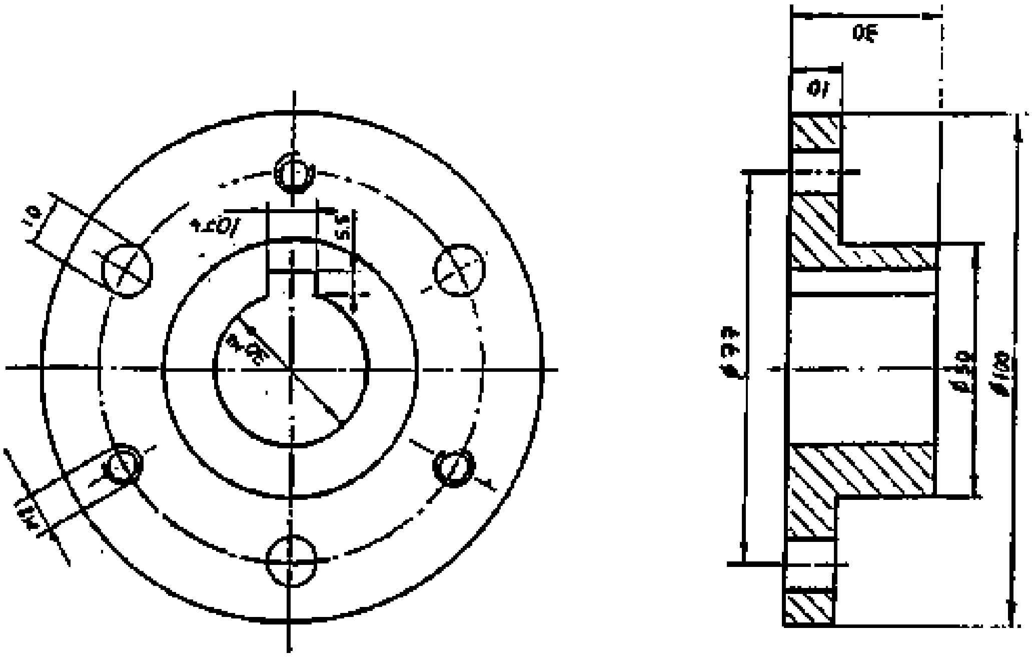
2. Set RPM for tinning surface F according to minimum diameter rather than maximum diameter? ☐ ☐

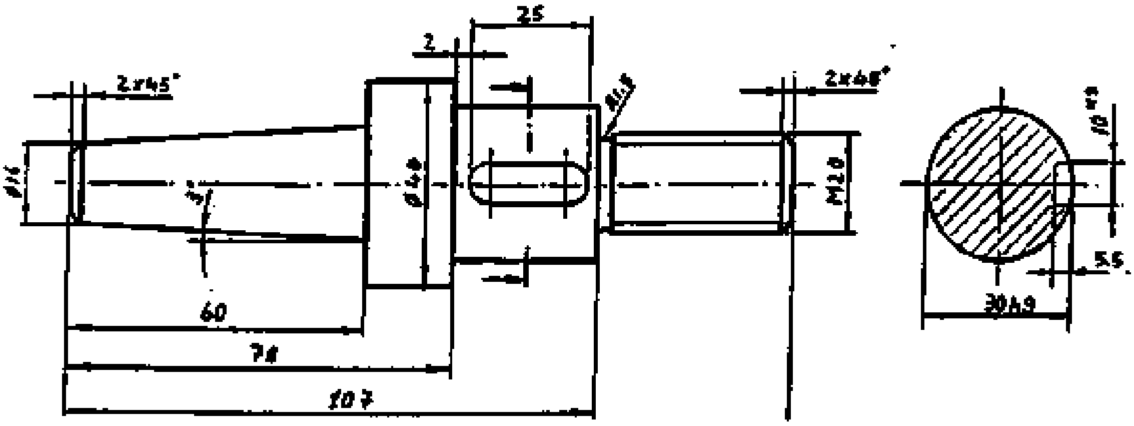


3. Turned/Finished surfaces A, B and C in same damping position (no rechucking)? [concentricity plus squareness specified in drawing] ☐ ☐

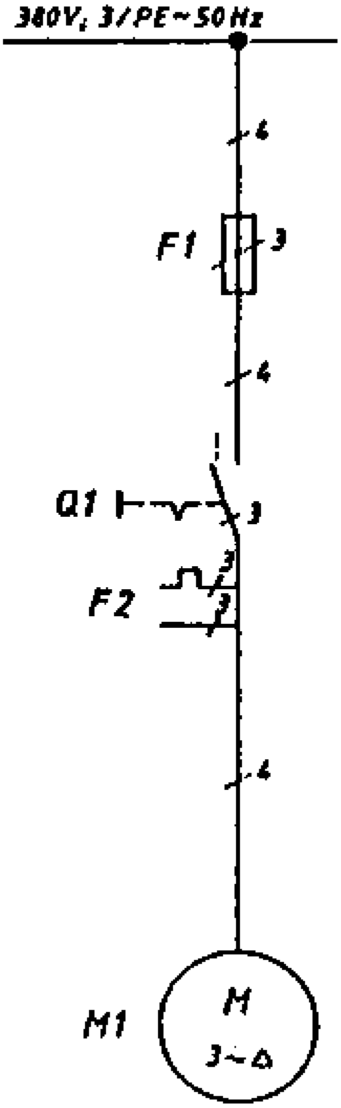


4. Used a mandrel for finishing face G? [squareness to axis 0.05 mm] ☐ ☐



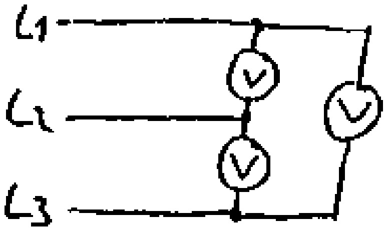


JOB SEQUENCE



1. Switch on power
2. Check voltage on motor terminals
3. Switch off power
4. Protect against reconnecting.
5. Check current to be dead
6. Short circuit and short to earth
7. Replace the cartridge fuse and lock the isolator.
8. Disconnect the motor cable
9. Check resistance of the windings
10. Clean the terminals of the winding with zero resistance.
11. Check resistance once more: If still zero the short is internal, send the motor for rewinding and replace it with the other.
12. Run the repaired motor/new motor: (work reversing steps 7 down to 1)

MARKING SCHEME



1. Measured terminal voltage with tolerance of ±5V (380V)?

2. Pulled out F1 and kept fuse elements in a place only accessible to him?

3. Bridged phases (L1, L2, L3) and earth (PE)?

4.

    (i) Measured resistance with a tolerance of ±5? on two windings?
    (ii) Measured zero resistance on the third winding?

5. Undertaken step 4 after step 3?
Undertaken step 5 after step 4?
Undertaken step 6 under step 5?
Undertaken step 7 under step 6?

c) Testing manual skills versus problem solving strategies

A major weakness for service trades is under−representation of troubleshooting exercises in tests. Too often, electricians are tested on productive work like simulated house wiring or switchgear assignments, while fault tracing in existing systems is ignored.

The same is true for auto−mechanics who are, for example, requested to adjust ignition timing but not confronted with an engine that has broken down completely and needs troubleshooting. There is a qualitative difference between testing a common job like "changing brake shoes", and testing a troubleshooting task like "identifying the cause for a malfunctioning brake system". The same difference is apparent between "exchanging a cooling system thermostat" and "interpreting symptoms for system overheating". Both abilities need to be covered in sessional tests. Real troubleshooting needs a boost.

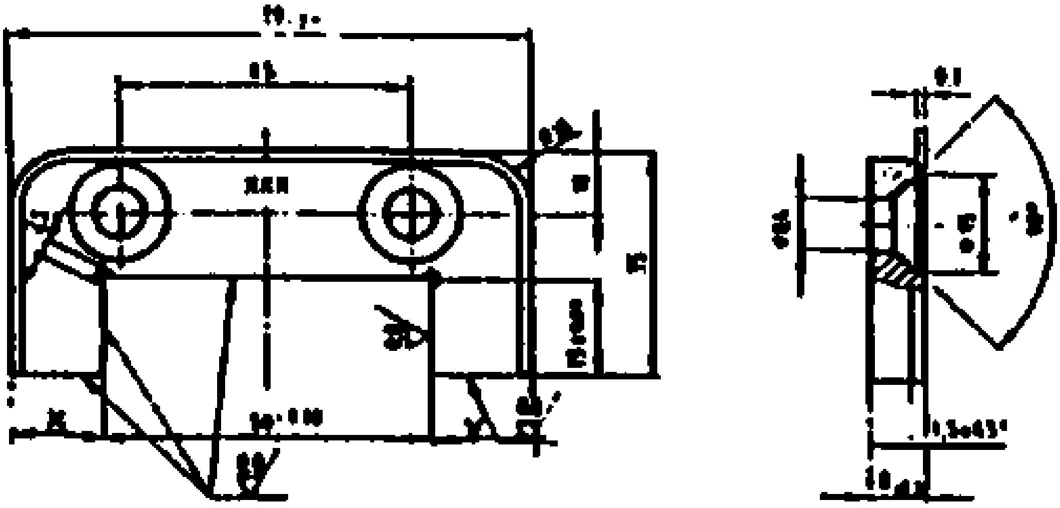
A further weakness of current tests is their excessive stress on mastery of motor skills at the expense of the mental skills involved in competent work step planning to tackle a problem. The media developer should remember that motor skill training will be of decreasing importance in an environment which requires flexible responses to new technologies.

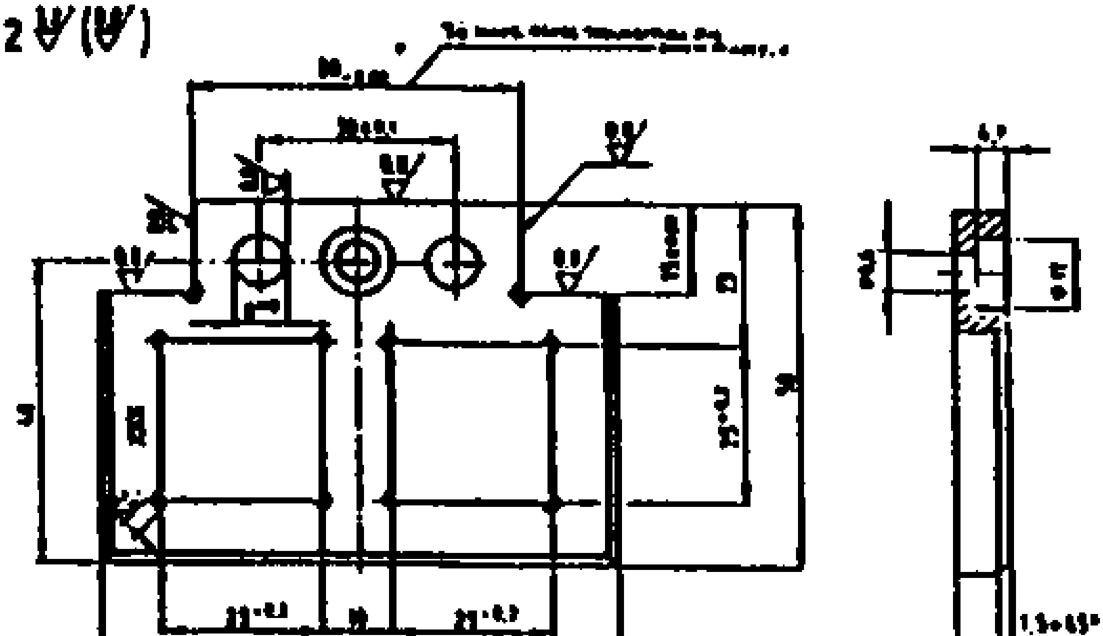
d) Variety and objectivity of product related marking criteria

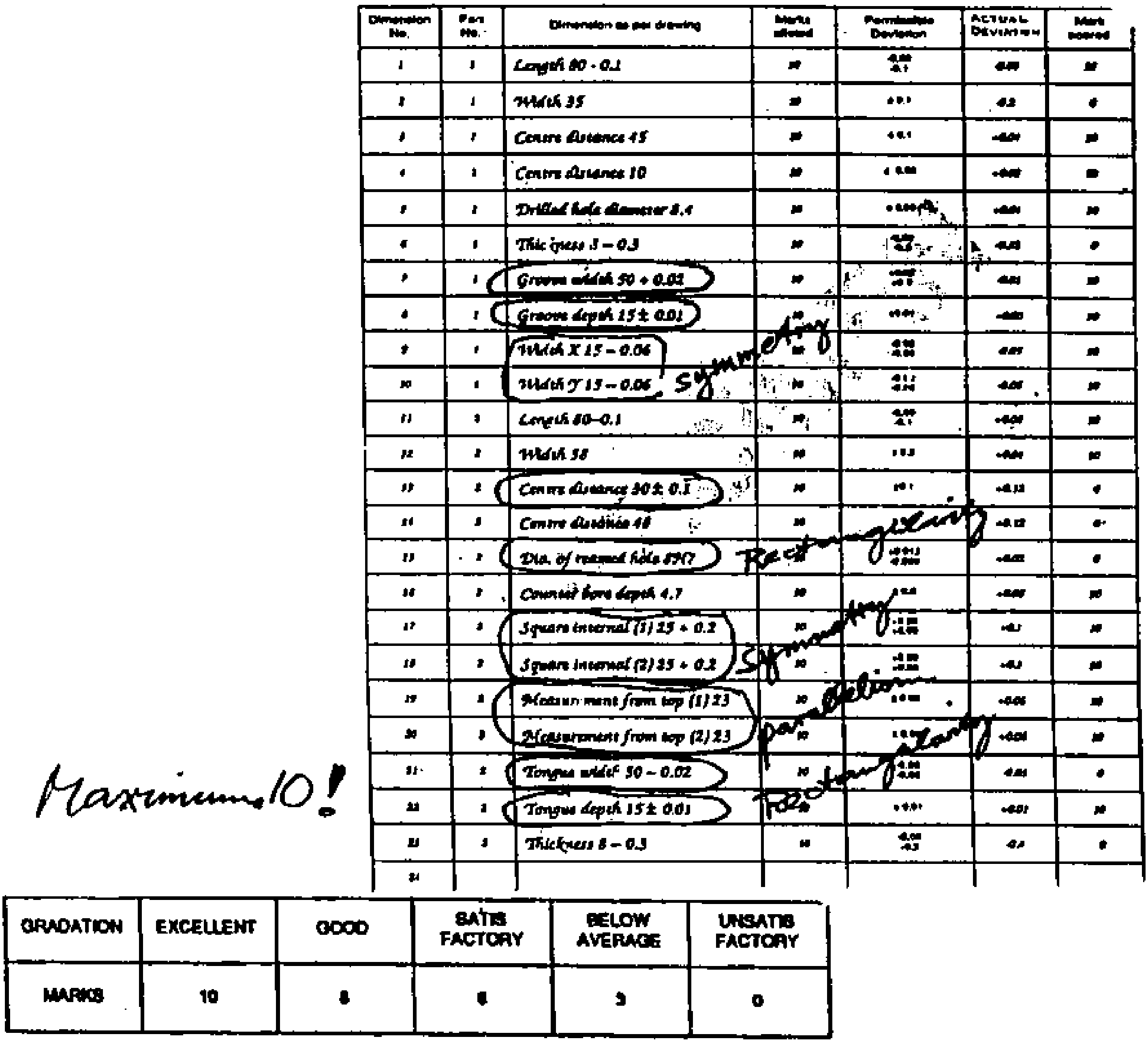
In the metal trades, special attention is needed to prevent perpetuation of a very one−sided checking procedure: only length dimensions are checked. The usual approach is to take selected dimensions (of varying relevance). Very often, however, it is not the absolute dimension that matters, but a geometrical deviation like lack of symmetry, parallelism, squareness or flatness. Criteria can be deduced by analyzing part functions. In many cases, they offer simpler checking procedures. In some cases the fault/malfunction is visible. This can be very important in reinforcing trainee motivation.

Practice tests can achieve the required validity only if a minimum range of skills and abilities are observed in the test. The sheer number of items to be checked can, however, be frustrating for the instructor making the sessional test. Advice on enhancing the variety of items (to be added to simple length dimensions) means that there could be a long list of marking criteria, but that the instructor can select the most essential items from this list. The maximum number of dimension checks (including lengths and geometrical tolerances) should not exceed 10. The same goes for performance checks. (Examples of how not to do it are shown later in the text).

Marking acc. to importance



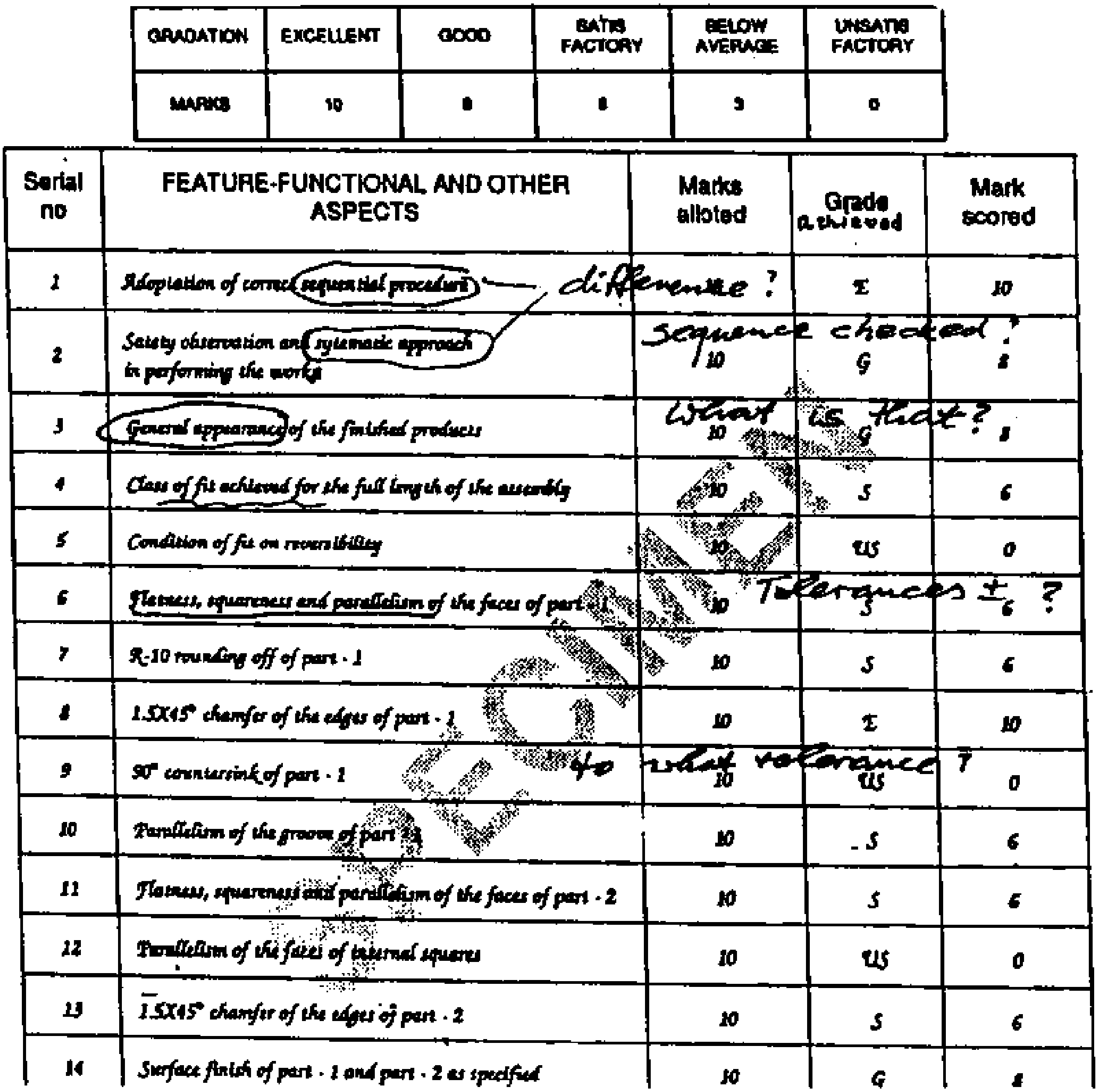




Dimension No.	Part No.	Dimension as per drawing	Marks allotted	Permissible Deviation	ACTUAL DEVIATION	Mark scored
1	1	Length 80 - 0.1	10	-0.00 -0.1	[illegible]	10
2	1	Width 35	10	± 0.1	-0.2	6
3	1	Centre distance 45	10	± 0.1	[illegible]	10
4	1	Centre distance 10	10	± 0.05	[illegible]	10
5	1	Drilled hole diameter 8.4	10	+ 0.05	[illegible]	10
6	1	Thicqness 5 – 0.3	10	-0.00 -0.3	[illegible]	6
7	1	Groove width 50 + 0.02	10	+0.02 +0.0	[illegible]	10
8	1	Groove depth 15 ± 0.01	10	±0.01	[illegible]	10
9	1	Width X 15 – 0.06	10	-0.00 -0.06	[illegible]	10
10	1	Width Y 15 – 0.06	10	-0.1 -0.06	[illegible]	10
11	2	Length 80–0.1	10	-0.00 -0.1	[illegible]	10
12	2	Width 58	10	± 0.2	[illegible]	10
13	2	Centre distance 30 ± 0.1	10	±0.1	+0.12	6
14	2	Centre distance 48	10	[illegible]	+0.12	6
15	2	Dia. of reamed hole 8H7	10	+0.012 -0.000	[illegible]	6
16	2	Counter bore depth 4.7	10	±0.1	[illegible]	10
17	2	Square internal (1) 25 + 0.2	10	+0.20 +0.00	+0.1	10
18	2	Square internal (2) 25 + 0.2	10	+0.20 +0.00	+0.1	10
19	2	Measurement from top (1) 23	10	± 0.05	[illegible]	10
20	2	Measurement from top (2) 23	10	± 0.05	[illegible]	10
21	2	Tongue width 50 – 0.02	10	-0.00 -0.02	[illegible]	6
22	2	Tongue depth 15 ± 0.01	10	± 0.01	+0.01	10
23	2	Thickness 8 – 0.3	10	-0.00 -0.3	-0.4	6
24						

GRADATION	EXCELLENT	GOOD	SATIS FACTORY	BELOW AVERAGE	UNSATIS FACTORY
MARKS	10	8	6	3	0

DIMENSIONAL ASPECT ASSESSMENT (OBJECTIVE)



GRADATION	EXCELLENT	GOOD	SATIS FACTORY	BELOW AVERAGE	UNSATIS FACTORY
MARKS	10	8	6	3	0

Serial no	FEATURE-FUNCTIONAL AND OTHER ASPECTS	Marks alloted	Grade achieved	Mark scored
1	Adoptation of correct sequential procedure		E	10
2	Safety observation and sytematic approach in performing the works	10	G	8
3	General appearance of the finished products	10	G	8
4	Class of fit achieved for the full length of the assembly	10	S	6
5	Condition of fit on reversibility	10	US	0
6	Flatness, squareness and parallelism of the faces of part - 1	10	S	6
7	R-10 rounding off of part - 1	10	S	6
8	1.5X45° chamfer of the edges of part - 1	10	E	10
9	90° countersink of part - 1	10	US	0
10	Parallelism of the groove of part 2	10	S	6
11	Flatness, squareness and parallelism of the faces of part - 2	10	S	6
12	Parallelism of the faces of internal squares	10	US	0
13	1.5X45° chamfer of the edges of part - 2	10	S	6
14	Surface finish of part - 1 and part - 2 as specified	10	G	8

difference ?

sequence checked ?

What is that ?

Tolerances ± ?

to what tolerance ?

e) Evaluation criteria for marking criteria

I. Performance marking in skill sequences

1. Are critical steps of sequence covered (but different from observation criteria)?
2. Is observation of safety measures by trainees checked?
3. Are tolerance limits for performance tighter than usual?

II. Performance marking in job sequences

1. Are at least two of the critical steps of each preceding skill sequence included?
2. Are criteria as specific as possible; preferably objectively verifiable?
3. Are all newly trained skills (since the previous job) covered?
4. Are there performance−related items for production and repair/maintenance jobs?
5. Are both motor skills and troubleshooting addressed?

III. Product marking in job sequences

1. Are the criteria checked on the final product as specific as possible and are there clearly verifiable tolerance limits?

2. Are aspects checked:

   a) relevant to the functioning of the part?

   b) relevant to the intended training effect (newly trained skills)?

II.4 IDENTIFICATION OF TYPICAL CLASSROOM CONTENT

a) Complexity and problem−orientation of trade theory

The relevance checking procedure will be helpful in identifying the most essential trade theory issues within a topic. By awarding marks for each of the criteria, with a total number of marks per topic, and comparing these marks for all topics of a package module, one can obtain a ranking order of topics−relevance for a certain training period e.g. half a year. This procedure helps to slim down the package. It screens out less relevant topics in a module or issues in a topic. It also eliminates those with poor interlinkage. Coverage of such items in the package can be restricted to skill sequence information or simply a cross−reference to other material, e.g. trade books already available on the market.

Each topic, issue or curricular component is scrutinized on four criteria, each yielding a maximum of 3 marks. The media developer team could then decide the minimum score for including a topic or issue in classroom trade theory.

Criteria for relevance of classroom content:

1. Relevance to practice: The media developer describes up to three workshop/lab situations (preferably critical working steps of a skill sequence) in which the theory content is important and helps to overcome problems.

   The examples listed must be actual workshop/lab situations, preferably problem situations.

2. Topic−internal interlinkage: List cause−effect or fault−cause−remedy links with a minimum of 4 links or different types of comparison and at least 5 essential differences. These examples are purely trade theory issues within the topic.

3. Curricular linkage: List other topics in the syllabus or topics relevant to new job requirements for which the present topic/issue represents vital preknowledge. This list addresses specific issues within other topics.

4. Transfer potential: List other topics/issues which could be partly or wholly omitted under time pressure because the present topic can be transferred.

Justification for the four relevance criteria

1. The fact that a particular issue is mentioned in the syllabus is not sufficient justification for covering it in a media package. Trade theory content is justified only if it enhances the efficiency of practice training.

2. Content with less than the required internal complexity should be checked to determine whether it would not be more appropriate to the shop talk. A comprehensive survey of links between the issues in a topic may ideally indicate potential cause−effect links. These can be used to form logical structures for discovery learning.

3. A topic representing preknowledge for several other topics is more important than an isolated topic. It enjoys higher priority because it is a link within a chain.

4. Training theory content should be multi−usable and worth training with a certain depth because of its transfer potential. Such topics allow issues under other headings to be skipped when time pressure dictates.

Transferability is vital for cutting volume.

Once the skill sequences, job sequences and experimental sequences are drafted, it is easy to find reference material for the first criterion, practice−relevance. Critical steps offer particularly good examples of problem situations in the workshop/lab where related trade theory can be very helpful.

The key question addressed in the second check is: What links exist within the topic? Linkage potential is a major selection tool for tracing content which will help trainees develop strategies for functional understanding of complex issues.

The third check is intended to search the syllabus (or parts of it) for context links between different topics, so that those with weaker overall linkage can be omitted if necessary.

The fourth criterion shows the media developer which issues tackle content re−appearing in similar form elsewhere, and hence possessing transfer value.

b) Giving top priority to issues with the highest relevance scores

The most important benefit is topic content reduction by eliminating unlinked facts or lists of equipment types. More pages will probably be needed for enhanced coverage of interlinked information, e.g. detailed functional descriptions and fault−remedy analysis (discovery learning material). But overall volume will shrink.

The relevance checking procedure should be applied to all topics commonly listed in the approved syllabus or trade standards. A ranking order emerges from the total scores for each topic.

The advice to the media developer is: start at the top of this ranking list and see what size of package results from covering the ten most essential topics in a six−month training programme.

Staff resources can then be focused on the most important topics with the highest priority. The checking procedure serves as a rough tool for weeding out popular but less relevant book learning.

Example of a relevance check: Pin and Bolt Joints

I. Workshop practice situation: 3 marks

a) Bolt joint intended as fulcrum does not permit tilting of parts, due to overtight fit.
b) Pins/bolts shear and bend owing to incorrect diameters of chosen pins.

c) After some use, pins/bolts loosen due to widening of drilled but unreamed hole.

II. Internal interlinkage: 3 marks

a) Function of pin/bolt – type of fit – dimensions of bore/shaft – related cutting operation – potential faults

b) Ratio of pin/bolt diameter to sheet thickness – effect on stress and deformation – resulting shearing/bending faults – remedies

III. Curricular linkage: 3 marks

a) Types of fit,
b) Surface roughness, material hardness, stresses
c) Drilling, reaming

d) Permanent – temporary joints

b) couplings, clutches 3 marks

IV. Transfer potential: 0 marks

a) Shafts and bush bearings (limited)

Relevance weighting: 9 marks

Possible conclusion in comparison to other topics in respective trade−related ranking list:

Needed for fitters and steel erectors

Questionable for turners and machinists

Example for relevance check: Bush bearings

I. Workshop practice situations: 3 marks

a) After assembly the bearing shows poor build−up of oil film.

b) Bush bearing gets hot after running well for a long time.

c) A defective bush bearing has to be repaired but no genuine spares are available.

d) A ball bearing is supposed to be replaced by a bush bearing

II. Internal interlinkage 3 marks

a) Conditions for hydrodynamic slipping effect – need for minimum speed – clearance – viscosity of lubrication

b) Effects of change of speed, oil viscosity, oil temperature and shaft load on oil film in bush bearings

c) Causes and remedies for rupture of oil film (with above links)

d) Parallel flanks of thrust bearings – lack of oil wedge – need artificial wedge for pressure build−up – restricted use

III. Curricular interlinkage: 3 marks

a) Fits, shafts, guideways,
b) Speed, pressure, surface roughness
c) Hydrostatic bearings for machine tools
d) Roller bearings

e) Coolants, lubricants, lubrication

IV. Transfer potential 1 mark

a) Guideways

Relevance weighting: 10 marks

Example of relevance check: Marking with Height gauge

I. Workshop practice situation: 2 to 3 marks

a) Several training jobs require marking of bore centres and parallel surfaces.

b) Height of marking lines changed during marking procedure due to non–clamping of screws.

c) A significant difference between the height set on the vernier scale and the real height resulted from dirty surfaces of table/gauge

II. Internal linkage: 1 mark

a) Effects of faulty handling of height gauge, e.g. failure to clamp screws or clean base surface

III. Curricular interlinkage: 1 to 2 marks

a) Measuring

b) Geometrical tolerances

IV. Transfer potential: none 0 marks

Relevance weighting: 4 marks

Possible conclusion: No justification for dealing with this topic in the classroom except for working principle (maximum 30 minutes). For other issues, shop talk plus references to available trade textbooks.

II.5 DISCOVERY LEARNING WITH CAUSE–EFFECT LINKS

a) Inference questions generating a new concept or rule

The instructor who does not only lecture but INSTEAD asks questions has to distinguish between *recall* questions and *inference* questions. Recalling existing knowledge relies chiefly on memory abilities, whereas inferences depend on logic: the trainee has to infer something he has not heard before.

Example for typical structure of inference questions:

a) Given or known information: Hardness of tool steel decreases with rising temperature.
b) Focus on a particular situation or phenomenon: At higher RPMs drills dull faster.
c) Inference question: Why?
d) Possible key: More friction leads to more heat, increasing temperature and stronger wear.

Example: Combustion engines burn a fuel–air mixture.

Atmospheric pressure and air density fade with increasing altitude. Automotive engines show reduces output in high mountains. Why?

Key: Less air intake, reduced heat energy, lower cylinder pressure

Example: Cheap arc welding transformers have a poor cooling system (no venting). It is advisable to interrupt the welding with thick electrodes every ten minutes for some 5 minutes. Why?

Key: Prevent overheating. Avoid burning of isolators.(or similar)

Correct answers to such questions can be expected with high probability from groups of trainees provided they are familiar with the method of teaching. Trainees may often attempt to find the answer by guesswork, but this generates reactions from other trainees based on better reasoning. This reasoning already represents a major improvement on merely listening to what the instructor says and recalling it later.

The new feature of this approach is that the instructor holds back a small item of information (the missing link), offering trainees the chance to apply logic.

The value of such questions in a lesson stems from the fact that they provide a tool for increased trainee interaction. If questions are ambiguous, the instructor can react accordingly and narrow the scope to get the class back on course.

By screening the information carefully, the media developer can identify small items of information suitable for use as missing links. These are presented to trainees via an inference question in the task bank. The item of information is not lost but simply shifted to the task portion of the package.

Such questions must not be confused with memory questions. If a question is to be defined as an inference question, the answers it expects from trainees must be in the form of statements not previously known or familiar to them.

b) Interlinked statements leading to complex logical structures

The first few times such logical structures are used, it is wise to begin with simple chains consisting of 3 to 4 statements linking up as linear chains.

Example:

Drilling machine
set for higher RPMs

Drill gets hotter

Hardness of cutting
lips fading

Dulling effect after
shorter time

It takes one exercise to make trainees understand the meaning of the vertical position of the cards: causes on top – effects below.

The one thing the instructor has to ensure is that the meaning of each of the statements is clear before the groups start shifting the cards. A trainee who does not understand the concepts “drill”, “hardness” and “dulling” cannot link them. Hints for instructors using discovery must insist on this point: the meaning of each statement must be made clear before the trainees try to establish the structure.

Assuming that a trainee has learned that

– grinding stones are composed of grains acting as cutting edges (tools) and held together by a bond;

– hard workpieces cause fast dulling of tools, with increased cutting force;

one can expect successful discovery learning of a complex new rule.

The set of statements given to the group consists of some information already familiar and known from previous topics (hard work – shorter tool life or dulling tool – increasing cutting pressure), with other items which are new. The trainees can work out their implications on the basis of concrete wording like “held by bond”, “grains break off” or “new ones appear” in connection with labelled pictures showing details (see example below).

The trick is to combine the given short statements with new linked statements, together forming the complete chain.

Trial−runs prove that groups of 4 to 6 trainees can put together such statements (handed out to them as mixed set of cards, each containing a separate statement) to form a logical structure.

Once they have become familiar with the meaning of the line symbols, trainees find such structures easier to “read” than continuous text passages, because of the brevity of the text element. So this form of presentation has some advantages. But its most essential potential is its suitability for discovery learning in groups of trainees.

The first condition for designing discovery exercises is the use of small steps to establish the ultimate cause−effect link. Only then are trainees able to sort out the scrambled statements.

The difficulty level of such exercises depends mainly on the number and lengths of statements to be connected. There is, however, another element of difficulty. This is made more apparent by the method of linking statements through lines which permit a distinction between AND and OR connections.

It is difficult for the media developer to recognize branching links at first glance, although with some experience they are detected immediately. With trainees, a common response is to place all statements in vertical order with no branching. There is nothing wrong with this approach; it brings out contradictions between the group members, in turn generating corrections and solutions.

This can be illustrated in detail from the example “grinding”.

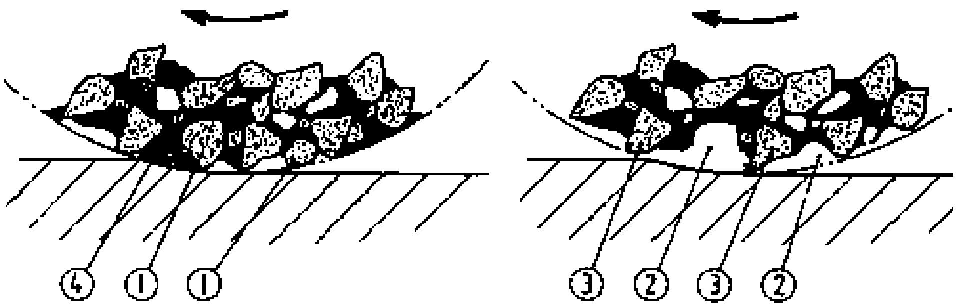
The grains are held by the bond and no other statement is the cause for this; so no other card can be placed on top of it. “Hard work is cut by grinding” describes a working constraint and is not caused by any of the other conditions either. This is the logical alarm signal that these two statements need top position, meaning that the structure is branched.

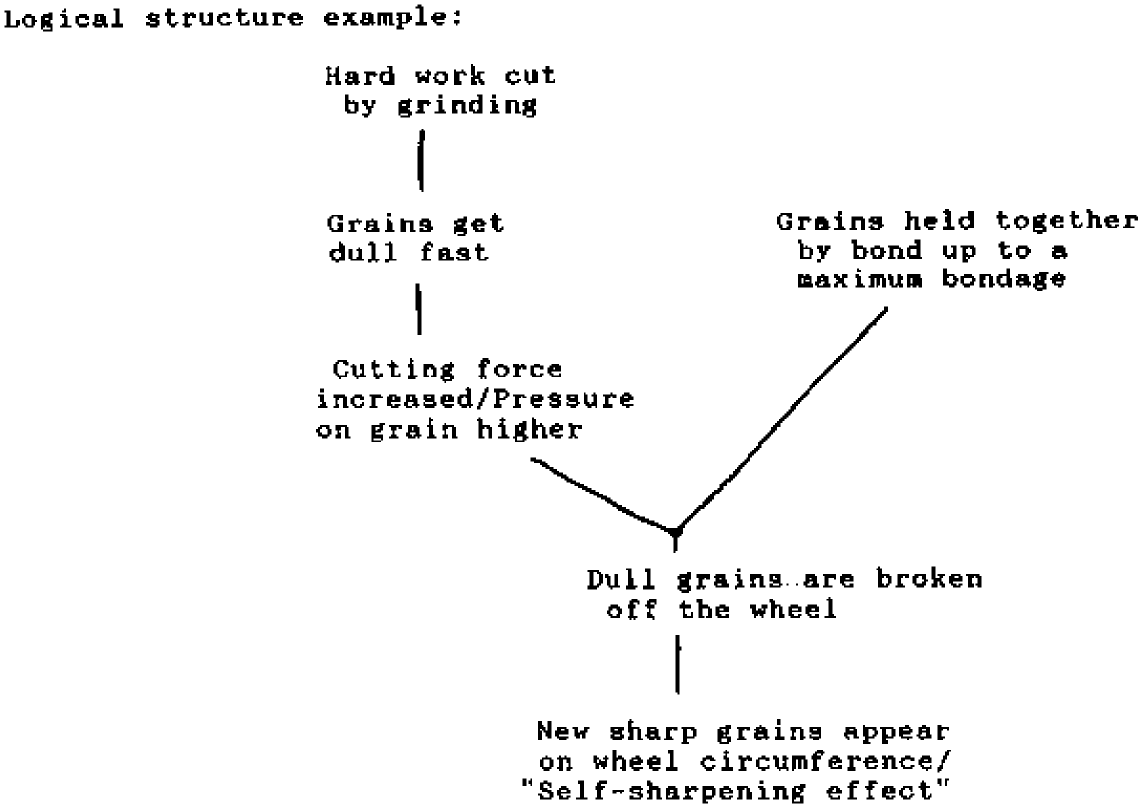
The distinction between AND and OR connections is like that in logic control circuits. If the effect can occur only when both causes act simultaneously, there is an AND−connection, as is the case here.

The rule for using the connecting lines states:

For AND−links, bring the lines together at a point, so that one line enters the effect box. For OR−connections, have the lines enter the effect box separately.

The true value of such “puzzle” style exercises lies in the fact that trainees can concentrate on making connections and searching the overall context, freed from the distracting requirement to formulate the statements themselves. A survey on job requirements asked German employers which abilities in their opinion needed urgent improvement. Most accorded top priority to the “ability to think in context”. Establishing links between a number of new phenomena within a technological context is a good example for the use of this ability.





Logical structure example:

As a continuous text this structure would be described like this:

When used for grinding hard workpieces the grains of a grinding wheels will dull faster. Since the grains are held to the wheel by means of a bond having a limited strength AND since the cutting pressure onto the grain will increase with its edges getting more dull, the grains will ultimately break off. Like this they give way to new sharp grains at the wheel circumference. Since this happens by itself this is called “self–sharpening effect”.

c) Features of logical structures

The system of logical structures for discovery learning exercises is suitable for any topic based on cause–effect linkage. These are self-evident in all fields subject to a hierarchy of rules, like science, electronics or pneumatic controls, but in everyday jobs like drilling or bending the hidden logic tends to get forgotten. The logical structures are there, but instructors do not use them to make trainees think and infer new links for themselves. Opportunities for trainees to discover new information for themselves are not exploited in training.

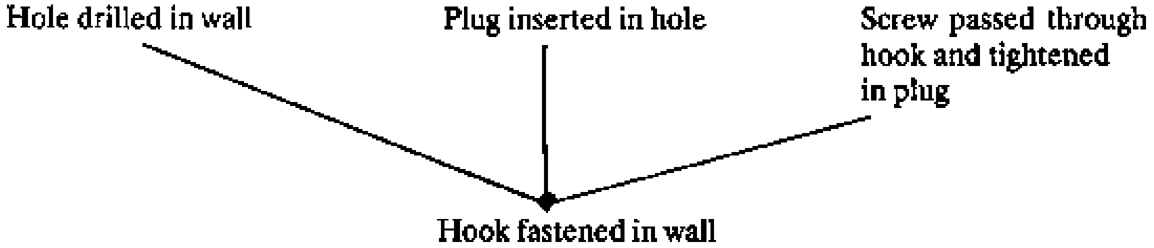
1) Chronological order is not the same as logical order

Developers encountering logical structures for the first time often confuse them with time–related sequences like skill or job sequences. A cause–effect link may follow a time pattern, but in most cases it does not.

For AND–connections in particular, the vital point is that all the necessary conditions should be satisfied at the same time.

Example: Job sequence for fixing a hook in the wall

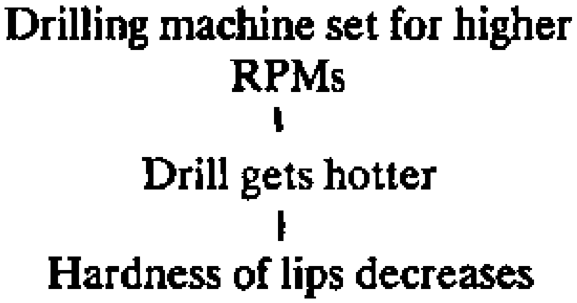
1. Drill a hole in the wall
2. Insert a plug in the hole
3. Pass a screw through the hook and put it into the plug
4. Turn the screw until it is firmly secured.



Logical structure for the same process

This example illustrates the main difference between a chronological sequence of working steps and the cause−effect links of logic structures. The three AND−statements have to be fulfilled before the result is achieved. The order in which they have been prepared is unimportant for the logical structure; all that matters is that all three are fulfilled at a certain time.

Some logical structures are identical with a time sequence, but they are the exception, not the rule:



The point here is that temperature increases and hardness decreases not one after the other but at the same time. The media developer must consciously divorce himself from the "first this, then that" approach.

Order is very important in a job sequence. Trainees' logic can also be called on in a time sequence, for example by mixing up work steps. Logic dictates that one cannot insert a plug before there is a hole.

This feature is utilized in the planning exercises attached to job sequences, where trainees have to plan working steps in correct order without having seen someone do the job or had the job described to them.

2) Texts must be digestible and specific

It is commonly accepted that items of information need to be limited in size in order to make them digestible. There is, however, a sobering experience ahead for every media developer who has written a number of information sheets and thinks he can easily do the same with logical structures. Much more time and attention is required to select wording that links a statement unambiguously with the next statement or statements in the chain.

A single abstract word creating ambiguity and vagueness can create an avalanche of misinterpretations. It can act as an irritant, preventing the group from finding the solution.

A word like "effects" or "changes" is not clear, since it can mean change in more than one direction. Lack of concreteness in the wording can make all the difference between a successful try−out and a flop.

Since trainees discuss the meaning they allot to a confusing or vague word or to ambiguous detail in an illustration, it is essential for authors to watch trainees closely during first try−outs. A discussion between trainees and authors is the most effective tool for improving a draft.

The use of illustrations is generally a precondition for compressed presentation of a context. Graphics consume less space and are more effective in setting the framework for a topic. Using a reference question helps in this direction, too.

In general, the graphics are part of the overall information. The text addresses very specific details of the illustration; this is why labels help to link the text with the pictorial elements. The labels show up both in the graphics and in the related text passages.

Without interaction between verbal and pictorial components of the overall information, the hidden structure would be much more difficult to decode (and hence inappropriate for discovery leaning).

Another reason why labels are vital in discovery learning material is that without them the names of all the parts would need to be known before the single statements could be understood. Using names and labels side by side means that the working principle of a mechanism or process (illustrated by graphics) can be understood even though the trainee has no idea what components are called. (He may of course learn the names in the exercise).

d) Features of learning with logical structures

Since it is essential to ensure direct availability, the tasks must be part of the trainee handouts. The following page demonstrates a task layout allowing use of the material by groups of some 4 to 6 trainees. One of them uses a sharp−edged ruler to tear off each statement strip separately. The lettering is large enough to be legible for a small group when the strips are placed on a table. Since strips are arranged and rearranged on the table surface, no special equipment is needed.

The advantage for the instructor is that he has no trouble with distribution of the material, since the trainees have it in their handout and retain their groupwork solution as an information sheet.

The text information promotes careful reading; it is not sufficient to read the verbal chain. Trainees have to dig into the conceptual meaning of the given text items in order to discover potential relationships between them.

The behavioral pattern is as follows:

The cards with the respective statements are placed randomly on the table. The first step is careful silent reading of each statement by the group.

One of the more daring or self−confident members of the group will then start shifting the cards to express his opinion.

The arrangement of the cards tells the others what he thinks about the interlinkage (beginning of group mental interaction).

The others will think carefully about his “overall statement” and start to react. This is the moment when talking, comments and quarreling commence.

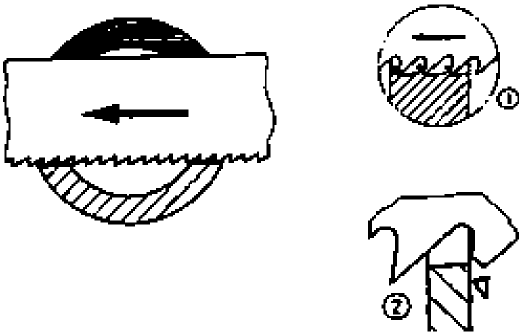
Other group members start making modifications here and there, usually justifying changes by argument and reasoning.

This heats up the discussion. More members are drawn in; subgroups and coalitions sometimes form.

TEETH BREAKAGE – SAWING

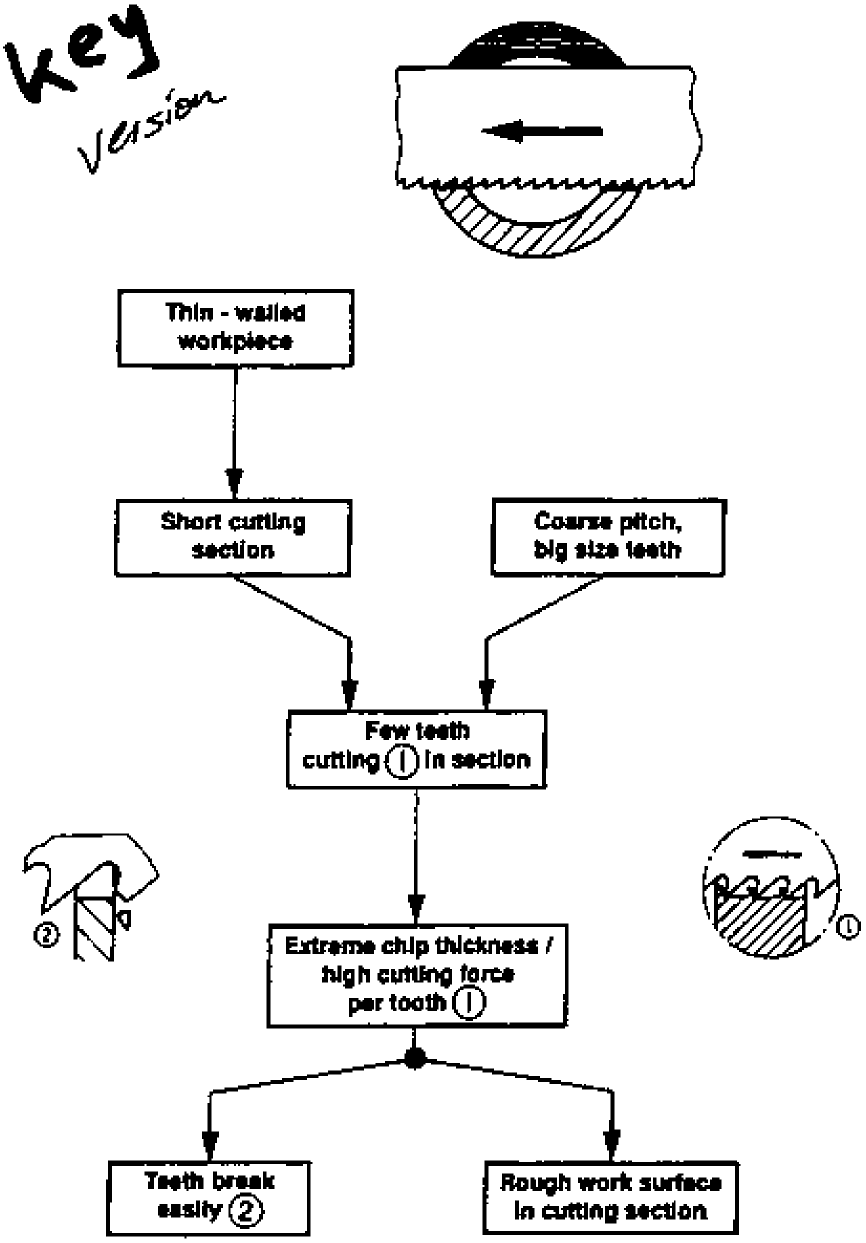
Task

as trainee - handout version

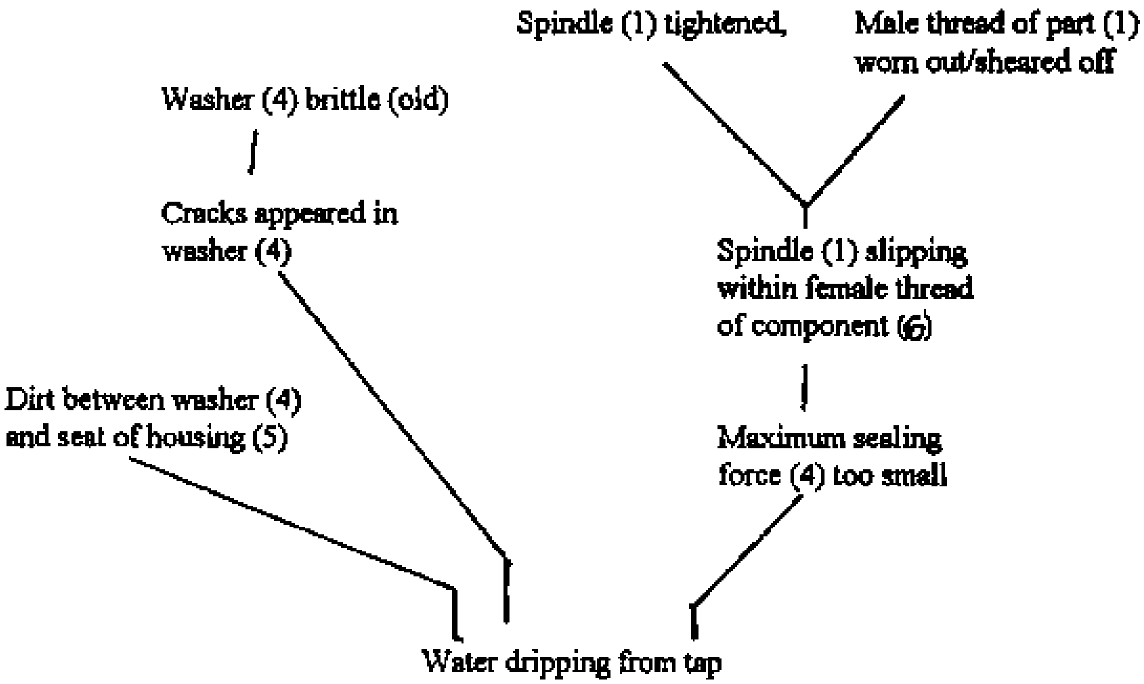


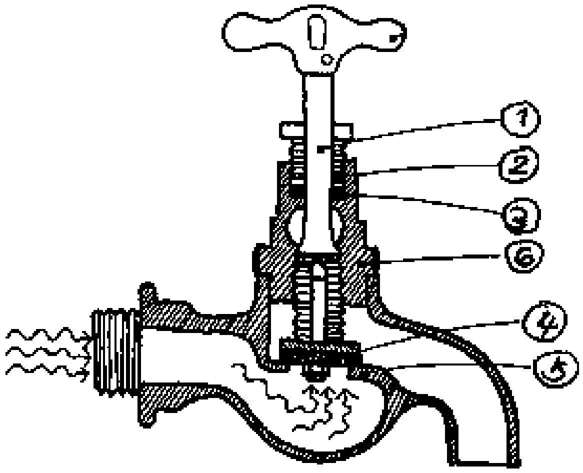
Teeth break easily (2)	**Extreme chip thickness/ high cutting force per tooth (1)**
Coarse pitch, big size teeth	**Short cutting section**
Few teeth cutting (1) in section	**Rough work surface in cutting section**
Thin – walled workpiece	

key version



TEETH BREAKAGE – SAWING





A majority agrees on a final version and the instructor is called in for comment or confirmation.

The superiority of this means of communication as compared to continuous text becomes obvious with technical details involving presentation of multiple causes and effects.

The essential differences from continuous text learning are that: The language barrier is lowered through

– use of pre–formulated statements;

– reduction of the total volume of verbal information to an absolute minimum;

– small cause–effect steps in a chain of brief statements, clearly referred to labelled details in the graphics;

– use of line symbols to denote relationships between statements, allowing AND statements to be distinguished from OR statements in branched links.

EVALUATION CRITERIA FOR DISCOVERY LEARNING OF LOGICAL STRUCTURES

A) for text information:

1. Can the statements be linked in a linear cause–effect chain or via AND– or OR–connections? Has confusion with a chronological sequence been avoided?

2. Is the chain of statements complete (no missing steps causing too large a gap) and have excessively wide steps been avoided?

3. Are statements short, legible and unambiguous/concrete? Are steps related to a labelled illustration or inferrable by the trainees?

4. Is the total number of statements no greater than 8 (5 to 7 statements most appropriate)?

B) for graphic information:

1. Does the illustration make the topic clear, with no risk of ambiguity?

2. Are essential details labelled for cross–reference to the linking text?

e) Hints for the media developer

1. Avoid **<u>vague or abstract statements.</u>**

A statement like “Part X affected” does not specify how.

Vague description: **Specific statement:**

position changes	part X moves to the left by 0,5 mm
good surface	surface roughness reduced to Ra = __
easy cutting	formation of continuous chips
valve reacts	valve B opens slowly

2. Do not **omit steps and do not make steps too wide.**

The completeness of the steps and manageable size of the items of information are decisive for successful discovery learning.

RPMs of drill increased

Tool life shortened

The above link is correct, but not self−explanatory, since there are several missing links which would specify the overall connection:

RPMs of drill increased

More heat generated
at cutting lip/
temperature increase
at cutting lip

Decreasing hardness of tool
material

Tool life shortened

3. Make sure there are enough **labelled illustrations and labels referring to particular details.**

Whenever possible and necessary, use labelled illustrations which

- make clear the overall context of an issue or topic and
- establish a close link between text passages and details of the illustration.

Assemblies of mechanisms, process and circuit diagrams and flow charts illustrating sequential stages are typical graphic information needed for logical structures.

4. Do not use **linear structures for topics which really have a branched structure**

Inexperienced media developers will develop linear structures and later discover that the structure is not actually linear but needs branching.

Most technical topics have a non−linear structure, since there are usually links between two factors causing a single effect (mostly AND−connections) or one factor causing two effects (one often desired and while the other is unwanted and has to be tolerated).

Trainees likewise first try to find a solution by arranging the cards in vertical order. They are accustomed to reading continuous text similarly arranged in a linear sequential order.

The media developer will experience a wide variety of structures when entering a new curricular field. Each topic is different and the combinations of both AND− and OR−connection in the structure are unpredictable.

One rule must, however, be observed whenever a draft produces a structure with double branching.

In an AND–connection, for example, double branching means that two causes generate two potential effects:

Double branching is ambiguous and confuses trainees trying to find the structure; it must be avoided.

The simplest remedy is to cut out one of the effects.

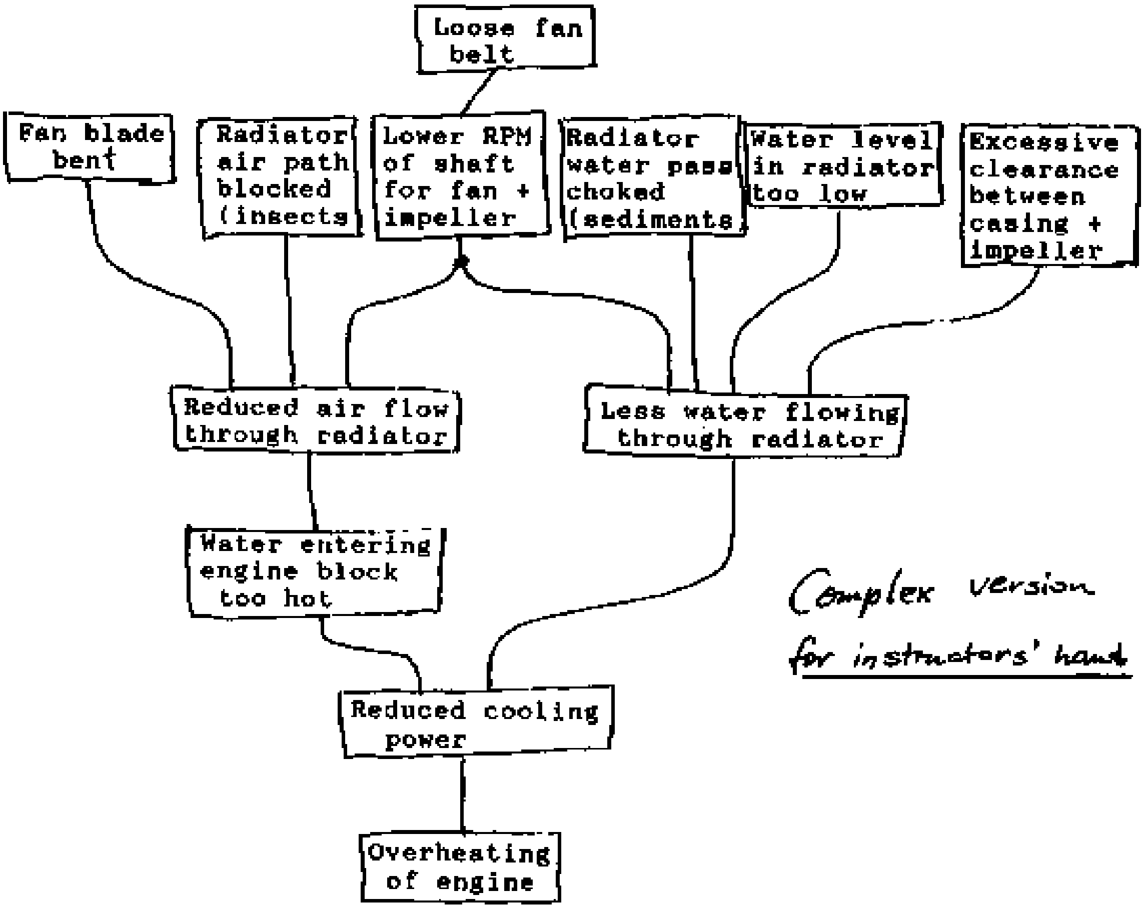
e) COMPREHENSIVE VERSIONS OF LOGICAL STRUCTURES

During the drafting stage the number of statements can and should be higher than the intended final number. The complex and comprehensive version which results is very helpful for the instructor and can be employed as handout material for instructors who will be using the trainee version. The comprehensive version provides background information for the instructor in case the trainees ask further questions (examples shown below).

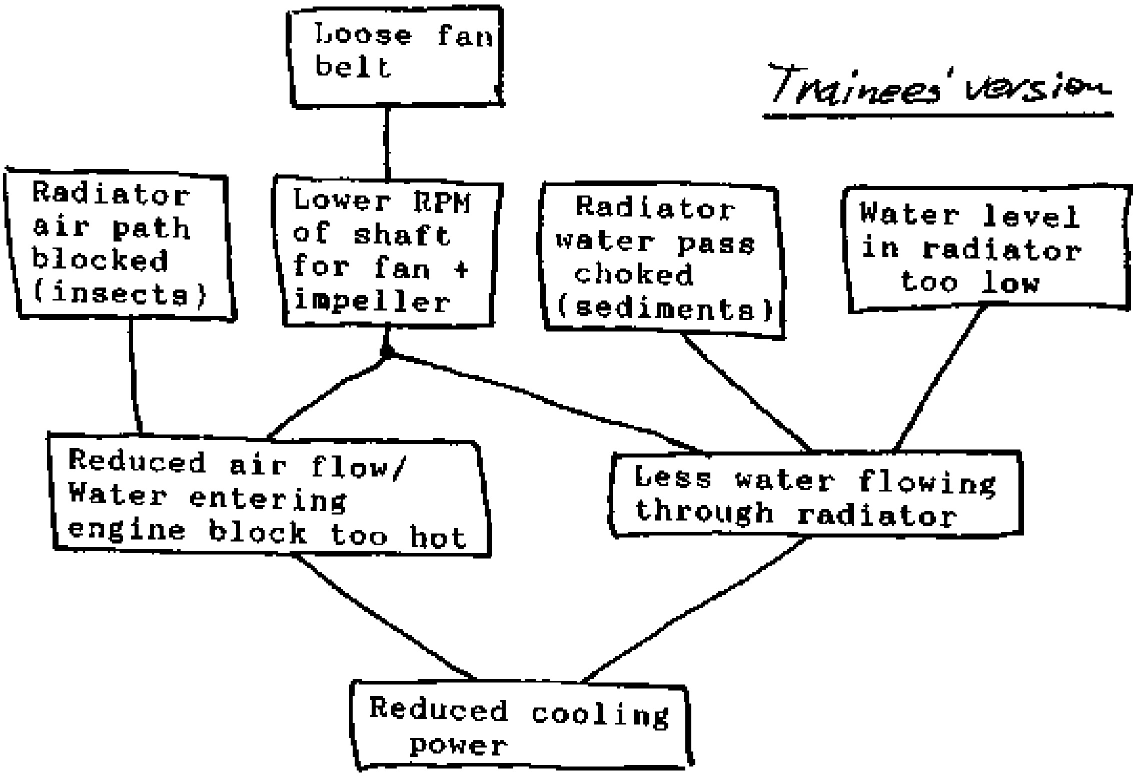
The logical structures in the comprehensive version provide highly condensed information which is more precise than a continuous text. AND– and OR–connections provide a unique means of distinguishing detailed information about interlinked processes. From comprehensive logical structures of this kind, it is quite easy to derive troubleshooting charts covering a wide range of causes for different types of faults.

Once the developer team has approved the logical connections in the comprehensive draft version, the media developer has to decide which elements of the complex version will be selected for the trainee version. Depending on the complexity of the comprehensive version, two simplified versions for trainees can be derived and used in trainee try–outs.

OVERHEATING OF WATER COOLING SYSTEM

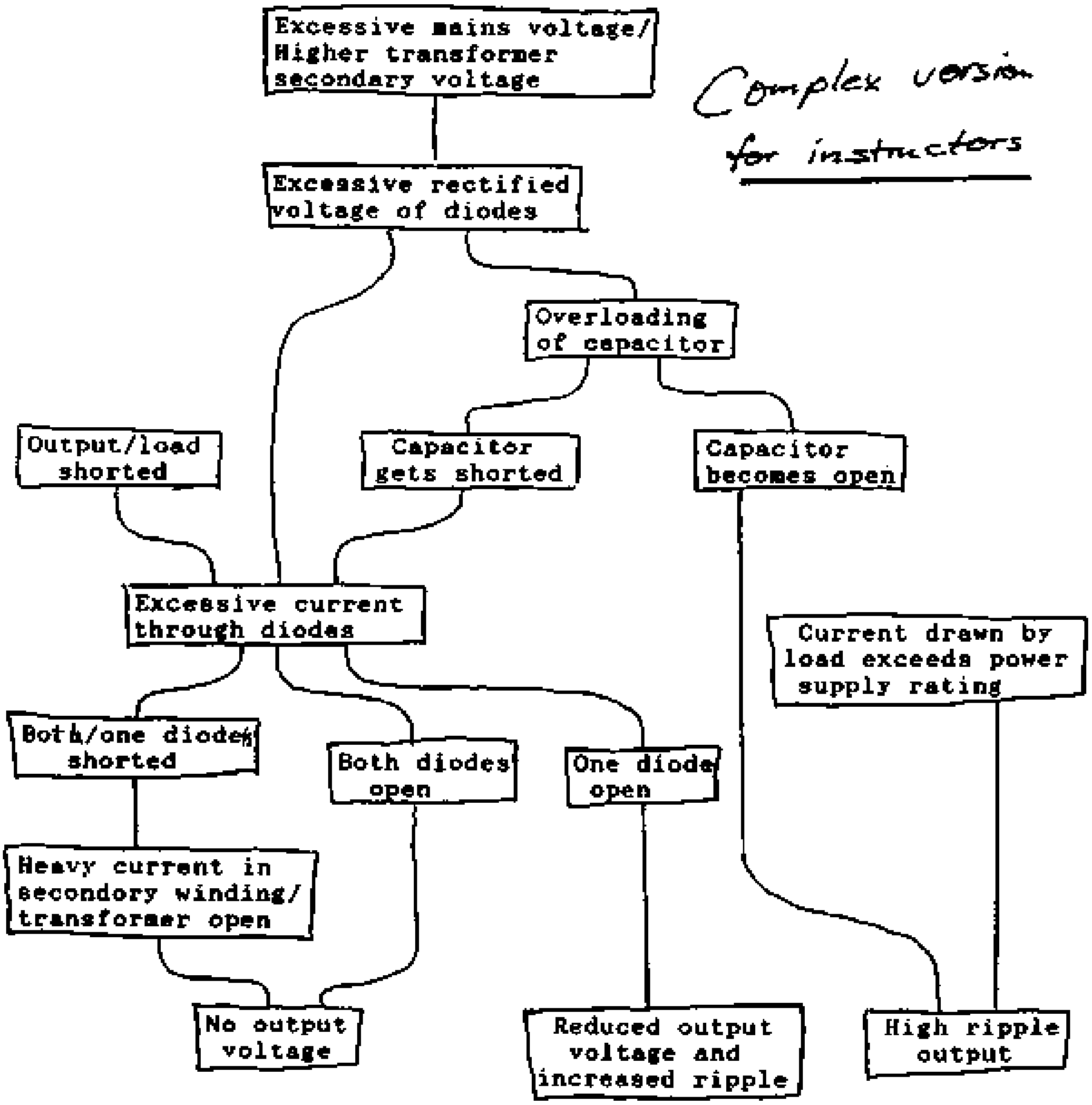


Complex version
for instructors' hand

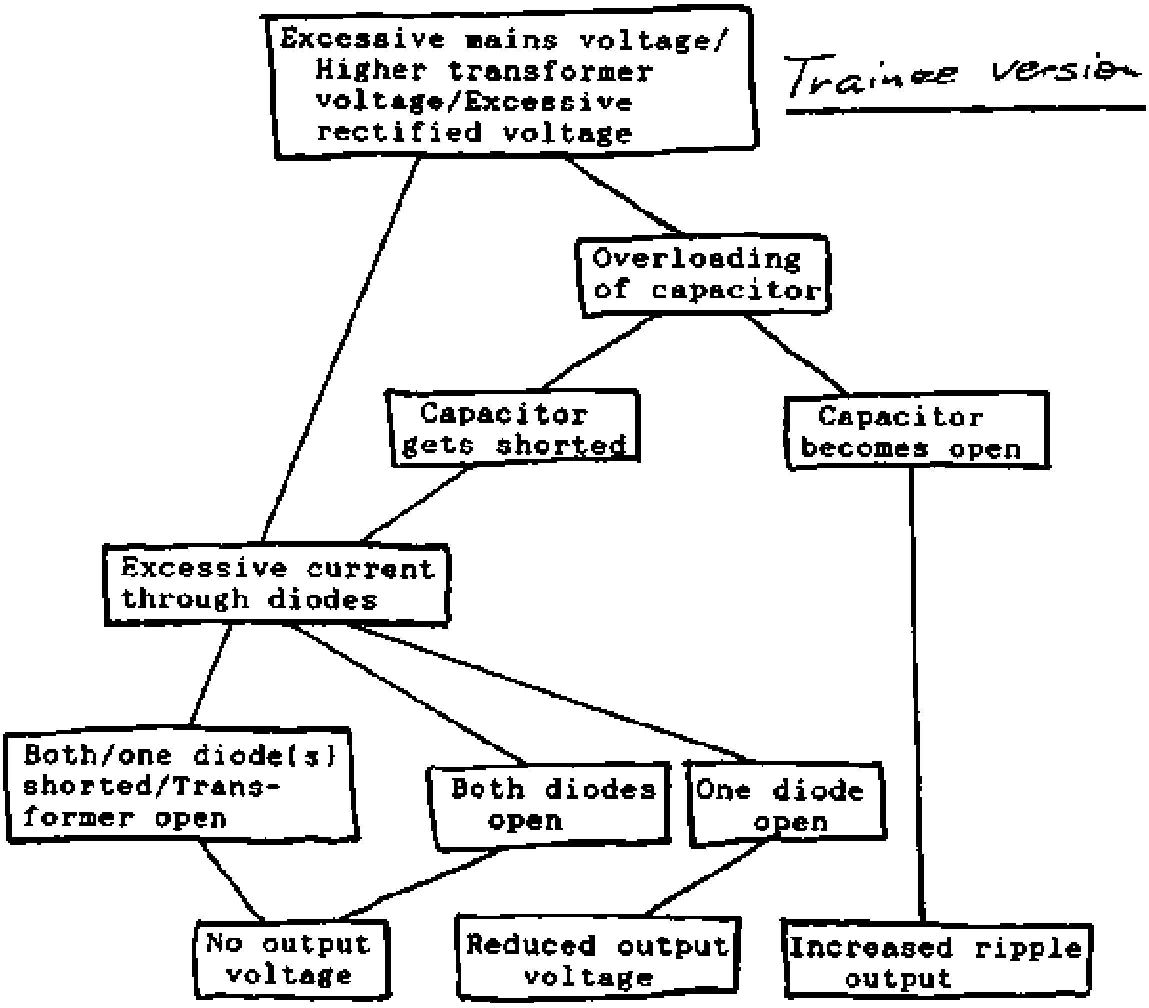


Trainees' version

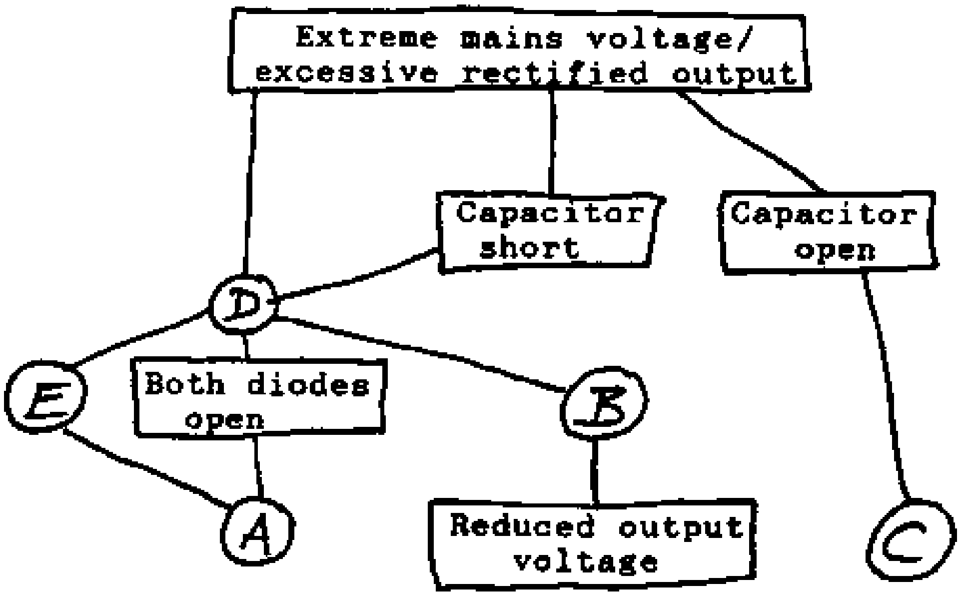
POWER SUPPLY DEFECTS



Complex version
for instructors



Trainee version



DERIVED MATCHING ITEM

A = No output voltage
B = One diode open
C = Increased ripple
D = Excessive current through diodes
E = Transformer open/one or both diodes shorted

HORIZONTAL MILLING ARBORS

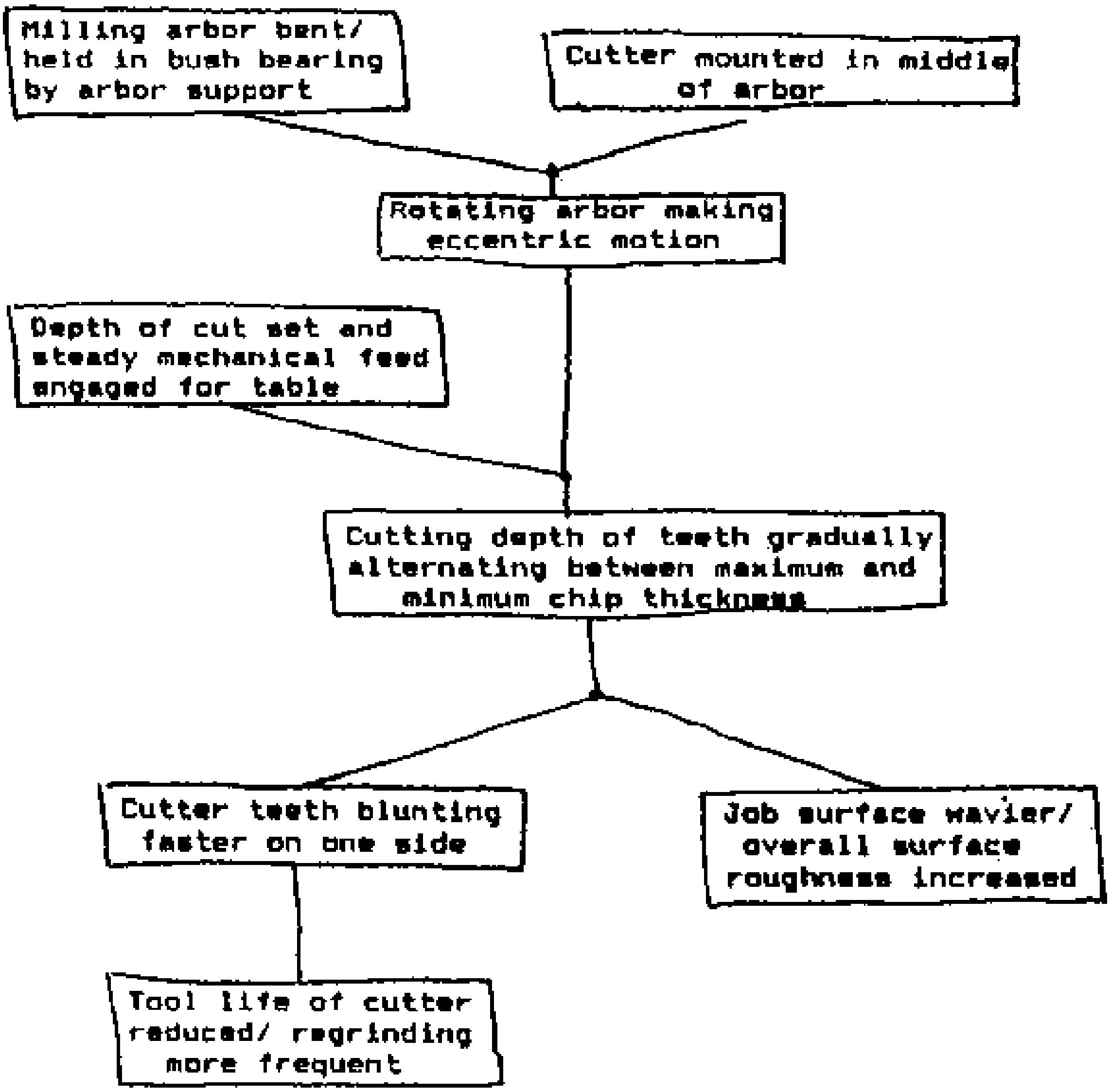
Horizontal milling arbors (Fig 708) are used to hold and drive cylindrical, slotting, side and face, slotting and form willing cutters, which have through holes of matching diameters.

Arbor diameters are standardised and are available for cutters whose bore diameters are 18, 22, 27, 32, 40 and 50 mm. The arbor shanks generally have ISO Tapers (Steep tapers, usually 1:3.429) The arbors are designated as ISO 40; ISO–50 etc. depending on their dimensions. See Page 339–a. The arbors have a taper shank and a flange (Fig 708 –A) which fit into the spindle nose of the milling machine. The flange of the arbor has o botches which fit the driving keys on the milling machine spindle nose.

The taper shank of the arbor locates the arbor in the matching tapered hole in the spindle nose. The arbor is secured in the spindle by a draw bolt. (Fig 709).

Spacing collars (Fig 708–B) are provided with each arbor. These are used to position and grip the cutter. Two of these collars are of larger size and are used as bearings which fit into arbor support (See Bearing bush in Fig 709) The cutter must sit smoothly on the arbor. While using spiral cutters, it should be ensured that the axial pressure is towards the spindle.

Another important consideration is that the cutter should be so positioned on the arbor that its distance from the spindle is was short as practicable. This is reduce the <u>bending forces</u> acting on the cutter during material removal.



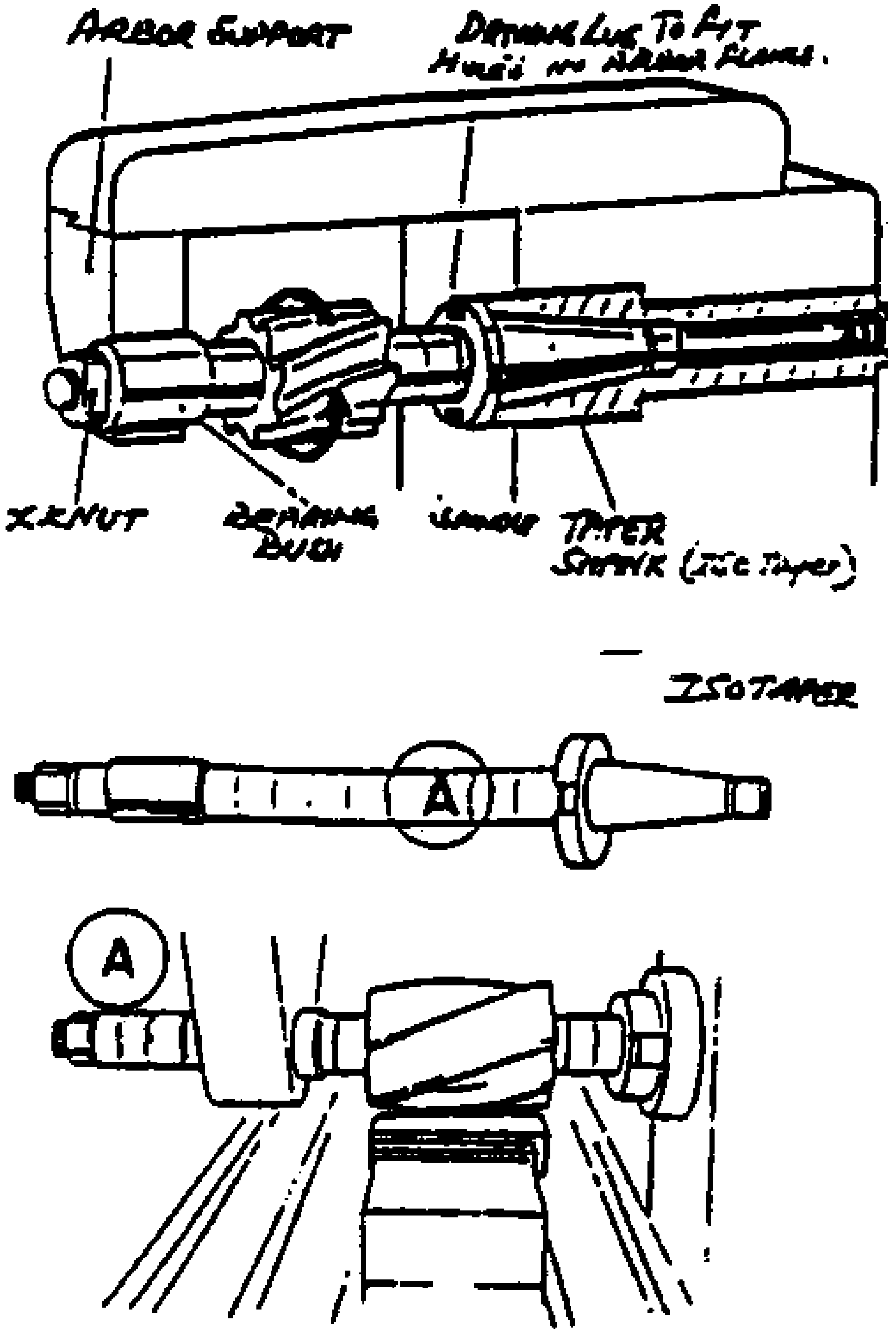
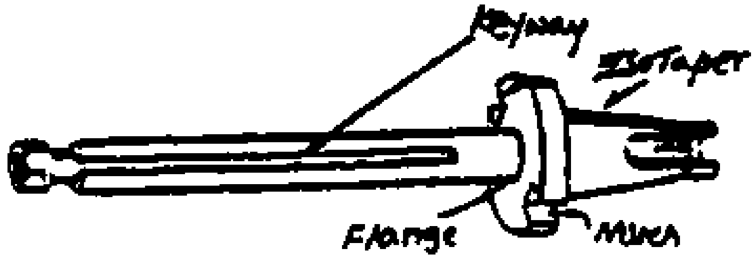


Fig 710-A: HORIZONTAL MACHINE ARBOR-Fy1

(B)

Fig 7a- SPACING COLLARS / BEAR COLLAR



f) Comparisons between conventional information and logic structures

The attempt to condense common book information by trimming it down to essentials can lead to a logical structure.

Whenever a paragraph in a book chapter describes the working principle of a mechanism or a process, the media developer should try to trim it down to essentials which can be interlinked.

The example “horizontal milling arbor” shows how a logical structure consisting of 8 statements tells more about the main factors affecting the way the arbor works than the book page. The media developer has to learn to ignore all non−related information.

Redundancy in trade theory books occurs most commonly with skill information; the text describes details of a skill sequence which are in fact learned automatically in the workshop.

Example: “The arbor is secured in the spindle by a draw bolt.” This statement would be justified if it addressed the principle of self−locking of cones depending on the taper angle.

“Two spacing collars are of large size and are used as bearings” − a statement which describes something a trainee will see as soon as he has to mount an arbor on the miller. Such a statement would make sense only if used to explain the bending effect of the arbor and the resulting dimensional effects on the workpiece, illustrating the role played by these bearings.

The following logic structure is confined to highly interlinked statements requiring a particular type of contextualized learning.

g) Matching test items/tasks derived from logical structures

Once logical structures have been tested and evaluated they can easily be transformed into matching test items.

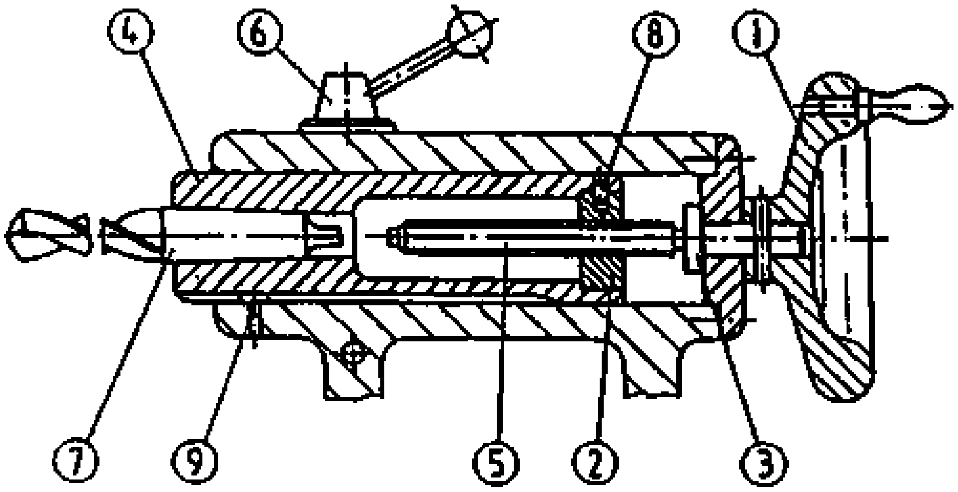
These items differ from all other matching−type items in that they are presented with the line−linked structure, leaving gaps to be filled with the related statements. The gaps are used as options. A minimum of four and a maximum of five options seems appropriate for the target group (see below).

h) The incomplete troubleshooting chart

The troubleshooting chart can be seen mainly as a spin−off from logical structures dealing with complex problems. Once a complex logical structure exists, the origins of several different faults can be traced by working back through the links towards the causes. The only new aspect is the formulation of symptoms.

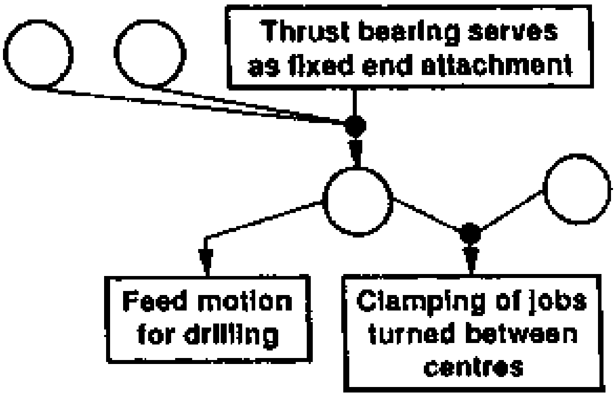
The distinction between faults/defects and symptoms may be unfamiliar to the media developer. The terminology is analogous to that used in medicine. Fever is a symptom of an illness but not the illness itself. Similarly, the unusually high temperature of a bush bearing is a symptom of a fault (e.g. lack of oil, breakdown of pressure build−up in the oil film etc.). Symptoms can be recognized by means of sensory perception (i.e. seen, heard, smelt or felt).

TAIL STOCK DESIGN



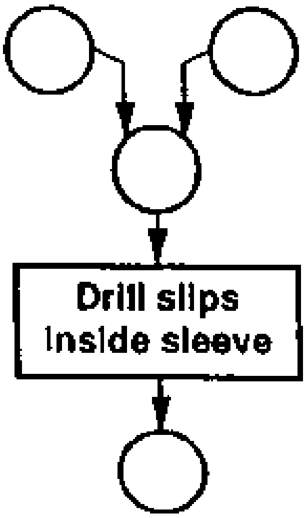
Match I

A = Nut ② and sleeve ④ moved in axial direction
B = Sleeve clamped by lever ⑥
C = Nut ② and sleeve ④ locked against turning by pins ⑧ + ⑨
D = Wheel ① turns acme spindle ⑤

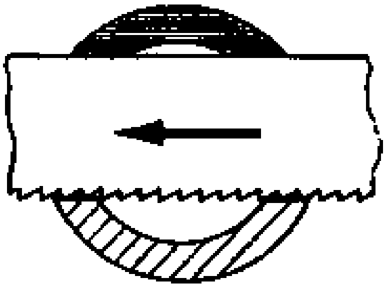


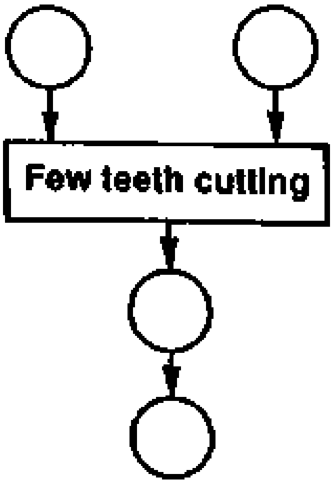
Match I

A = Morse taper requires cleaning / drill with proper shank needed
B = Taper shank of drill damaged / notched
C = Self - locking of drill not ensured
D = Taper shank of tail stock sleeve dirty



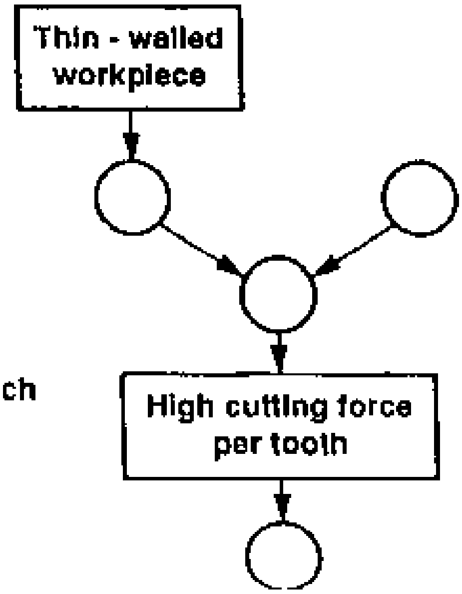
TEETH BREAKAGE – SAWING





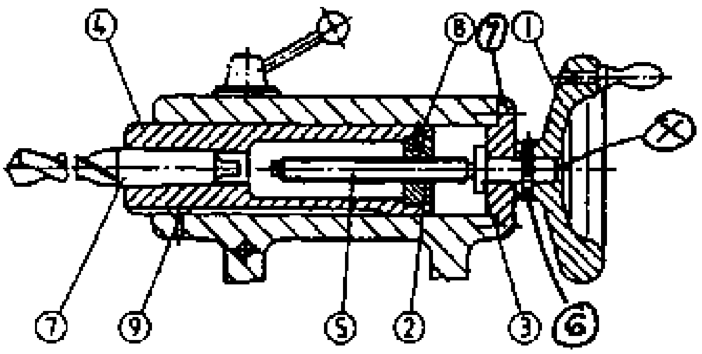
Match !

A = Extreme cutting force per tooth
B = Thin - walled work / short cutting section
C = High risk of tooth breakage
D = Coarse sawing blade / big size teeth

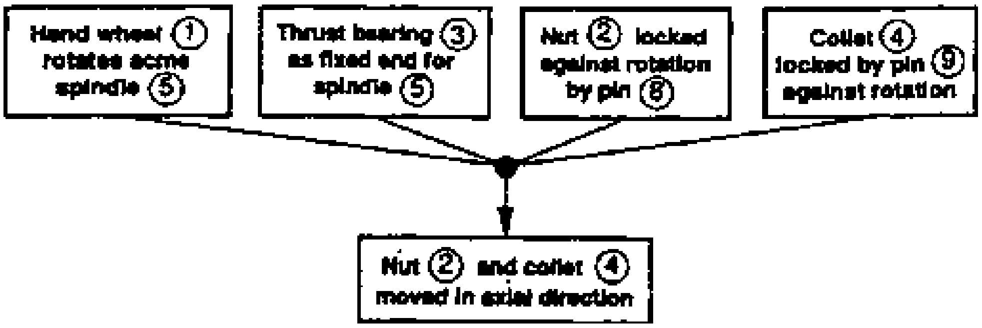


Match !

A = Very short cutting section
B = Teeth break
C = Few teeth cutting
D = Coarse blade with wide pitch



Logical structure



TROUBLE SHOOTING STRATEGY

Defective tail stock mechanism

Defect	Observable symptoms	Cause of defect	Remedial measures
Collet 4 not moving in axial direction in spite wheel 1	a) Collet rotates with wheel 1.	Pin 9 is sheared off or missing	Renew pin 9!
	b) Plate 7 is pushed off in axial direction while wheel 1 is turned.	Thrust bearing 3 not held by plate 7	Fix plate 7 firmly
	c) Spindle 3 rotates while collet 4 does not (visible at point X)	Pin 8 sheared off, nut 2 rotates inside collet 4.	Replace pin 8!
	d) Wheel 1 rotates, but spindle 3 does not (visible at point X)	Pin 6 sheared off, Spindle 3 can rotate freely	Replace pin 6!

Defect	Observable symptoms	Cause of defect
Collet 4 not moving in axial direction in spite of rotation of wheel 1	a) Collet rotates with wheel 1.	○
	b) Plate 7 is pushed off in axial direction while wheel 1 is turned.	○
	c) Spindle 3 rotates while collet 4 does not (visible at point X)	○
	d) Wheel 1 rotates, but spindle 3 does not (visible at point X)	○

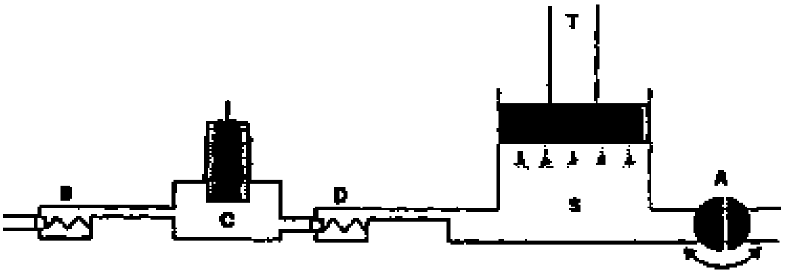
Task version

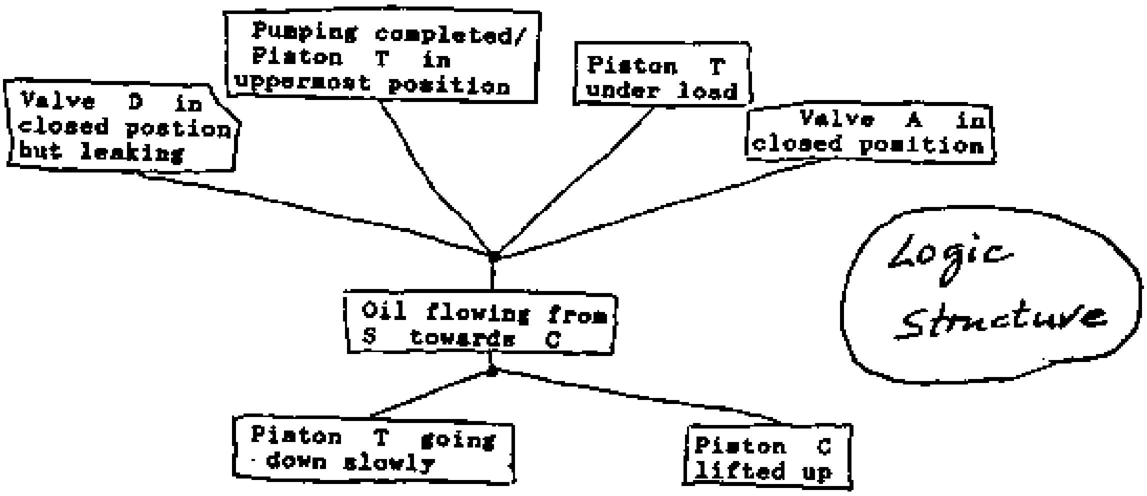
A = Thrust bearing 3 not held by plate 7

B = Pin 9 is sheared off or missing

C = Pin 8 sheared off, nut 2 rotates inside collet 4.

D = Pin 6 sheared off, Spindle 3 can rotate freely

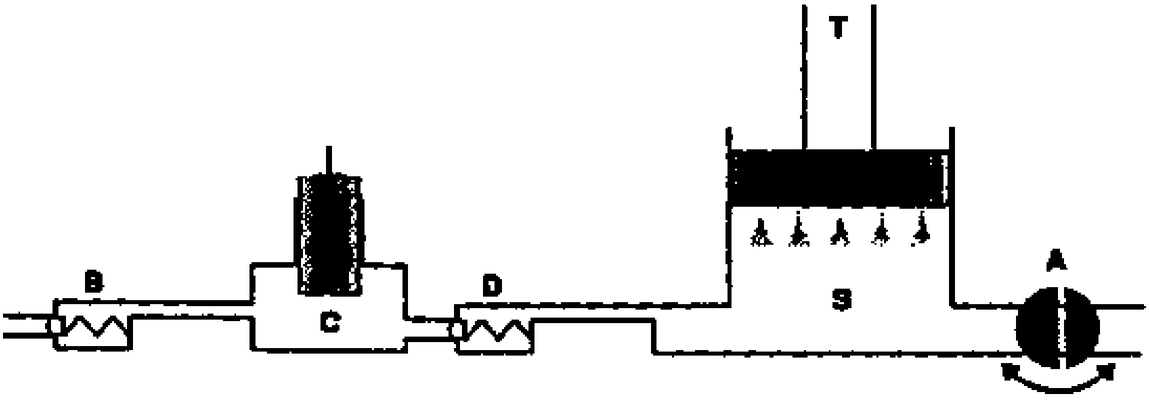




Trouble Shooting chart for HYDRAULIC JACK

Problems	Symptoms	Cause	Remedy
No lifting of piston C in spite of pumping action	No lifting in spite of quick pumping action	Valve A open Oil flows back through A	Close A!
	Slow lifting in spite of quick pumping	Valve B or valve A are leaking	Clean valves A and B! Renew seals!
After being lifted to top position the piston T lowers slowly when pumping is halted	While piston T lowers, piston C remains unaffected	Valve A is leaking	Clean valve A and exchange its seal!
	While piston T lowers, piston C is lifted	Valve D is leaking	Clean valve D and exchange its seal!

Key



Trouble Shooting chart for HYDRAULIC JACK

Problem	Symptoms	Cause
No lifting of piston C in spite of pumping action	No lifting in spite of quick pumping action	○
	Slow lifting in spite of quick pumping	○
After being lifted to top position the piston T lowers slowly when pumping is halted	While piston T lowers, piston C remains unaffected	○
	While piston T lowers, piston C is lifted	○

Task

A = Valve D is leaking, A is not	Clean valve D and exchange its seal!
B = Valve A is leaking	Clean valve A and exchange its seal!
C= Valve B or valve A are leaking	Clean valves A and B! Renew seals!
D = Valve A open Oil flows back through A	Close A!

For a doctor, it is essential that his diagnosis should be based on the symptoms of an illness. Similarly, an essential qualification for skilled workers dealing with troubleshooting is the ability to identify a fault by interpreting symptoms. Once the fault is clearly identified and the cause is linked to the symptoms, remedial measures can be planned. Troubleshooting charts can be used to train this strategic context.

The three columns “fault”, “cause” and “remedy” in the chart can be taken straight from the logical structure; it is the distinction between faults and symptoms which creates most difficulties for the media developer.

If a fault is immediately visible, the “fault” and “symptom” columns are effectively identical.

In some cases, a combination of several symptoms may provide the clue to the cause of a fault.

A fan running at reduced speed has a weakened magnetic field, due either to reduced feed current/voltage, to a partial short in its winding or to a leaky capacitor. The reduced speed can be a symptom for any of these faults. Further symptoms need to be detected in order to identify the (supposedly) single fault which is actually causing the speed reduction.

Special measuring techniques may be required, e.g. measuring current, measuring coil resistance or measuring leakage current in the capacitor.

A turning job showing a marked deviation from cylindricity is defective. The fault could be a taper shape, a barrel shape or eccentricity. If all the drawing specifies are tolerance limits for the workpiece diameter, the fault is the off−tolerance.

The cause cannot, however, be traced without determining the type of geometrical deviation. In this case, the geometrical deviations are symptoms indicating the type of cause for an identified fault.

If measurement reveals a taper shape, the tailstock needs adjustment. If it reveals a barrel shape, it may be necessary to use a steady. If the part is eccentric, the spindle stock centre may need cleaning. Additional symptoms are established to specify the general fault more closely, allowing systematic planning of remedial steps.

i) Comparative tables for discovery learning

Listing types of tools, machines or machine elements seems to be a favourite activity of metal trade media developers. It usually involves presentation of several graphics and a host of component names, with lecturing on all manner of details. It keeps the class busy for quite some time and demonstrates the instructor’s encyclopaedic knowledge. Tests commonly require trainees to memorize exotic details of odd types of tool, machine and process (preferably names and definitions).

Comparative tables of features of different types are useful only where there are obvious attributes permitting discrimination, so that some logic can be applied. Such tables then also provide a chance for discovery learning. This automatically trims the number of types to digestible size.

EVALUATION CRITERIA FOR COMPARATIVE TABLES

1. Do the options (types of equipment/components of an assembly/stages of a process) exhibit obviously contrasting details?

2. Do the options belong to a common context (e.g. several types of one class of tool or several stages of the same process)?

3. Are there a maximum of 6 and a minimum of 3 options (2 in exceptional cases)?

4. Can the statements the trainee is asked to match be linked unambiguously to one option (or the link be indicated if it matches two options)? Is wording concrete and specific?

5. Is the number of statements for matching higher than the number of options (preferably a minimum of 2 statements per option)?

6. Have graphics been used as options instead of texts wherever possible?

7. Have graphics been used for matching instead of text statements wherever possible?

This list of criteria might seem to herald a difficult procedure for designing such exercises, but this first impression is misleading. It takes less experience to design this type of discovery learning exercise than to design a logic structure.

In comparative tables the trainees can handle three to five options with up to five matching statements, i.e. some 20 statements in all. More statements are required than in logic structures, where any statement may potentially fit any position of the structure, yielding a larger number of options. With statements in a comparative table, the trainee has only to tally with the three to five options given.

Since many current packages already offer lists of types in their task/test item/assignment section, these can be used for initial screening. The first items eliminated are those which are too close to each other (minor or pseudo−differences).

The examples below illustrate the scope of change needed to convert a list of types into discovery learning material.

Example “Washers”:

A closer look at the many types listed (see example below) reveals that differing classifying attributes have been applied.

The best discriminative attribute is the basic working principle of the washers. Those meant for protection of work surfaces are listed next to those meant for locking the bolt joint.

Another class attribute of washers is suitability for rectangular surfaces as opposed to inclined surfaces.

A third distinction may be drawn between punched washers and machined (chamfered) washers. This aspect is least helpful for an understanding of essentials (table book details).

When designing a comparative table, one need include only those washer types which help to clarify the typical features of washers protecting the work surface as opposed to those meant for locking the joint. This reduces the number of types to 3. The tapered washer is eliminated and types which look different but employ the same working principle are combined in a single option (spring washers and toothed washer).

Options: A = surface – protecting type B = nut–locking with friction C = nut locking due to shape

The discriminative power of statements like the ones found in the original is questionable, because trainees have no clue which type they refer to. A statement like "prevents damage to the workpiece" is not specific because, it could mean denting or scratching of the surface is prevented or that the nut cannot loosen. The media developer must ensure better quality statements, meeting the criteria of specificity and non–ambiguity.

A true discriminative statement might read: "While the nut is turning, it must not scratch work surfaces". This excludes the nut locking types B or C.

The statements: "The sharp edges of the washer penetrate into the work surface when the nut is tightened" or "the washer is intended to increase frictional grip" would refer only to Type B. "Form fit is applied after the nut has been tightened" refers exclusively to C. "Surface pressure is reduced by distributing force over an area larger than the thrust area of the nut" addresses A only, as does the statement "Prone to slackening/loosening of the joint".

"Used for joints exposed to shocks and vibrations" is not unambiguous, since it relates to B and C. Its discriminative power can be enhanced by modifying it to: "Used only in exceptional cases where shocks and vibrations affect the joint"; it then addresses C.

The material is usually mentioned without setting a context for material selection. Here the material in context: "It is made of hardened spring steel" for B; "Very high ductility steel is needed for repeated use" for C or "It must be softer than the work" for A.

The key for a comparative table replacing this section of an information sheet could be as follows:

WASHERS – TYPES AND USES

At the end of this lesson you shall be able to

- **state the purpose of washers**
- **identify the types of washers**
- **state the uses of each type of washers**
- **specify the washers as per B.I.S.**

Purpose

It is a common practice to provide washers under the nuts in bolted joints. (Fig 1)

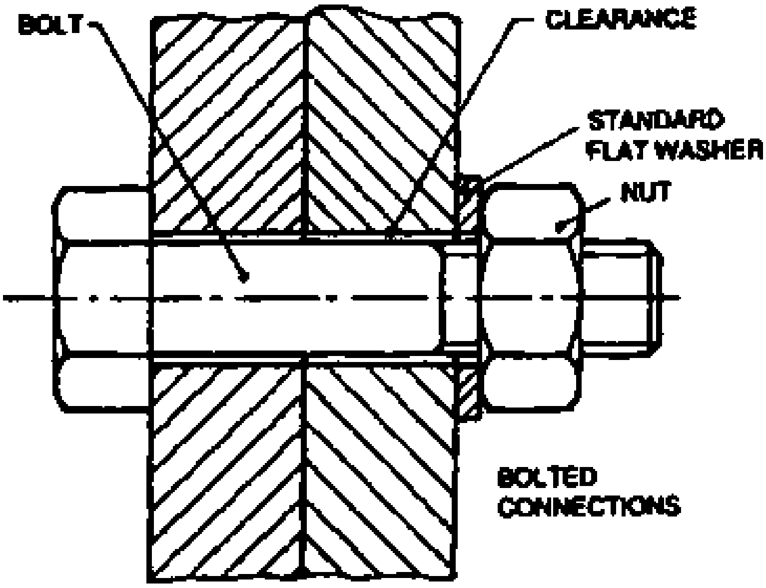


Fig 1

Washers help to

- increase the frictional grip
- prevent loosening of nuts due to vibrations
- prevent damage to the workpiece, and
- distribute force over a larger area.

Types of washers

There are different types of washers available. They are

- plain or flat washers
- taper washers
- spring washers
- tab washers
- toothed lock washers.

Plain or flat washers (Figs 2 and 3)

These washers are used for bolting assemblies with flat surfaces. The diameter, thickness and the bore diameter are proportional to the diameter of the bolt. (I.S. 2016)

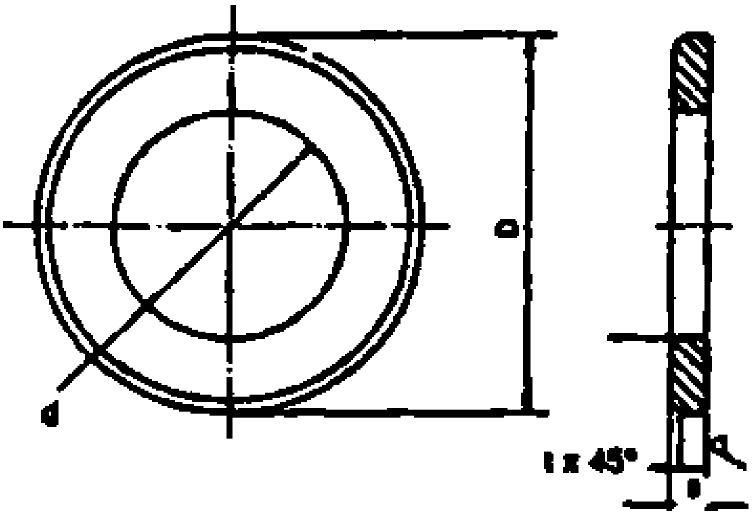


Fig 2

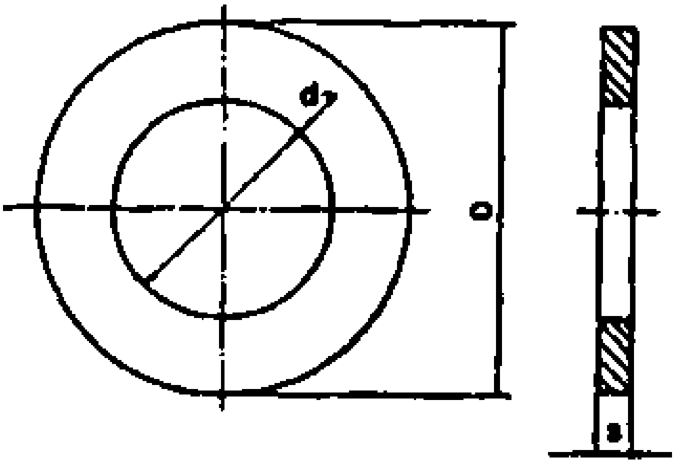


Fig 3

Plain washers are available as machined or punched washers.

Machined washers

These washers are used for assemblies using machined components. These washers are available with chamfer on one side or on both sides. They are heat–treated and ground.

Punched washers

These do not have chamfers and are commonly used in structural fabrication work.

Tapered washers (Figs 4 and 5)

These are used in structural assemblies with tapered surfaces like inside of I–Beams, chan etc. These washers help the bolt head or nut to square to the hole.

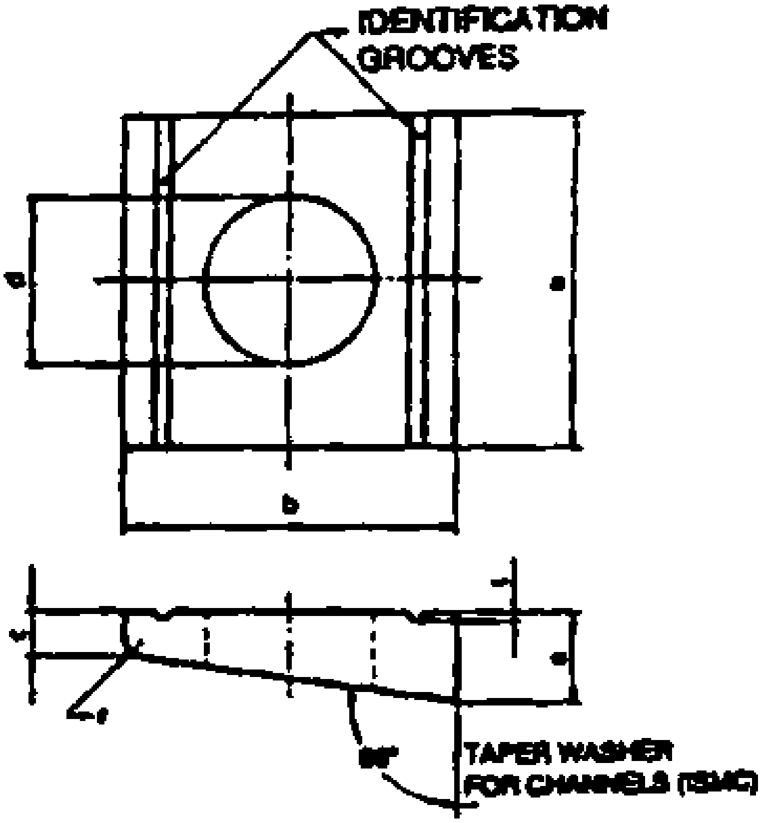


Fig 4

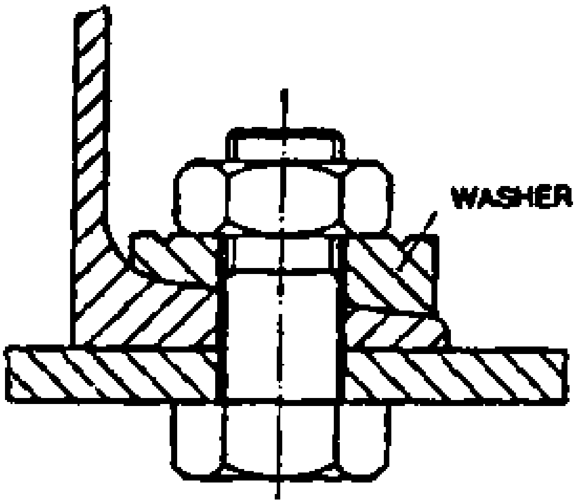


Fig 5

Spring washers (Figs 6 and 7)

Spring washers are used under nuts to prevent slackening of the nuts due to vibrations. They are made of spring steel, and when compressed they create tension between the bolt and the nut.

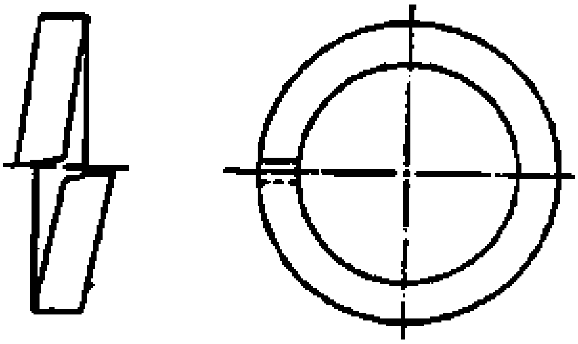


Fig 6

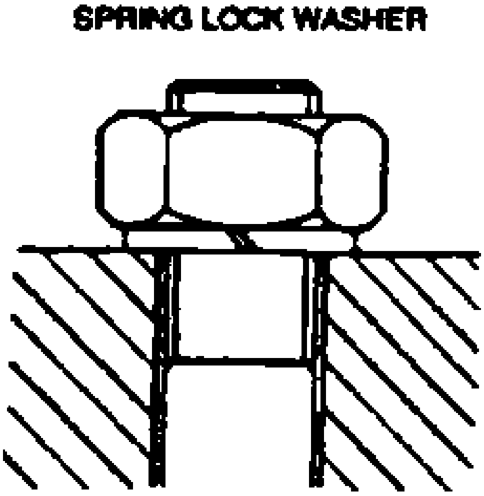


Fig 7

Tab washers (Fig 8)

These washers are used for locking the nuts.

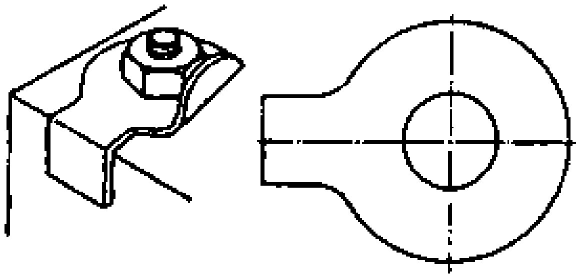


Fig 8

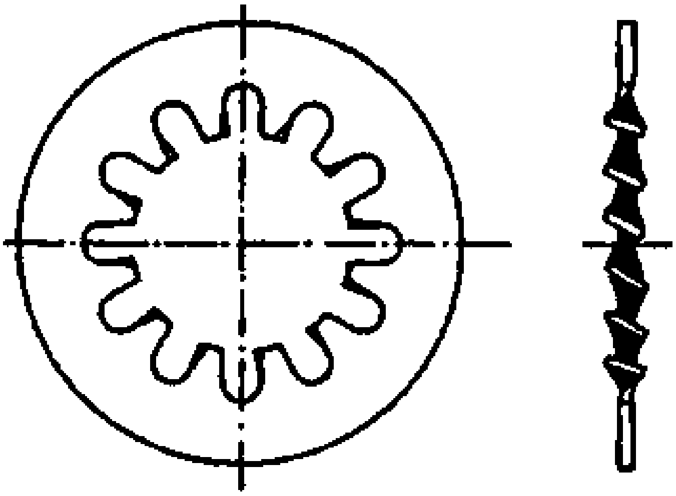


Fig 9

Toothed locked washers (Figs 9, 10 and 11)

These washers have serrations, cut and twisted. When placed between the nut and the assembly, this washer exerts friction on both the contacting surfaces. This prevents the nuts from slackening.

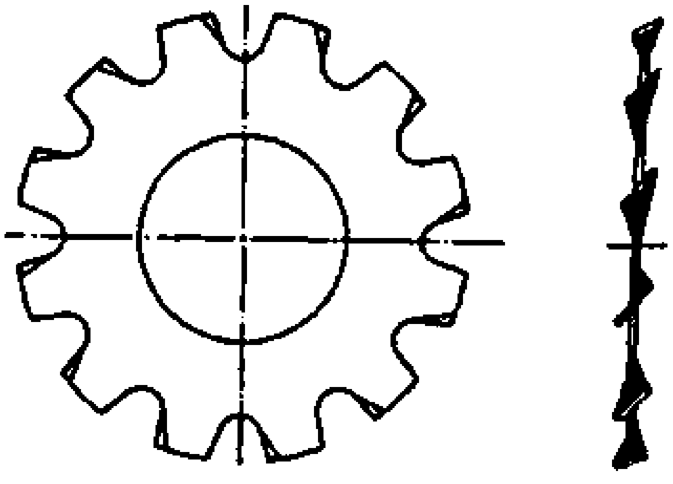


Fig 10

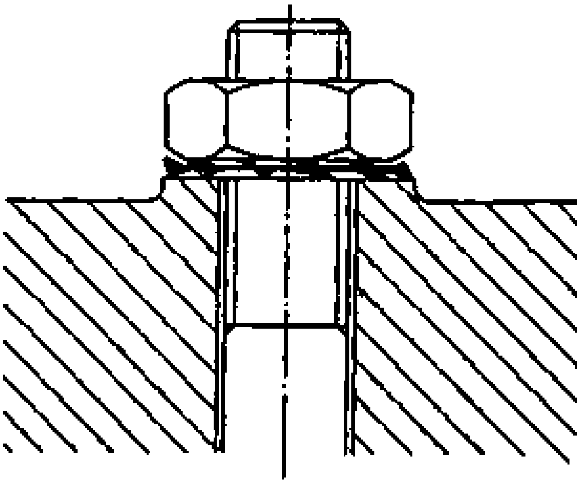


Fig 11

Specifications

The Indian Standard IS: 2016 – 1967 designates a washer by name, type, size and number of the standard and material.

Example

A machined washer of size 10.5 mm made of brass shall be designated as Machined washer 10.5 IS: 2016 – Brass.

Note

For detailed specification of different types of washers, refer to the following IS specifications.

Taper washer – IS: 5374 and IS: 5372

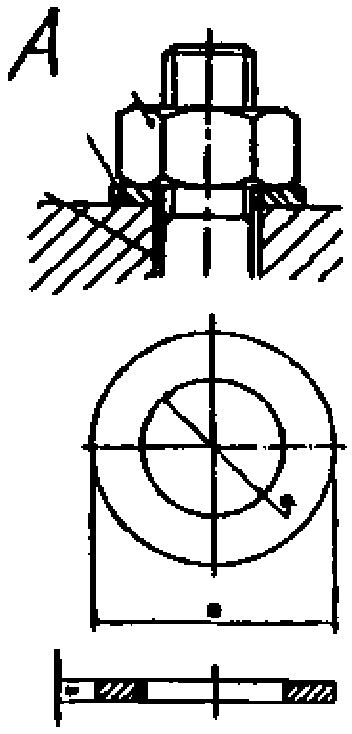
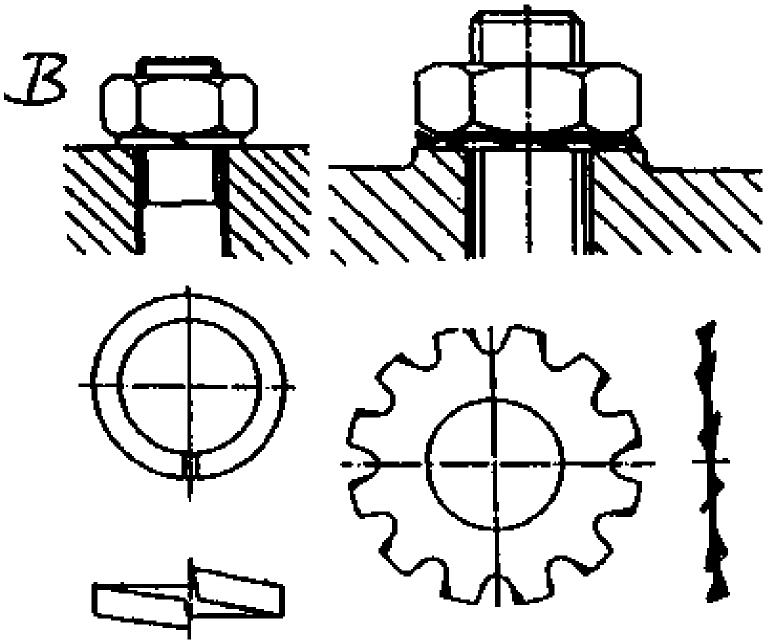
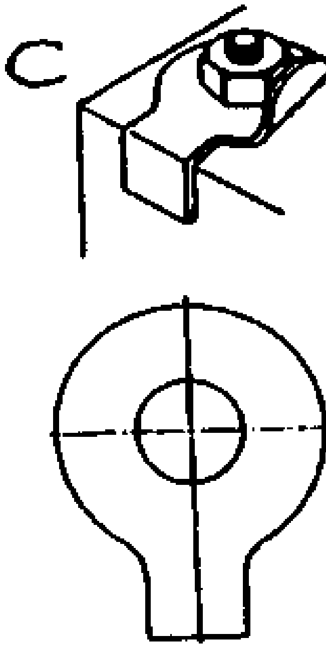
Tab washer – IS: 8068

Toothed lock washer IS: 5371

Plain washer IS: 2016

Original version

The key for the comparative table that is meant to replace this part of an information sheet could look like the following:

		
Surface pressure is reduced due to new contact area being bigger than nut thrust area	The sharp edges of the washer penetrate into the work surface	Bending creates a form locking effect for nut
Washers must be softer than work	Damage to the surface must be tolerated	Used only in cases of exceptional shocks/vibrations
Prone to slackening/loosening of nut	Increase in frictional grip is intended	Repeated use only possible with very ductile steel or brass
Is meant to protect the surface of work	Made of hardened spring steel	

8.09.2: STUB ARBORS

Stub arbor (Fig 711) are used to mount various types of cutters in the spindles of horizontal and vertical milling machines. The arbors held in the machine spindles by a taper (for location) and a draw bolt as in the case of standard horizontal arbors.

Stub arbors are available in different lengths with a range of diameters to suit cutters with bores of 1? mm, 22 mm, 27 mm, 32 mm, 40 and 50 mm diameter.

Three types of stub arbors are shown in Fig. 711. Type (A) is used to mount shell and mills and similar cutters. The cutter is pushed on to the arbor, so that the driving key of the arbor fits into a matching slot in the cutter. The cutter is then tightened on to the arbor using a locking screw. (Fig. 712 (A)) g 710: B: Horizontal Mk Arbor - Type B.

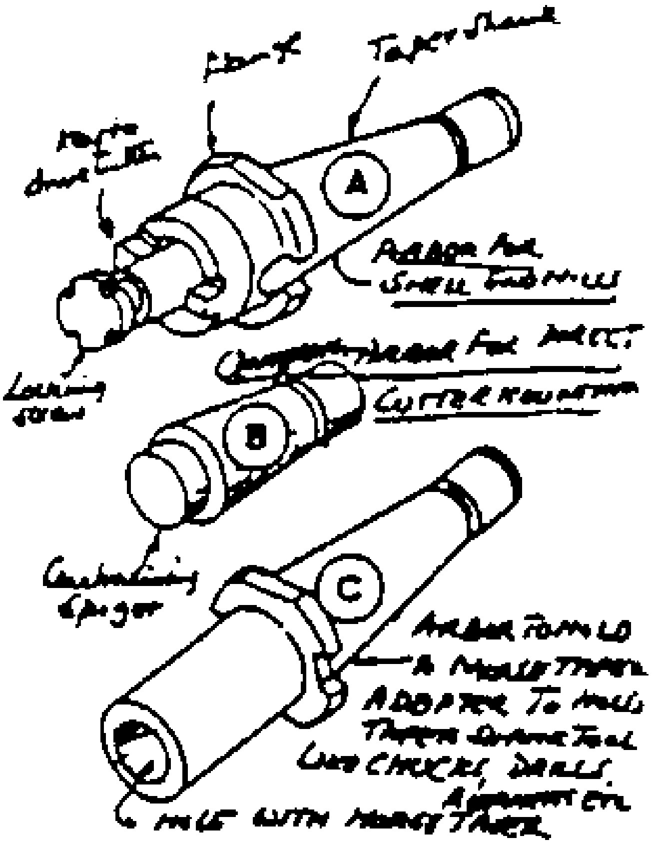
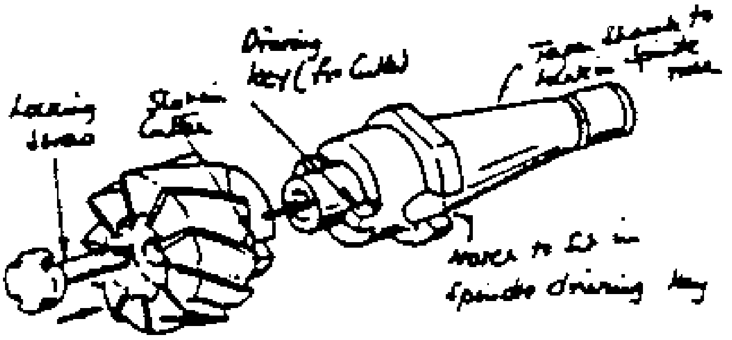


Fig 711: Stub Arbor Types



(A)
Fig 712: Mounting a Shell End mill on a Stub arbor

Type (B) stub arbor is used to mount large milling cutters directly on the spindles. It is made with a centralising spigot to ensure that the cutter is aligned properly with the cutter spindle. The cutter is fitted on to the arbor in such a way that the slots in the cutter locate in the driving keys of the machine spindle. The cutter is then located to the machine spindle by four screws. (See Fig 713)

Type (C) is an arbor to hold Morse Taper adopters. It is used to hold Morse Taper adopters. It is used to hold drills, reamers, chucks etc. which have tapered shanks with Morse Taper. They are also used for Morse Taper sleeves used to adopt one Morse Taper to a larger taper.

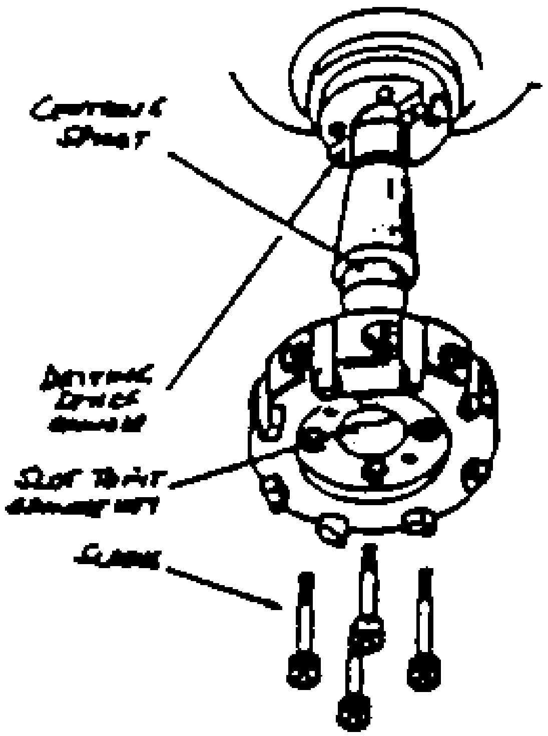


Fig 712. Direct Mounting of a Large Milling Cutter – The Stub Arbor (Centering Shaft) Aligns The Cutter Which Is Clamped Directly'

Type (A)

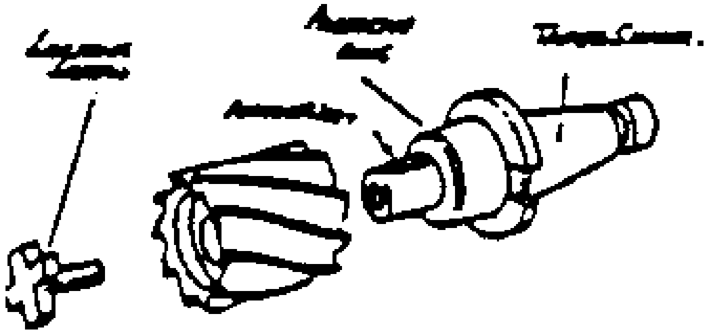


Fig 713 – An Stub Arbor To Hold Cutter Type 'A'.

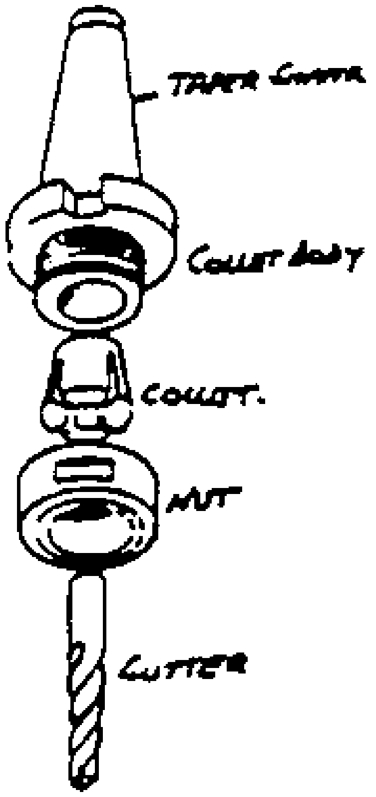
These are suitable for mounting cutters with through holes and a keyway. The cutter is mounted on the arbor with correct alignment and looked with the help of locking screw. The arbor itself is fitted in the machine spindle with the help of draw bolt.

8.09.3: COLLET CHUCKS (Fig 714)

Collet chucks are used to hold small cutters with straight shanks. The chuck is generally supplied with a set of collets to suit shanks of standard straight shank cutters. The collet chuck has standard ISO taper shank and is fitted in the machine spindle in the same way as the horizontal milling arbor.

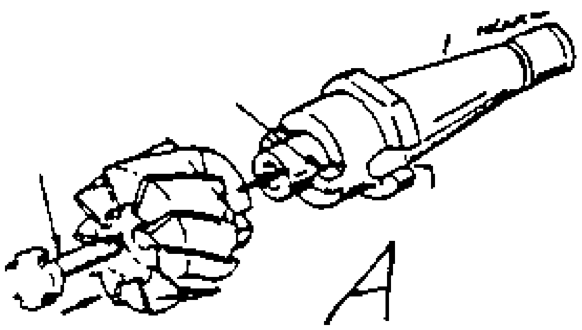
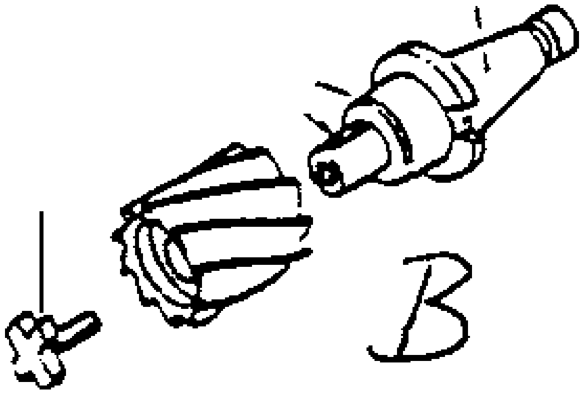
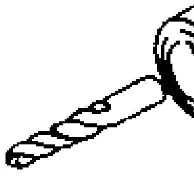
The cutter is mounted in the chuck as follows:–

(i) a collet of the sue size as the cutter shank is pushed into the chuck body.
(ii) The nut is screwed on until it just gripe the collet.
(iii) The cutter is then inserted into the collet
(iv) The nut is fully tightened using a special spanner supplied

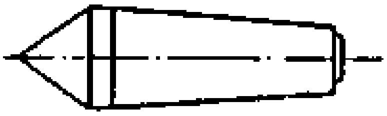
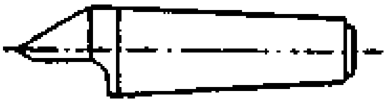
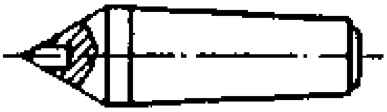
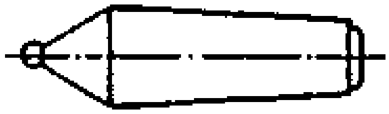
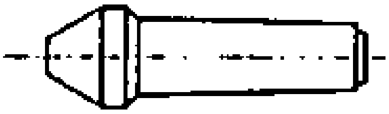
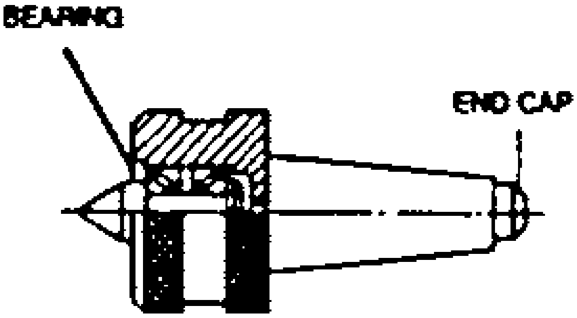
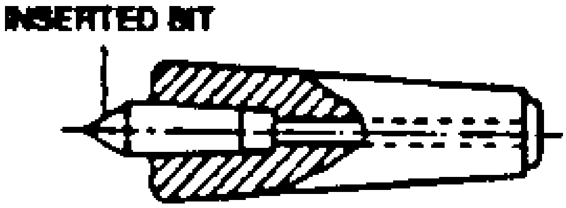
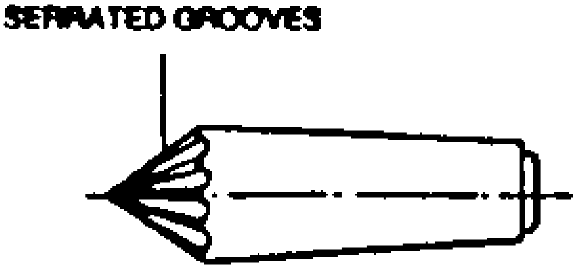
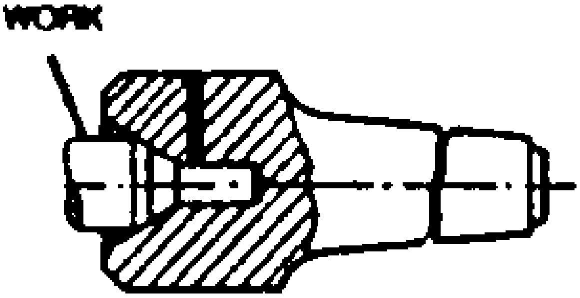


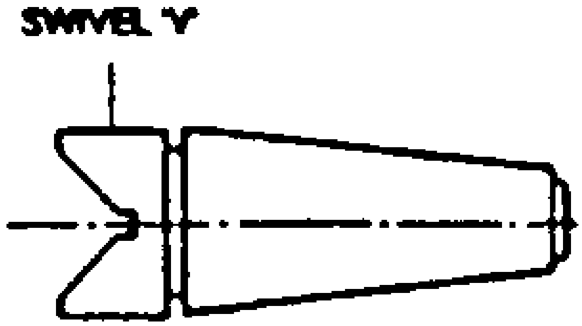
[illegible] : COLLET CHUCK.

Milling arbors

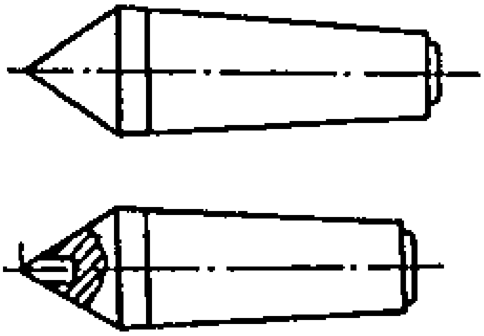
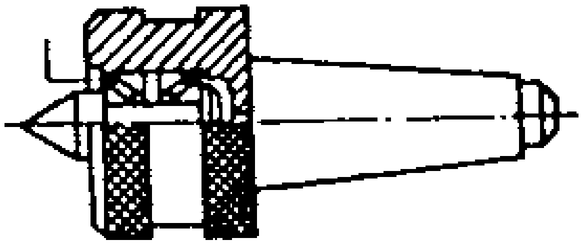
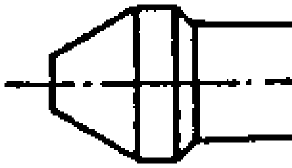
		
Driving key (y) fits, into cutter slot at cutter backside	Driving key (y) fits into slotted cutter bore	Clamping of cutt split collet (y)
Key (y) is needed for transmitting very big forces. Transmits forces very rigidly/no shattering effect	Due to its small distance from arbor center this key (y) shears off under heavy cutting load of big dia cutters	Cutting force is t Holds and drives (dual function)
The locking screw (z) prevents tilting of cutter during face milling. Strong bending effect on arbor prevented.	Locking screw (z) holds the cutter and prevents slipping off due to thrust effect in cutting	Tightening nut (z taper bore of arb
Central spigot (x) only holds cutter in central position, no driving function.	Central spigot (x) has dual function of positioning and driving the cutter.	A set of collets is of cutter shafts c
Provides rigid holding of face milling cutters with carbide tips	Can hold the same cutters that are used with long horizontal arbors.	Typically used fo or dovetail cutter

TYPES OF LATHE CENTRES

1 Ordinary centres (common type)		Used for general purpose
2 Half centre		Though it is termed as half centre, little less than half is relieved at the tip portion. Used while facing the job without disturbing the setting.
3 Tipped centre		A carbide or a hard alloy tip is brazed into an ordinary steel shank. The hard tip is wear−resistant.
4 Ball centre		Minimum wear and strain. Particularly suitable for taper turning.
5 Pipe centre		Used for supporting pipes, shells and hollow end jobs.
6 Revolving centre		Frictionless. Used for supporting heavy jobs and jobs revolving with high speeds. A highspeed steel inserted centre, it is supported by two bearings housed in a body. It is also called the revolving dead centre.
7 Insert type centre		Economical. Only the small high−speed steel insert is replaced.
8 Self−driving live centre		Usually mounted on the headstock spindle. Used while machining the entire length of the job in one setting. Grooves cut around the circumference of the centre point provide for good gripping for the job. This centre can be used only for soft metal jobs and not for hardened jobs.
9 Female centre		This centre is used to support the end of the job where no countersink hole is permitted.

10 Swivel V centre		This centre is used to support a job In the V portion and to drill holes across the round job by using a drill bit in the

VARIOUS TYPES OF LATHE CENTRES

A	B	C
 Ordinary Centre	 Revolving Centre	 Pipe C
Rotates with the spindel, tip made of common steel	Is held in the non−revolving tail stock barrel	Used for pipes and tube bore
Non−cleaning of shaft and bore causes eccentricity	Non−cleaning of shaft and bore causes conical shape	The workpieces preferab bigger contact area
Center runs with dogs even when dogs slip	The bearing are pre−loaded so that no clearance appears	It is available in stepped
Provided with carbide tips for longer life	Lubricating the centre tip is not needed during turning	In case of overload it is t instead of the tip of the c
When used for the dead end low clamping force and repeated greasing is needed		

II.6 DESIGNING A TASK BANK PRIOR TO WRITING INFORMATION SHEETS

The term “tasks” has been used intentionally, because alternative terms like “test items” may produce a slightly misleading impression of the intended use of the task bank.

Task is a neutral term, not indicating whether a specific question or instruction from the bank is used:

a) for test purposes after the training session or
b) during the lesson as a group work assignment.

Although there may be certain differences and certain modifications seem advisable depending on the purpose for which a task is meant, tasks will not usually be dedicated to one application or the other.

After the content of a topic has been screened for potential discovery learning material and the major cause−effect links and most obvious comparative features have been included in appropriate drafts, the task bank will still need to be structured before information sheets are written.

Assuming that a developer is following the rule that information outside the coverage of the task bank is redundant, he acquires a useful tool for getting information quantity under control. Task banks for a topic can be validated just like tests.

Once the bank of tasks/test questions has been validated for the trade, the package developer is forced to provide the necessary relevant information. He cannot flood the pages with names and definitions, because trainees will be looking for answers to problem–oriented tasks, and the information section of the package must cater for their needs.

The main reason for designing the task bank of a package module/topic before writing information sheets is the observed behaviour of media developers. They tend to expand information subpackages needlessly, but impose unnecessary restraint when writing tasks at Levels II and II.

Information is not an end in itself; the measure of what information is required is the content covered by the task bank. The task bank determines the scope of an issue/topic throughout the package, and the information subpackage has to remain within this scope.

Tasks represent the quality of a training course better than the related information content. But it is more difficult to develop appropriate tasks than to write suitable information. Hence the highest priority for the media developer is to provide the instructor with a task bank.

A few of the potential types of tasks are not recommended here. Neither the TRUE–FALSE type nor the so–called COMPLETION type (using single–word blanks) is suitable. The former gives the trainees a 50% chance of guessing right; the latter is too limited in its complexity (dealing mostly with level I).

Three basic types will be promoted here:

a) the essay question or instruction
b) matching–type items
c) multiple–choice items

All three types are already found in available packages. More attention is, however, needed to enhancing the unambiguity of essay questions, the complexity of matching–type items (often misused for name–matching) and the discriminative power of multiple–choice items

There are three key points that need special attention:

1. Wide–scoped essay questions are ineffective for objective marking and for unambiguous interpretation of training progress. They urgently need conversion into tightly–targeted short–answer questions and/or matching–type items.

2. The evident lack of a sufficient quantity of appropriate matching items. The potential of this type of question is still largely untapped. Matching items offer a unique opportunity for combining all three levels in a single test–item. Names, functions, materials, production or handling problems and typical faults can all be integrated in a single task.

3. Multiple–choice items need careful screening before they are included in a package. Sourcing one of the many multiple–choice question banks is fine, but it is essential to sort out defective items or adapt them to comply with the evaluation criteria. Otherwise the quality of the new package cannot be guaranteed.

a) The ambiguity problem with essay questions

Instructors remain unaware that they have asked too many wide–scoped questions until several correct answers emerge in sessional tests, especially from able trainees.

Example: When asked to answer the wide–scoped question: “How do grinding wheels remain sharp?” the more able trainees tend to give a variety of correct answers, whereas poor trainees try to avoid the issue by writing long, imprecise answers retailing any information they happen to have picked up. It is more difficult for weak trainees to waffle when confronted with a tight question setting a specific, narrow context.

A short–answer question addressing the vital element of a complex issue measures proficiency of understanding just as well as a wide–scoped question, but the trainee can give a much shorter

answer. Marking is also much easier, and more difficult for the trainees to dispute.

Recommendations for narrowing down a wide-scoped question:

1. Refer to particular details supplementing the core question and needing to be taken up in the responses.

2. Shift various conditions upward into the question, so that potential answers which are not wanted are too easy in the context are already excluded.

The general motto: Longer questions elicit shorter answers.

One example for narrowing down a wide-scoped scoped question by adding supplementary qualifiers might be as follows:

The capillary action during soldering is poor. Explain by referring to

a) gap width
b) condition of contact surface
c) temperature of base metals

The disadvantage of this method of adaptation is that the examiner provides key words which often open up a 50% chance of guessing the right answer, as with gap width and temperature (up or down) in the above example.

An example of narrowing scope by shifting various conditions upward into the question would be:

Fluxes have melted the oxide layers on the previously clean contact surfaces, but the solder still fails to spread on the surface of the base metal and run into the gap. Why?

> The long question excludes the unclean surface as a reason for non-spreading, leaving inadequate temperature as the sole explanation.
>
> Another example: Although the solder melts when held against the base metals and although flux is applied, the solder does not flow into the lap joint gap. What is wrong?
>
> Two of the three possible reasons for non-flowing solder are excluded in the question; one is singled out.

In place of long lists giving several reasons for a phenomenon, the supervisor receives a short response (maximum one sentence). This does not mean that the answer is too easy. On the contrary, it allows the examiner to select the most difficult aspect of the question.

The difficulty level of short-answer questions is considerable if the stock answers are excluded by the wording of the question. So the least familiar factor in the overall answer is specifically required.

> Example: Although there is full voltage at the fan terminals, a fan is running at reduced speed. The bearings are rotating smoothly. The capacitor has been exchanged already, but there has been no improvement. Name one other possible cause of this malfunction.
>
> Expected key: Winding could have a partial short.
>
> Due to wear, the clearance between the piston and cylinder bore of a diesel engine has widened beyond the tolerance. Power losses and increased oil consumption would be acceptable. What is the main reason for warning the customer to have the engine overhauled before the next cold winter?
>
> Expected key: Cold starting impossible due to low compression.

The main problem to be aware of is the chance of guessing the answer where only two options are left open, as in the following:

What will happen to the oil consumption of a diesel engine if the clearance between piston and cylinder bore widens?

A turning tool is clamped below centre. How does this affect the actual rake and clearance?

A fan regulator shows increased resistance. How does this affect the voltage at the terminals?

Such questions are fine as a method of teaching during a lesson. They address logic and are inferential if the answer has never been discussed before.

However, such 50% chance tasks are not appropriate for marking purposes.

Most of the present Level I essay questions require unambiguous responses due to their simplicity. But with Level II or Level III questions there is a high probability that several different correct responses will emerge, simply because of the wide scope of the complex questions.

Examples of unambiguous Level I tasks:

What is the name of the part shown here?

What is meant by transformation of current?

Examples of ambiguous level III tasks:

What are the reasons for poor capillary action in a solder joint?

Explain the self−sharpening effect on grinding wheels.

What are the reasons for reduced fan speed on ceiling fans?

There is no chance of ambiguous questions/instructions receiving short answers (e.g. single sentence) and it is a tricky job to decide if a given response is correct, partly correct or totally wrong. Marking the responses to such wide−scoped essay questions is a very subjective affair.

Most often, instructors and media developers are not aware that a question is too wide−scoped until someone else provides several different correct answers.

Original question:	What are the reasons for poor capillary action?
Possible answers:	Gap and contact surfaces not clean, oxidized. Gap too wide, base metal too cold etc.

The main recommendation is to convert one wide−scoped question into several short−answer questions, making the expected answer unambiguous and increasing the objectivity of marking.

When asked about a particular detail of a complex issue, a trainee who has doubts cannot give a short response. Since less time is spent on each topic, the number of topics or issues addressed in a test can be increased (an essential precondition for increased validity) as compared to tests with wide−scoped questions where one response takes more than 10 minutes.

For the media developer, the main priority is to use a short−answer question to address the most sensitive area of a complex issue.

b) Matching tasks for the sake of context and complexity

The matching type is not a new invention and is quite often used together with graphics or complex mechanical assemblies. For some reason, however, media developers overload the graphics with name−matching tasks and forget about functions and processes.

Although this objective type of task has an enormous potential for addressing Level I, II and III issues in a single item, this potential is rarely exploited. Instead of attempting in vain to surmount the huge language barrier formed by every multiple−choice item with four balanced statements (one key plus three distractors), media developers should grasp the opportunity offered by the easier and more rewarding matching−type task.

Matching items offer several advantages to the designer:

1. Matching−type tasks need only one statement at a time, related unambiguously to one of the options.

2. They can be related easily to graphic options like

   − an assembled mechanism whose components are labelled and serve as options.
   − stages of a process which can be distinguished clearly and have clearly differing features.
   − types of the same class of tools, components, machines or processes.

3. The range of statements which can be matched is very wide (as compared to all other types of task) since one can relate functions and effects, materials, typical production features, common work rules, typical faults, special assembling or dismantling difficulties or any other property of the options, all in one task. Several levels of complexity can be covered in this way.

Writing a comprehensive composition to answer a wide−scoped essay question may take some 20 to 30 minutes. During the same period, at least 6 matching items covering a wider scope could be applied in the test, greatly increasing the validity of the test.

MACHINIST

Wide scoped essay

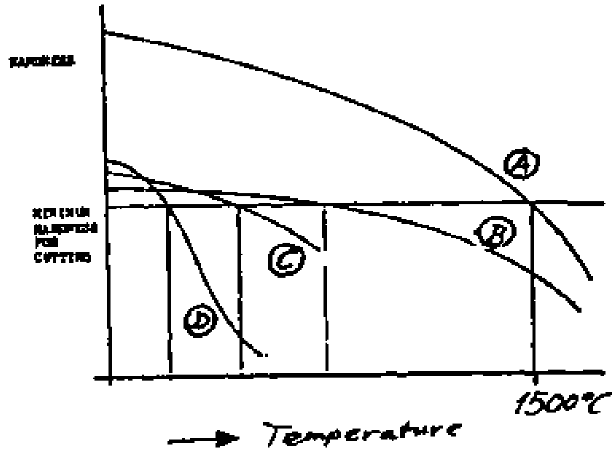
2. (a) Define the terms: Red Hardness, Abrasion Resistance and Toughness as applied to cutting tool materials.

(c) State and explain four reason why cemented−carbide tools have been widely accepted by the industry.

At present ↗

Alternative →

Matching type



___ Minimum hardness is still available at temperatures three times higher than with high speed steel

___ Its hardness at room temperature is high due to boundary cementite but this transforms soon with rising temperature.

___ More than 5% of tungsten and molybdenium provide−this steel with a minimum hardness at higher temperature.

___ This non−ferrous alloy consists of mainly chromium and tungstem and is hard when glowing red.

___ The hard tool tips are fixed by clamping or by brazing with pure copper.

___ Its maximum cutting temperature is double the limit of plain carbon steel.

___ Carbides of tungsten and of titanium bounded together as powder provide the hardness of this tool.

___ No coolant should be applied to the tool so that the chips come off red hot at highest cutting power.

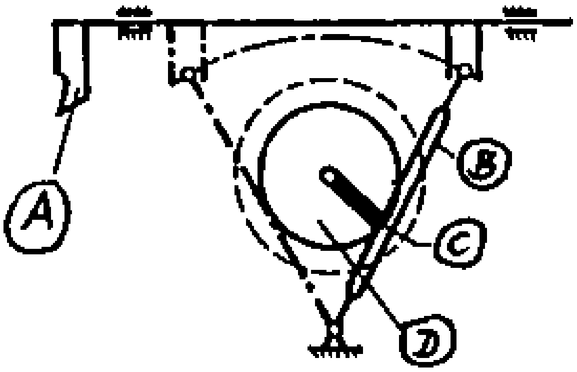
(b) Discuss the effect of tungsten, Cobalt and Molybdenum in high speed steel.

Match the steel types to the applications:

A = C 0,42 / Cr 1 / Mo
B = C 1,2 / Mn 12
C = C 0.15 / Cr 1,5 / Ni
D = C 0,05 / Cr 18 / Ni 9
E = C 2,1 / Cr 12

___ Punching tool die plate
___ Sink basin for kitchen
___ Bolt shaft for dynamic loads.
___ Stone crusher (breaker)
___ Gears to be case−hardened after milling

5. (a) Explain briefly the cutting action of the <u>shaper</u>. Why is the <u>return stroke</u> of the crank−type shaper faster than the cutting stroke. .



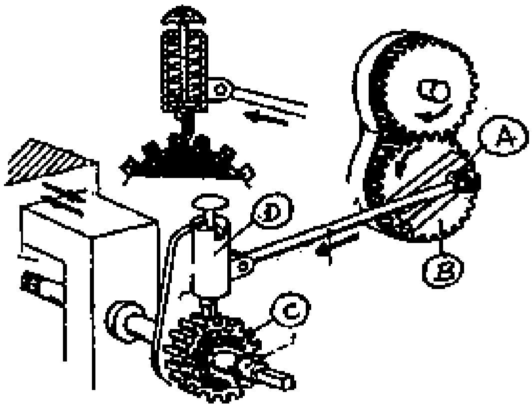
___ It converts the rotary motion into a lateral motion.
___ It is used for setting the stroke length.
___ Its swivelling speed is maximum in vertical position.
___ It rotates with permanent speed and is very heavy to compensate sudden acceleration forces.
___ Maximum speed is achieved during cutting stroke.
___ Its stroke is always longer than the work length.

TRADE: MACHINIST
SUBJECT: THEORY

Wide scope essay

b) Explain with a neat sketch the feed mechanism of a(...) shaper.

Matching type



___ It swivels to and fro.

___ It rotates with permanent speed.

___ Its eccentricity effects the size of the feed.

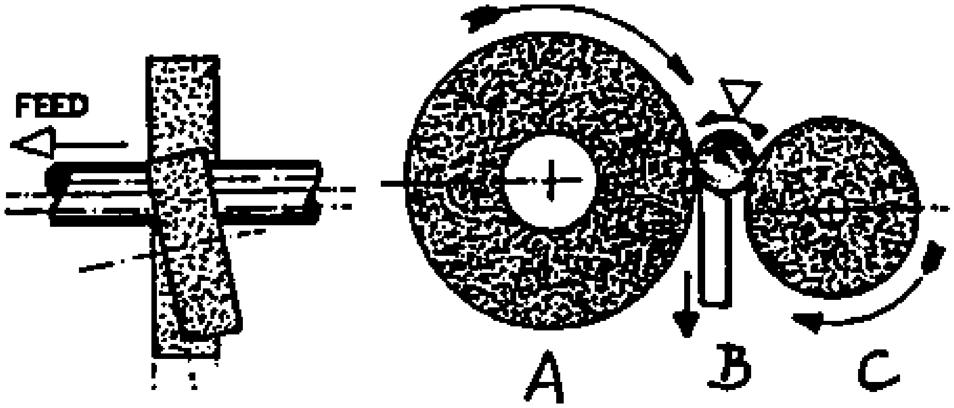
___ When fixed in centre position the feed is zero.

___ Its ratchet slips over the ratchet wheel teeth during backward motion. It is fitted to the feed spindle.

___ Feed can be stepped only as fraction of the number of its teeth caught by the ratchet.

___ It can be clamped in any position.

b) Explain how a centreless grinder can grind stock.



___ It deviates work weight and cutting pressure towards control wheel.

___ It provides the grinding action.

___ It rotates the work with little slip.

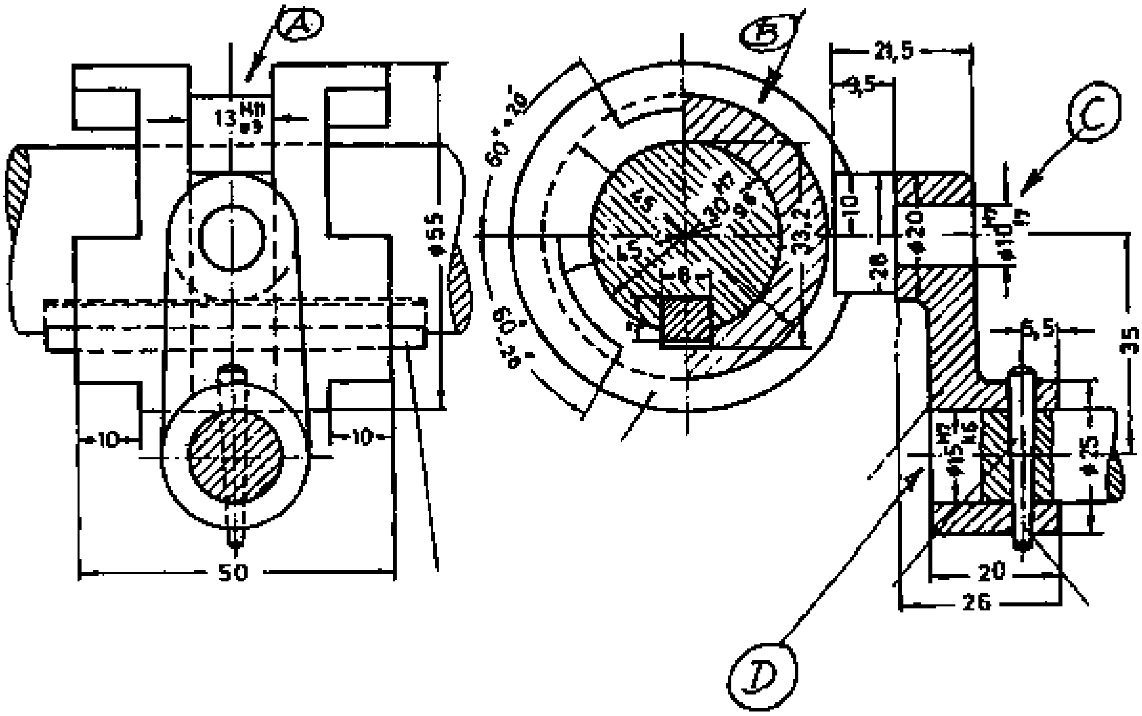
___ When set to Inclined position it provides the through feed for cylindrical bolt.

___ Due to its inclination or off−centre position the work is pressed against the control wheel.

___ It circumferential speed is highest.

___ Its shape is not exactly cylindrical but convex for through feed.

4. (a) Differentiate between 'tolerance' and 'allowance' in a limit system. Describe with the help of sketch three different types of fits used in simple engineering assemblies.



13 e9	– 32/ – 75
13 H11	+ 110/ – 0
10 f7	– 13/ – 26
10 H7	+ 15/ – 0
15 k6	+ 12/ + 1
15 H7	* 18/ + 0
30 96	– 7/ – 20
30 H7	* 21/ – 0
ISO Symbol	allowances

2.1 A = Nominal size 13
B = Nominal size 30
C = Nominal size 10
D = Nominal size 15

___ This transition fit allows for easy assembling with slight push–in pressure when needed.
__ Among the clearance fits this provides the widest gaps.

___ Although the clearance fit is the most narrow one the fit permits easy shifting of the part to be assembled.

___ With a minimum clearance of 0,032 mm gliding action between the parts is very easy.

– Some tilting motion between these parts goes with the shifting of the clutch so that the clearance fit is appropriate.

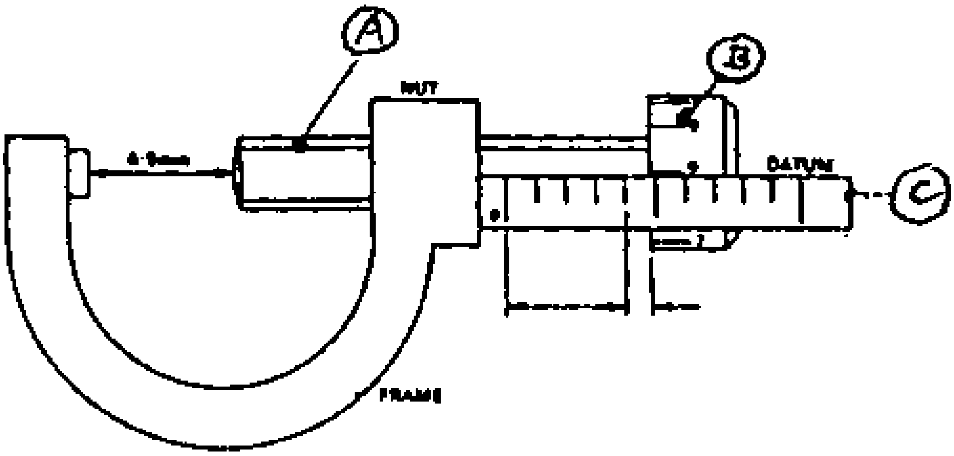
___ A firm matching is necessary to keep the pieces aligned but a clearance of maximum 0,014 mm may occure.

___ The maximum clearance is 0,185 mm

___ The minimum clearance is 0,007 mm

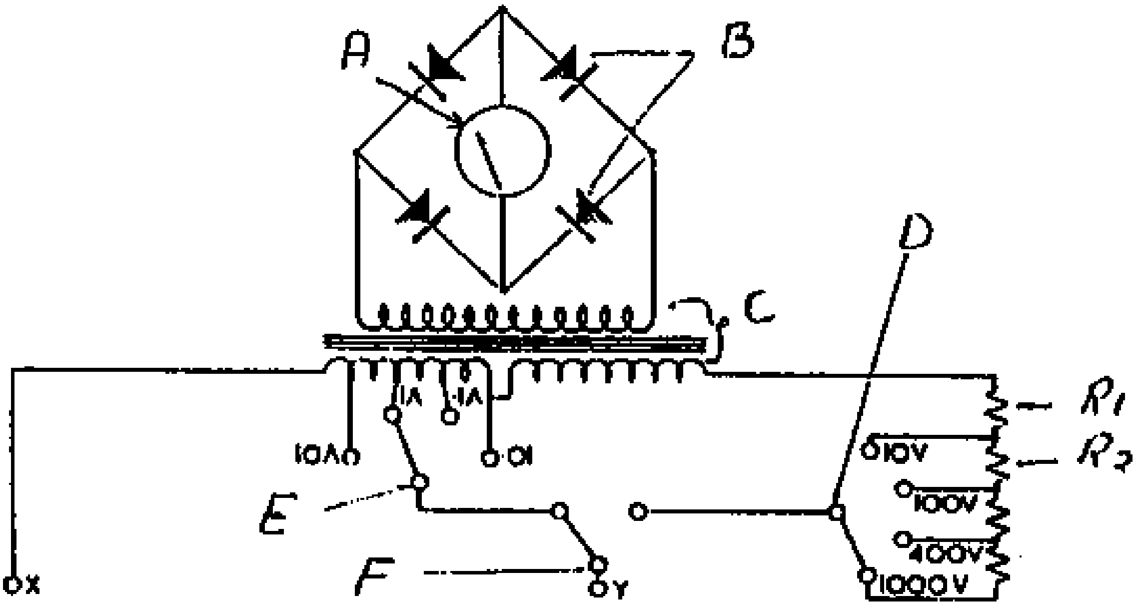
___ Interference can go up to 0,012 mm.

(b) Explain why a micrometer provides a more precise reading than vernier callipers?



Model for Micrometer 0,1 mm accuracy

___ 4 full millimeters can be read from this scale.
___ The pitch is 1 mm.
___ Each full turn advances this part by 1 mm.
___ This scale spans the full length of the screw (measuring range).
___ The ten divisions divide the full turning motion of spindle into small pitch sections.
___ The 0,1 mm reading comes from this scale.



Universal Avometer as an A.C. Instrument

FUNCTIONS

___ Generates a field which turns the pointer on the scale according to the amount of current flowing through the coil.

___ Rectifies the a.c. voltage for the meter.

___ Is tapped to give a variety of transformation ratios.

___ Is 9 times bigger than R1.

___ Is an a.c. current range selector.

___ Selects between voltage and current measurements.

DEFECTS

___ If defect, voltage more than 10V can not be measured.

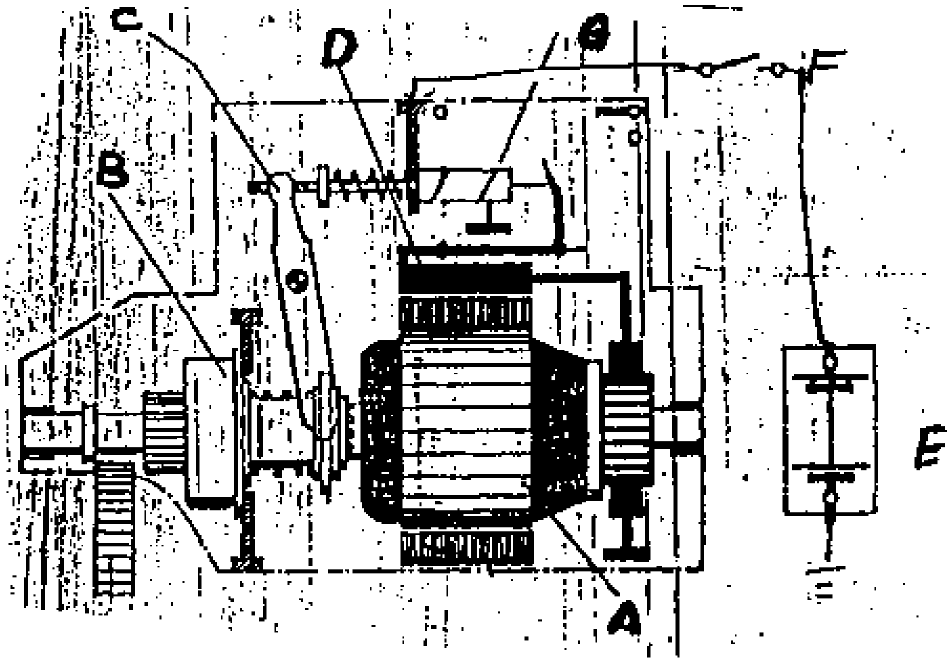
___ Partial short in it would cause overvoltage on the meter.

___ If one of these defect, the meter voltage would drop by about 10%.

___ Frequencies more than 2.5 KHZ will introduce errors due to reactive effects in the rectifiers and in this component.

___ A short circuit in this component produces zero reading on the meter.

___ If defect the instrument works only as an ammeter.



STARTER MOTOR

Match the labels of the defective components!

___ A new battery (E) is fitted. Terminals are well secured and clean. Ignition switch F on starting position. The starter motor runs, but does not engage and no clicking sound is heard.

___ The starter motor runs and engages but it does not disengage with ignition in on position.

___ Starter motor working properly. A fully charged battery is installed. Ignition is placed to starting position but no reaction.

___ Ignition to starting position: The engine turns with a gradually decreasing speed and eventually stops.

___ On no load position starter works okay. Filled windings had been replaced, but starter motor does not turn engine at required speed.

___ Relay G was checked and Battery E is ok, too. When started the motor runs, but does not engage its pinion.

Like wide–scoped essay questions, sketching exercises are very popular, e.g. “make a neat sketch of...”.

This generally costs substantial test time lost for other issues, while subject matter validity is often poor. The alternative is an illustration with labelled details establishing a uniform context and background for all trainees in the test situation.

This should not be taken to imply that sketching should not be tested as a skill. But where the target ability is the trainee's knowledge of how a mechanism functions, the test should not be overloaded with an additional request for sketching.

Sketching makes sense where, for example, a spare part is given to the trainees and they have to make a free−hand production sketch with all the necessary specifications and dimensions (including sensible tolerance limits derived from functional aspects). Sketching of a single machine component can be entirely justified.

The range of applications for matching test items is very wide, and one special advantage is that they are highly suitable whenever graphics can be used and elements in the illustration can be labelled. This offers the media developer an easy start. The following pages provide numerous examples from the metal trade.

They show matching−type items that could replace the wide−scoped questions next to them (taken from a final test). The wide−scoped essay questions are taken from a final test. Substitute matching−type items are placed next to them. The examples demonstrate how matching items can cover an issue in a complex way by referring to functional aspects.

CRITERIA FOR MATCHING TEST ITEMS

1. Do the options belong to a common context (e.g. several types of one class of tools or several stages of the same process)?

2. Is the number of options limited to not more than 6 options and are there at least 3 for groupwork exercises?

3. Can the statements for matching be linked unambiguously to a single option? Is the wording concrete and specific?

4. Are there more statements than options (preferably a minimum of 2 statements per option)?

5. Have illustration options been used instead of text options whenever possible?

6. Have illustrations been used instead of texts for matching whenever possible?

The evaluation criteria for matching items are very much like those proposed for comparative tables in discovery learning.

Minor differences exist. The features distinguishing the options must be very obvious and more contrastive for discovery learning of a new content (trainees have to see by themselves) than for testing something already addressed.

With Criterion 3 the opposite is the case: a relation between one statement and two options is a possible variant for a discovery learning table (statement then fits into two columns), but not for test purposes, where it must be scrapped in the interests of unambiguity and objectivity.

With Criterion 2: two options are intolerable for testing, due to the chance of guessing right.

c) Multiple−choice items: The pseudo−distractor problem

Although it is the most widely−used type of task, multiple choice imposes a strong reading barrier; the media developer has to bear in mind that he may simply be testing reading ability. Multiple−choice items with short wording seldom achieve sufficient quality.

The main reason why the media developer should aim for matching tests before trying multiple choice is the stress on mastery of language. Multiple−choice items require the designer to formulate four

statements belonging to the same context (defined by the stem/task description), so that all four look plausible but three are unambiguously wrong and one is unambiguously right. This is a formidable job.

The main concern of this chapter is to provide the media developer with a tool for evaluating existing items before he adopts them for the package task bank. Available material from existing banks should be tapped, scrapping the unusable items.

EVALUATION CRITERIA FOR MULTIPLE−CHOICE ITEMS

1. Does the stem (introductory question/order) set an unambiguous and specific context? (No hidden true−false version starting with the stem "Which of the following.... is correct/wrong?")

2. Is the key the only correct response, or is there a distractor that could also be regarded as key? (two keys create a 50% chance of guessing in a four statement multiple−choice item)

3. Are the distractors seemingly plausible in that they:

   a) do not contain any easily−eliminated nonsense statements?
   b) are related to the stem (and in the same context as the key)?
   c) contain no supportive clues likely to generate doubts (e.g. "always/never" or largely identical wording in key and one distractor)

4. Is the appearance of the key a give−away, because it

   a) is obviously longer, more specific in its wording or different in context from all the distractors?

   b) is identical in wording with one of the distractors except for one word, usually an adjective or adverb (e.g. "larger" instead of "smaller")

   c) contains the statements "all the above/none of the above"

5. Does the stem include an illustration/relate to an illustration?

As a basic rule, the media developer should reject items where:

− the stem asks "Which of the statements is wrong/right?";

− one of the distractors cannot seriously be taken for the key (a pseudo−distractor, restricting real choice to the remaining statements);

− the wording of one of the distractors differs from that of the key by only a single word (e.g. key: decreasing; distractor: increasing), again effectively providing a 50% chance of success;

− the key is "all the above" or "none of the above".

Since in many developing countries test banks have to be translated into local languages, and since translations are often made by non−technical specialists, the fine language structure of an MC−item is easily lost. The result confuses trainees more than it helps them. Since every word in the 5 interrelated statements of an MC−item (stem plus key plus a minimum of 3 distractors) is important, translation is a potential nightmare. This is another reason why designing new MC−items is not recommended here. Adaptation of promising existing items, on the other hand, may be very worthwhile.

Special items for tests in technical drawing for metal trades:

The two pages below show samples for test items used to measure the ability to read technical drawings. These test items are special in that they require no drawing, line work or text reading. The stem is set by a three three view presentation of an assembly and the key and the distractors are presented as views of single components. The trainees cannot find the key unless they understand the working principle of the assembly. This is a remarkable tool for the metal trades, where this ability is vital.

d) Item analysis for multiple−choice items and matching items

Item analysis is carried out during the trial runs for MC−items on the basis of the responses given by trainees. It is important to document thoroughly which of the statements has been ticked by the trainees.

The first check is the DIFFICULTY INDEX. The number of correct responses for each item is divided by the total number of participants. A D−index of 0.74 means that 74% of trainees responded successfully to this item (an average difficulty level for a test item offering a 25% chance of guessing right). A D−index of 03 sound an alarm, indicating an unusually high failure rate. There could be several reasons for this:

a) very poor coverage of this issue during training (punishing the trainees for the sins of the instructors);

b) confused wording of the stem, leaving several possible keys (designer's fault);

c) one distractor looks more like the key, and perhaps is.

A D−index of 0.98 may indicate that:

− content has been trained excessively to drum it into everyone;

− the item tests common sense rather than trade know−how;

− all the distractors look so implausible that only a trainee of substandard intelligence could mistake them for the key.

The latter two cases are the most common reasons for adapting items before admitting them to the package banks. They would otherwise be useless, being unable to discriminate between a highly−qualified and a less well−qualified trainee.

Further analysis is needed before judging the actual reason for an unusual difficulty level. The alarm sounded by the D−index raises several questions. Other indicators like the DISCRIMINATION INDEX can help to establish the answers.

The media developer counts the frequency with which each item (the key and each of the distractors) is taken for the key, enabling him to draw some additional conclusions.

Example: The tap broke during tapping. What is the reason?

A Cutting oil was used so that friction became too low (slipping)

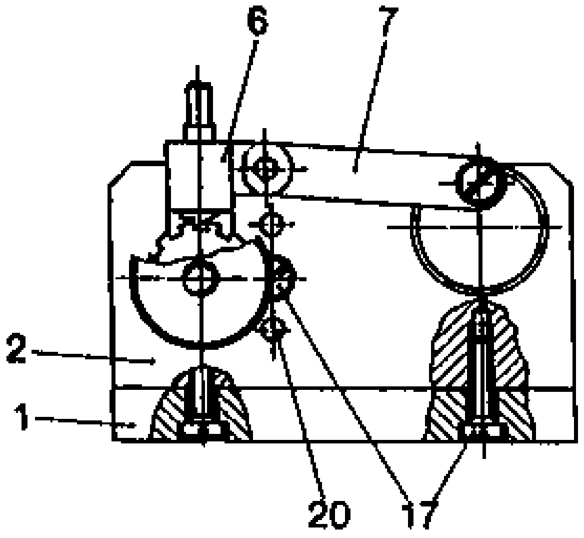
B Feed motion was too fast.

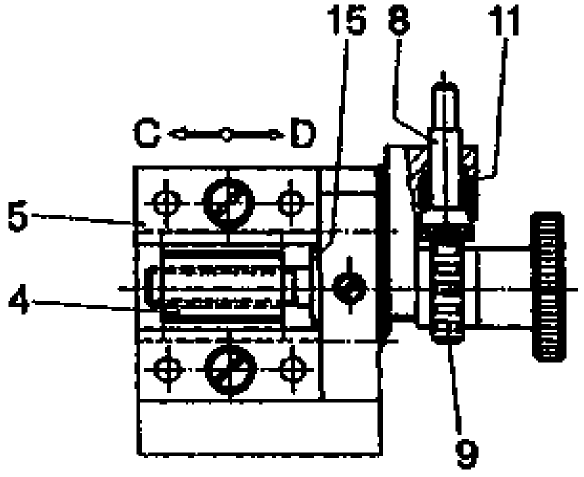
C Drill for making the core hole was too big.

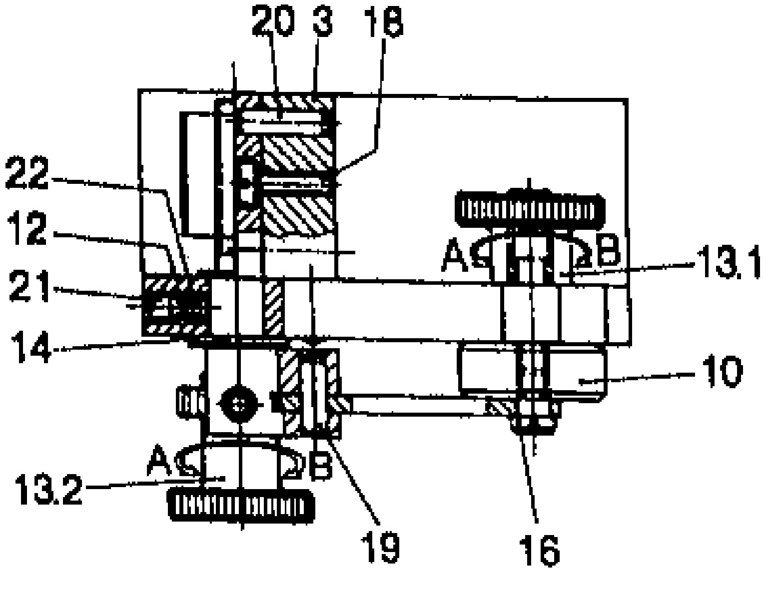
D Unequal hand pressure towards the wrench caused the tap to bend.

Special items for tests in technical drawing for metal trades:

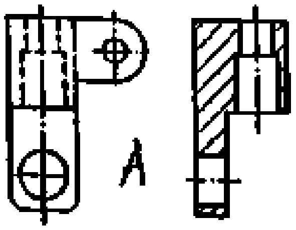
The last two pages show samples for test items used in the measuring of the ability to read technical drawings. These test items are special in that they require no drawing or line work nor the reading of text. The stem is set by three view assemblies and the key and the distractors are presented as views of single components. Without an understanding of the working principle of the assembly the trainees will not find out the key. This is a remarkable tool for the metal trades where this ability is vital.

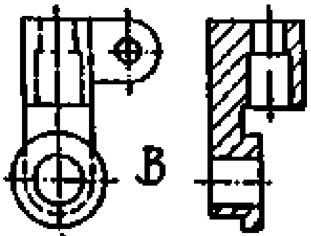

6
7
2
1
20
17

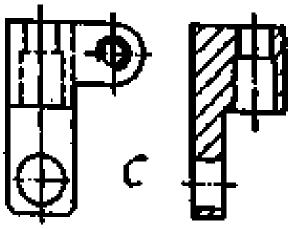

15
8
11
C
D
5
4
9

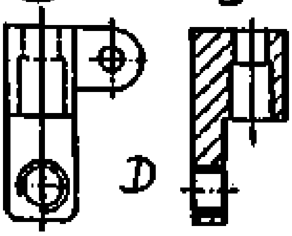

20
3
18
22
12
21
14
A
B
13.1
10
A
B
13.2
19
16

Part 6

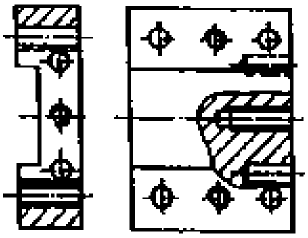

A

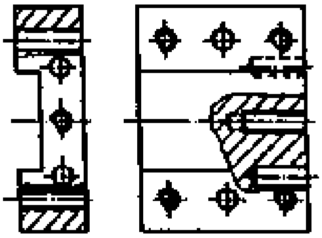

B

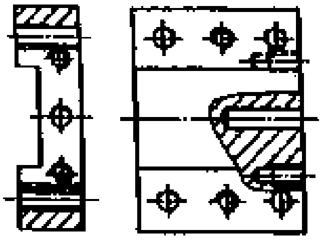

C

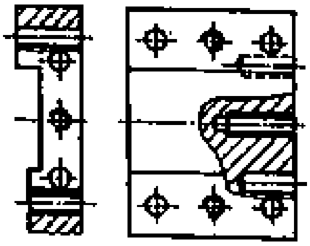

D

Part 3

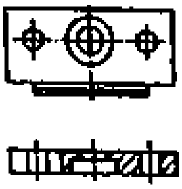

A

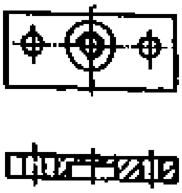

B

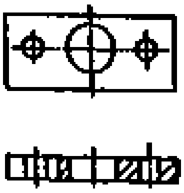

C

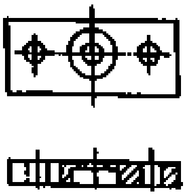

D

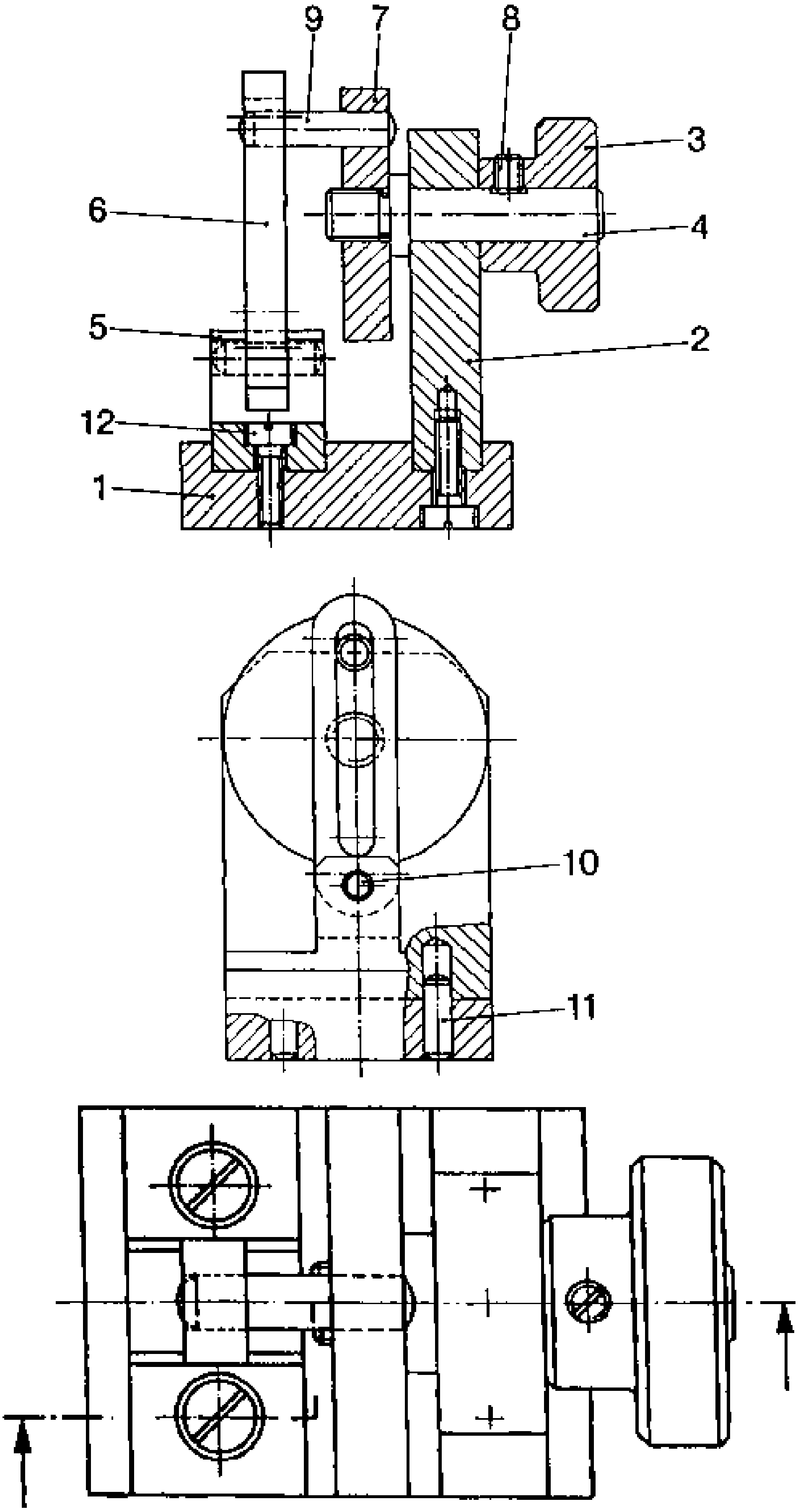
Part 5


A


B

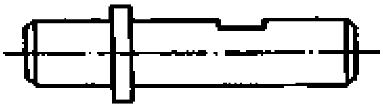

C


D

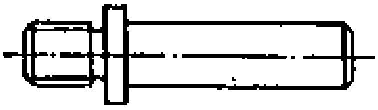

9
7
8
3
6
4
5
2
12
1
10
11

Part 4 ?

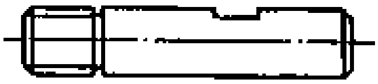
A



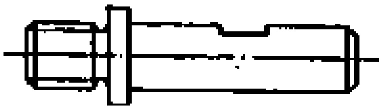
B



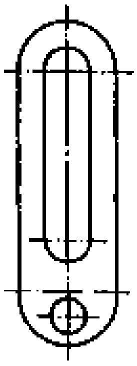
C



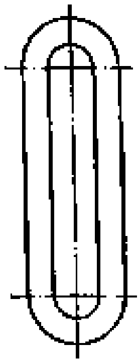
D



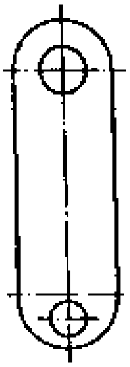
Part 6



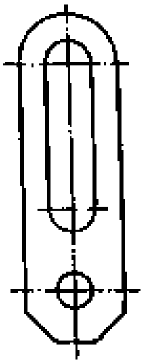
A



B

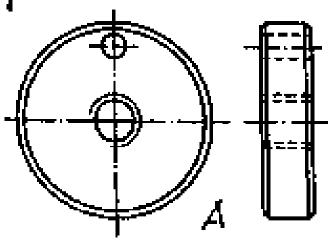


C

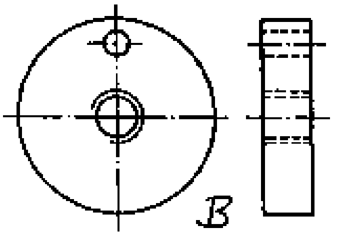


D

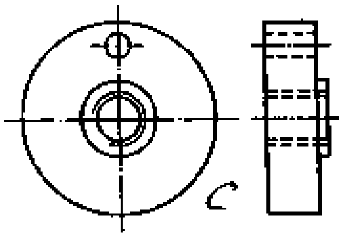
Part 7



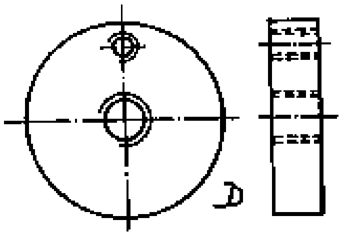
A



B



C



D

Out of a total of 74 trainees

- none took distractor A
- 12 accepted distractor B
- only 2 fell for distractor C
- 60 realized that D is the key.

The high success rate may be due to the fact that A is an odd distractor, better termed a “pseudo−distractor”. It does not DISTRACT attention away from the key. Adaptation of this distractor will also lead to a more normal D−index.

Further example:

The clearance angle of hacksaw blades is relatively large. Why?

A More space is provided for the chips between two teeth.

B Wedge angle can be small because sawing blades always have a short tool life due to frequent breakages.

C Penetration of the teeth into the work is made easier.

D Machine hacksaw blades are made of HSS−steel.

Statistics: The D−index is in a normal range, with no trainee accepting distractor D, only 8 trainees taking B and 18 thinking that distractor C is the key.

However, the index for distractor D shows the media developer that D is too far out of context to seem plausible to an intelligent trainee.

Some improvement is also advisable for distractor B. If the clue “always” is scrapped, some knowledgeable trainees might argue that this is a second key. This shows how delicate in terms of linguistic analysis the adaptation of MC−items can be.

II.7 CHECKING THE VALIDITY OF TASK BANKS AND TESTS

Adapting single items/tasks to ensure their quality does not necessarily assure the composition of valid tests.

The common academic approach to checking test validity is not very helpful for a training system where trade standards and curricular details are rather imprecise.

The term “subject−matter−validity” refers to the balanced coverage of training objectives, not a suitable yardstick in this case, since they do not comply with MAGER’s criteria for objectives. Without objectives adequately specifying scope of content and depth of perception, the best point of reference is the task bank for each topic.

Since the task banks

- constitute a much more specific and concrete description of the intended training outcome;
- cover the approved trade standards and
- contain tasks at Levels I, II and III

it makes sense to devote special attention to them.

The trade standards or curriculum provide only the overall frame for subject matter structuring; the task bank for each topic helps to clarify the details.

MATRIX FOR CHECKING VALIDITY OF A TEST

The matrix helps to analyze given task banks (draft versions) so that shortcomings can be traced and modified.

The number of the test item appears in Column 1

MATRIX FOR CHECKING VALIDITY OF A TEST

Test item No	Curricular units/issues								Levels of complexity			Types of test items				Pictorial items	
	1	2	3	4	5	6	7	8	I	II	III	WE	SA	MA	MC	YES	NO
1																	
2																	
3																	
4																	
etc.																	

The second column accommodates 8 curricular units.

The third column is used to document whether the item is a short−answer question (SA), a matching−type item (MA), a multiple−choice item (MC) or a wide−scoped essay question (WE). Other types, e.g. true/false or completion (single−word blank) exercises should not be used for marking purposes.

The final column is a yes/no count of items with or without associated graphics.

a) Slicing the content into roughly equal sections

A list of approximately 8 issues or main components of a topic with similar weight is needed, so that the overall content of the task bank for a topic is divided into roughly equal sections. If a sessional test is being compiled, the overall content to be tested goes beyond a single topic and has to be sliced into equal parts, taking the varying importance of the topics into account.

Since topics differ in scope and complexity, mere listing of topics taken from the syllabus does not help. There is too much difference between a topic like “sawing” and a topic like “turning”. More detailed listing of issues is needed to generate an overall content for a period (between two sessional tests) which can be subdivided into between 5 and 7 similarly−sized parts.

Example: Sawing

1. Shape of teeth, pitch of blade
2. Relation of pitch to work hardness and wall thickness of work
3. Free−cutting action

Example: Brazing

1. Difference between brazing, welding and adhesive bonding
2. Conditions for diffusion of metals
3. Factors influencing capillary action
4. Selection of filler metals according to job
5. Critical aspects of the skill sequence
6. Miscellaneous issues

If the topic “sawing” became a curricular unit, “brazing” would require a double unit (weighting factor 2). Let us assume that some 5 topics have to be covered in a sessional test and that 3 of them have a weighting factor of 1, one topic represents double unit and one a triple unit. This would add up to a total of 8 units needing balanced testing.

b) Classifying test items

Academic works on test analysis also stress the need for a classification of test items with respect to difficulty level. Difficulty level is a statistical value (see MC−item analysis in II.5) resulting from calculation by the test administering authority after the implementation of a test. It is more helpful for tracing defective items than for designing tests. In the design phase, the level of complexity is used instead.

There is no way for media developers to anticipate the difficulty level of an item with sufficient reliability.

Since BLOOM proposed his taxonomy, the need to classify training objectives and test items has been generally accepted. Since everyone interpreted the meaning of this taxonomy differently, much controversy resulted, unfortunately without producing a commonly acceptable substitute. The simplified system recommended here has the merit of being easy to handle while still helping to check the hierarchical validity of a task bank (for a package topic) or a test.

The problem of classifying a test item correctly is most evident with test items like:

“What feature of the sawing blade depends on the work hardness?”

Expected short–answer: pitch

At first sight, the single word answer looks like a name, so Level I is assigned in the matrix. But the question actually requires the trainee to link the concept work hardness with a feature of the blade. This makes it a Level II item. Although the answer consists of only one word, it does not represent isolated quotation of a name. By contrast, a Level I item might be

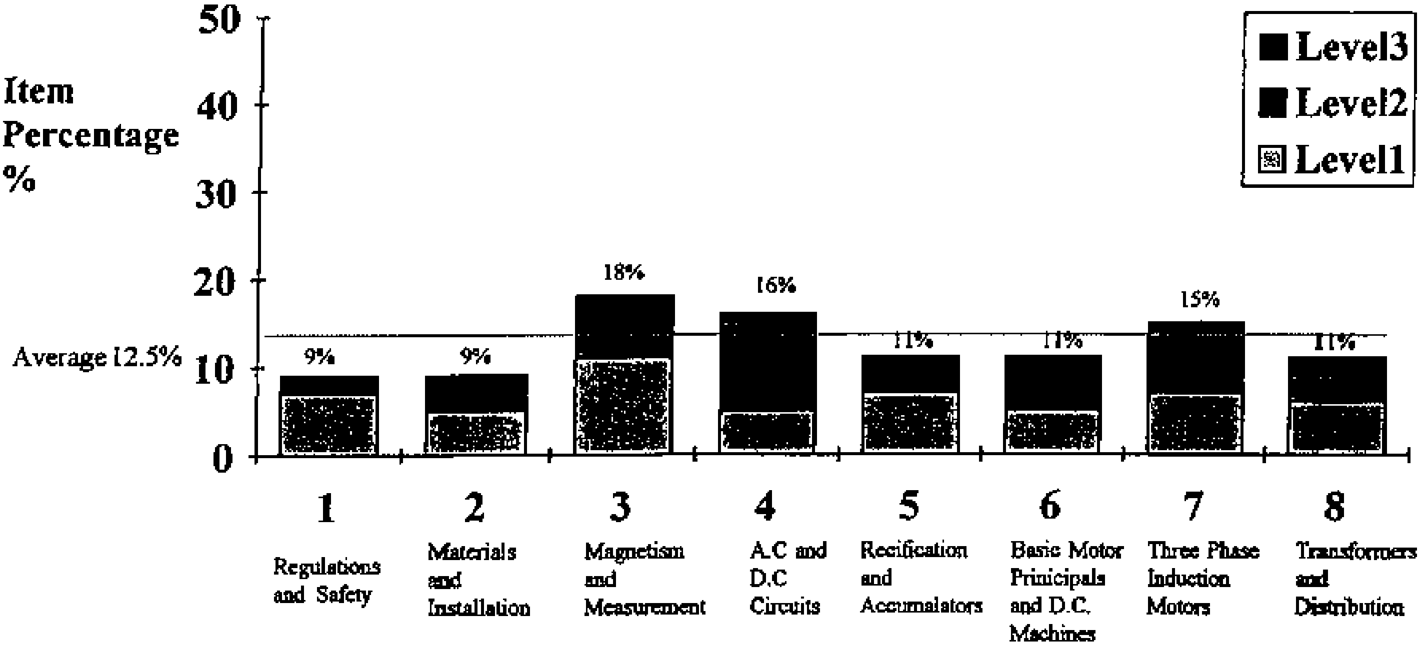
“What is meant by the distance between two teeth of a sawing blade?” Expected answer: pitch

Since this represents only a definition, Level I can be assigned.

In neither case is any distinction made between memorizing (of previously learned issues) and application (of preknowledge to a new situation), a distinction of special importance in BLOOM’s taxonomy. Since each trainee brings a different preknowledge with him, the same question frequently generates memorizing for one trainee and application for another. It is for this reason that it makes little sense to use BLOOM’s taxonomy for a validity check in testing.

Defining the key distinction between Level I and Level II here is the more tricky part of the complexity–level–validity check. Level I is represented if isolated facts are tested, e.g.

- names or figures (118° point angle for steel drills);
- formulas (U = RxI, p = F/A)), definitions or the wording of rules (not the use of rules in a context)



NCC Test Electrical Technology 1992 Revised

The media developer can ask three questions to classify a test item for the validity check. They may be asked in the following order, because it is easiest to recognize level III:

1. Does it deal with a technical defect or an abnormal/problem situation involving problem−solving strategies or diagnostic aspects (dealing with either symptoms or causes or remedies)? If so, it is classified as level III task.

2. Does it require mere quotation of a name, a figure, a formula, the wording of a rule or the wording of a definition? If so, it is level I.

3. Does it fit neither the first nor the second question, but instead require the linking of concepts or rules? If so, it is level II.

Level II items are identified more easily by checking for non−compliance with level III and level I. The main purpose of this approach is to remind the test developer

– that problem orientation should not be forgotten
– that too many names, figures and formulas and definitions have been asked up to now.

Even assuming that there will be a certain error rate of say 10% in the distinction between Level I and Level II, this will have no decisive impact on the overall effect which is intended.

There is one detail in the count which requires special attention. The matching test items often cover several levels of complexity. If all three levels of complexity are addressed in one matching test item, only the two most widely covered levels should be counted in the validity checking matrix.

c) Ensuring the variety of types of test items/tasks

The use of different types of item is stressed because essay questions (short answers less so) might favour the trainees with better general educational background (not necessarily the most suitable skilled workers), multiple−choice items could lean towards testing reading ability too much and, unless there is a higher proportion of pictorial items, trainees from rural areas using local dialects would not have a fair chance in skill tests. The matching test item offers a little of everything, because only single statements have to be matched (not four at a time as in multiple choice) and because they usually refer to a set of pictures or of components of an overall picture.

Since each type of test item measures abilities beyond trade know−how, some interference with fair marking cannot be excluded. The best neutralizing effect may be achieved by mixing and balancing different types as a measure of validity. The third column of the matrix takes care of this.

Last, but by no means least, it is the ratio of tasks/test items with pictorial elements that affects this variety. The uniformity of some tests, without even a single test item incorporating a picture or diagram, is surely not appropriate for countries with a poor literacy level and a multitude of local dialects. This situation is worsened by the fact that trade tests are often carried out in English although this is not the mother tongue of the trainees.

d) Setting the quality marks for test complexity

The distribution ratio for the levels I – II – III in a test is a direct indicator of the intended practice relevance of a training system. No ratio is forced upon a media developer as long as the testing authority implements tests which do not comply with any such rules. But as a guideline for its own work, a developer team should set quality marks.

A ratio of 1:2:1 would mean restricting name learning to a maximum of 25%; a marked improvement in some trades, and as far as Level III is concerned an improvement for nearly all trades.

A ratio of 1:3:2 would cut the limit for Level I to 17% and lift the Level III percentage to 33%, leaving the remaining half of the test for Level II. With a tolerance range of +/− 3% this would be very ambitious, but feasible for a dedicated team.

A training system testing the theoretical subject matter content with a 30% ratio of level III questions to which the trainees react with an average 80% success rate can be classified as highly practice−oriented. With an average success rate of only 50% it is heading for that goal, but the rate points to internal friction (e.g. during the transitional period).

A training system confronting trainees with a test containing 30% of Level I items and only 10% of level III items is not even trying to pretend that it is practice−oriented.

Due to the divergence of item types, a weighting factor may be needed. To simplify the counting procedure, a common weighting factor of 3 for all matching items could reflect the fact that they often cover more than one level of complexity.

Setting an equivalence factor for wide−scoped essay questions is doubtful, in view of the fluctuating length of the expected answers. A maximum total number can be used as an upper limit for WE (e.g. a maximum of 2 or 3 in a sessional test), restricting their effect on grading as a whole.

Setting a distribution ratio for types of test items requires a comparison of the weighting factor for each type of item. The average time needed for answering each type could be a meaningful weighting factor. The reading of a multiple−choice item and the writing of the answer to short−answer questions are not so far apart (provided the short−answer items require a mix of single words or single sentences as a response). This leaves the matching test item, for which the weighting factor depends very much on the number of statements to be matched. On average, a weighting factor of 3 would be a tolerable simplification, considering that matching of 10 items is recommended wherever possible.

The percentage of items incorporating pictures signals the willingness of a training system to cater for training in rural areas and for the informal sector. Offering these target groups a final test open to everyone and disregarding formal training as a condition for entry will gear the certification system towards measuring abilities and job requirements, rather than asking for language mastery first and formal vocational qualifications next.

e) Subject matter validity of final tests

Final tests need a procedure for the first validity criterion of subject−matter−coverage which is slightly different from that for sessional tests. Since the final test covers a much wider scope, the list of topics exceeds 8 in number.

In order to make sure that checking of the content validity does not become too difficult, the number of CURRICULAR UNITS to be identified should not be higher than 8.

The scope of the various topics again differs. Consequently, the aim of the procedure is to combine several lightweight topics in one curricular unit, so that together with the more complex topics they form a list of curricular units of similar weight, complexity or scope.

A combination of several less complex topics is needed for the final tests, whereas the division of complex topics is a must for the sessional tests, in order to obtain balanced units for the content−validity check.

Example of contents of similar scope for fitter final trade test:

1. Basic/advanced measuring (from vernier caliper to plug gauges)
2. Benchwork with hand tools (chiseling, filing, sawing, marking)
3. Drilling machine jobs (drilling, c−boring, reaming, tapping)
4. Basic turning and tool resharpening (cylinders in/external)
5. Shaping and basic milling (up to dovetail shapes)
6. Clamping of tools and works (drilling, shaper, lathe)
7. Maintenance of machines, machine elements (working principles)
8. Miscellaneous (all other/smaller parts of syllabus combined)

f) Interpretation of validity check results

When applied carefully **the validity check tells developers**

− which curricular units (topics) need additional coverage or where cuts are needed

− which level of complexity has to be boosted or scaled down for better compliance with set ratios

– which types of test items the media developer should choose in order to achieve the two above results

– to what extent the media developer should try hard for inclusion of an illustration.

Telling a media developer that a graphics−related Level III matching test item is needed for Topic XY can be a considerable help in improving a test or task bank.

One can trace some obvious faults with the help of the sample chart below:

Curricular units 4 and 6 are not covered appropriately and Unit 2 not at all, while Units 5 and 7 are over−represented.

There are too many Level I and too few Level III questions.

The ratio of test item types may be regarded as acceptable.

The number of short−answer items with pictures must be increased.

If the total number were to remain unchanged, trimming would start with purely verbal test items at Level I dealing with Units 5 or 8, Item 4 (a short−answer item) and Item 17 (a matching item), though only because Item 20 covers Level II as well.

The most urgent adaptation would be to insert matching and short−answer items related to topic problems in Units 2 and 4 and 6, incorporating graphics.

Test item No	**Curricular units/issues**								**Levels of complexity**			**Types of test 1 items 1**				**Pictorial items**	
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**I**	**II**	**III**	**WE**	**SA**	**MA**	**MC**	**YES**	**NO**
1			x								x		x				x
2			x							x			x				x
3				x						x			x			x	
4					x				x				x				
5					x						x		x				x
6					x					x			x				x
7					x					x			x				x
8						x			x				x				x
9							x			x			x				x
10								x	x				x				x
11	x									x					x		
12			x						x						x		x
13							x		X						x		
14							x			x					x		x
15							x			x					x		x
16	x									x	x			3x		x	
17					x				x	x				3x			
18					x					x	x			3x			x

19							x			x				3x		x	
20								x	x	x				3x		x	
	2	0	3	1	6	1	5	2	7	13	4	0	10	15	5	8	12

II.8 INFORMATION SHEETS WITH STRESS ON CONTEXT AND INTERLINKAGE

There are three major aspects that need special attention during the writing of information sheets.

1) The lack of coherence and interlinkage within the items of information is the single most important aspect for adaptation.

Each issue needs to be covered in such a way that the reader can see the overall context; not just a list of paragraphs with headlines showing the key concepts of the issue. The flow of text information must be interlinked.

2) The wording of individual sentences must be checked to avoid abstract statements which fail to generate images in the mind of the trainee.

3) Details of graphics must be labelled, not whole illustrations.

Reference numbers referring to a whole illustration are of little help in establishing a close link between a particular text passage and the related component of the pictorial information. The linkage between the text and the pictures is too coarse.

4) The total lengths of the information items must be limited to digestible size. As a rule of thumb, the time for coverage of an issue should not exceed half an hour. More than one page of A4 size indicates excessive coverage of, for example, the working principle of a mechanism (the target group being skilled worker level).

5) The layout for a topic should clearly help to distinguish between essential core information and further aspects of the working principle and/or further influencing factors to be added after the core message has sunk in.

6) Cuts are needed to get the total volume of the package under control. For the information, this means restricting information to matters covered in the task bank and converting as much information as possible into tasks for discovery learning.

Example “Grinding wheel”

As an alternative to the information sheet, a logical structure is given. Although the headings look different one can say that both items deal with the same issue Asking “What is the construction of the grinding wheel?” leads to a response that should clarify how wheels are selected for a given job.

In the information sheet there is no interlinkage among the paragraphs (from abrasives to grades to bond and structure). Vague statements hint at the fact that “abrasives are selected depending upon the material being ground” (good as an introductory statement, but here it is all that is said) or “white aluminium is used for....” (no reason why).

Effects of wrong choices or typical faults (Level III) are not addressed. There is not even any mention of the main influencing factors (work hardness, cutting speed, contact area with circumferential or face grinding etc.) in an overall context.

Finally, no illustration is used to help trainees to imagine concepts like grade and structure.

Instead, the major portion of the text deals with details about bonds which are completely irrelevant for this target group. A technician may have to concentrate on this issue, but basically it is information suited (if at all) to a table book. The page is a good demonstration of what information material should not be like.

CONSTRUCTION OF THE GRINDING WHEEL

At the end of this lesson you shall be able to

- state the different types of abrasives and their uses
- state the different grain sizes and their uses
- state the different grades of grinding wheels
- state the structure of a grinding wheel
- name the bonding materials used for grinding wheels.

In order to suit the grinding wheel for different work situations, the features can be varied such as abrasive, grainsize grade, structure and bonding materials.

A grinding wheel consists of

the abrasive that does the cutting, and the bond that holds the abrasive particles together.

Abrasives

There are two types of abrasives.

Natural abrasive
Artificial abrasive
The natural abrasives are emery and corrundum,. These are impure forms of aluminium oxide.

Artificial abrasives are Silicon carbide and Aluminium oxide.

The abrasives are selected depending upon the material being ground.

‘Brown’ aluminium oxide is used for general purpose grinding of tough materials.

‘White’ aluminium oxide is used for grinding die steels.

‘Green’ silicon carbide is used for very hard materials with low lensile strength such as cemented carbides.

Grain size (Grit size)

The number indicating the size of the grit represents the number of openings in the sieve used to size the grain. The larger the grit size number, the finer the grit

Grade

Grade indicates the strength of the bond and, therefore, the ‘hardness’ of the wheel. In a hard wheel the bond Is strong, and securely anchors the grit in place and, therefore, reduces the rate of wear. In a soft wheel, the bond Is weak and the grit is easily detached resulting in a high rats of wear.

Structure

This Indicates the amount of bond present between the Individual abrasive grains and the closeness of the individual grains to each other. An open structured wheel will cut more freely. That is, it will remove more metal in a given time and produce less heat. It will not produce such a good finish as a closeby structured wheel.

Bond

The bond is the substance which, when mixed with abrasive grains, hold them together, enabling the mixture to be shaped to the form of the wheel, and after suitable treatment to take on the necessary mechanical strength (or its work. The degree of hardness possessed by the bond is called the ‘grade’ of the wheel, and indicates the ability of the bond to hold the abrasive grains in the wheel. There are several types of bonding materials used for making wheels.

Vitrified bond

This is the most widely used bond. It has high porosity and strength which makes this type of wheel suitable for high rate of stock removal. It is not adversely affected by water, acid, oils or ordinary temperature conditions.

Silicate bond

Silicate wheels have a milder action and cut with less harshness than vitrified wheels. For this reason they are suitable for grinding fine edge tools, cutlery etc.

Shellac bond

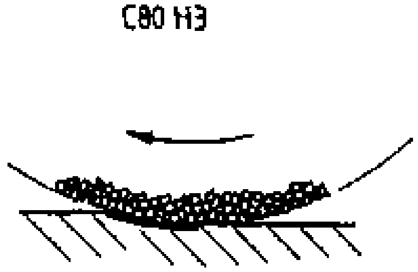
This is used for heavy duty, large diameter wheels where a fine finish to required. For example, the grinding of millrolls.

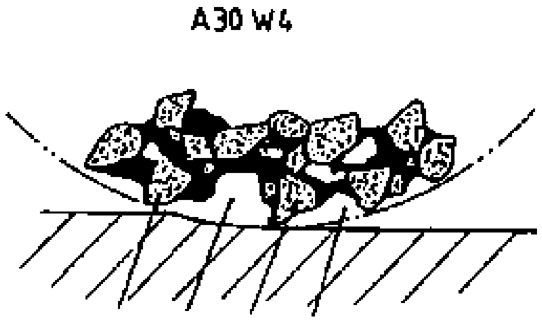
Rubber bond

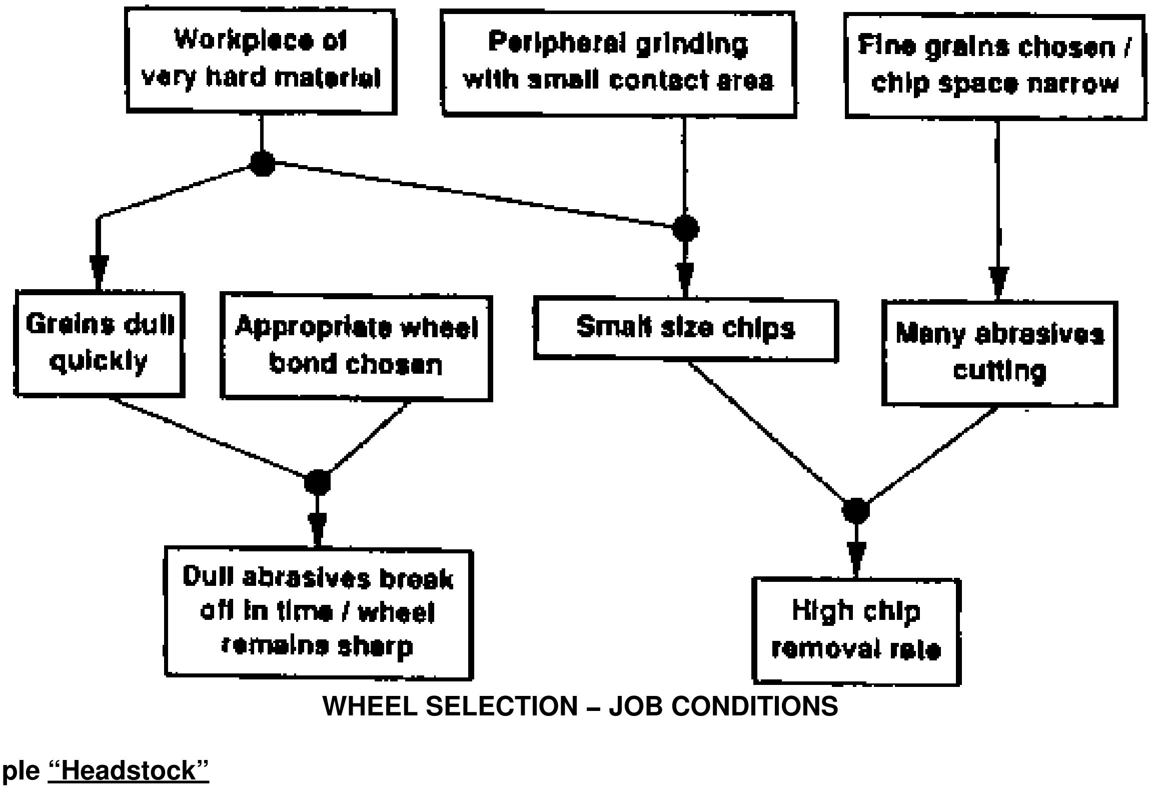
This is used where a small degree of flexibility is required on the wheel as in the cutting off wheels.

Resinoid bond

This to used for high speed wheels. Such wheels are used in foundries for dressing castings. Resinoid bond wheels are also used for cutting off. They are strong enough to withstand considerable abuse.







WHEEL SELECTION – JOB CONDITIONS

Example <u>“Headstock”</u>

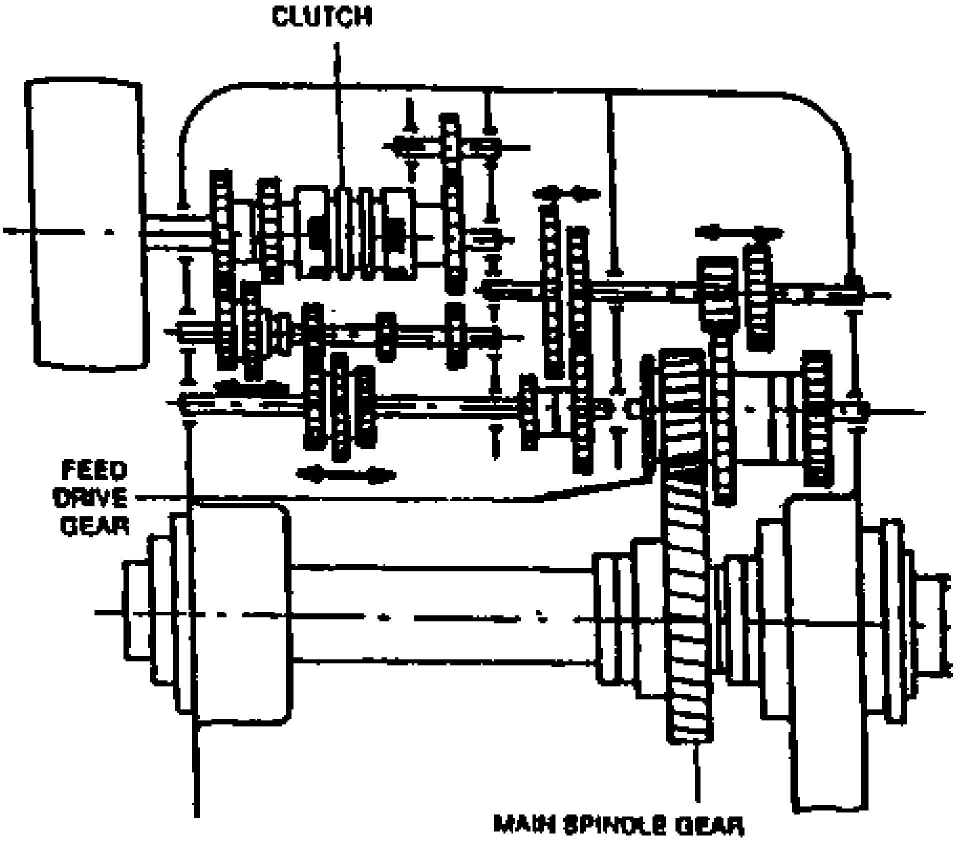
For the accommodation of the shafts it is completely irrelevant whether the housing is of cast or welded design. Only the author knows how a trainee at skilled worker level is intended to grasp the connection between internal webs (not shown anywhere) and stiffening (a highly complex concept). The first two sentences are of no benefit to functional understanding for the target group, because they are pseudo−concrete and generate vague images.

Several elements mentioned in the following sentence ("input shaft", "V−belts", "main motor" or "brake") are unlabelled, providing no link between their location in the picture and the related text information. "Sliding gears" are also mentioned, but there is no detailed information about the flow of power depending on the position of the gears.

The paragraph "functions" (not shown here) states that the headstock "accommodates shafts, gears and levers for a wide range of varying speeds".

This information is too vague to generate images in the mind of the trainee. It simply creates verbalism (verbal chains of words without meaning to the target group, who then have to learn them by heart.

The topic has all the ingredients for a logical structure, but this would require full−page coverage of the relevant details in concrete, visualizable wording related an illustration with labelled details. It would possibly lead to a discovery learning exercise keeping a class busy for 20 minutes with the instructor watching the trainees work out for themselves how the varying speeds are achieved..



All geared headstock (Fig 2)

It is a box section casting having a removable top cover. It has Internal webs for stiffening, and to take shaft bearings. It has an Input shaft which Is connected by means of 'V' belts to the main motor, and It runs at a constant speed. It is equipped with clutches and a brake.

There may be two or more Intermediate shafts on which sliding gears are mounted. The main spindle is the last driven shall In the headstock assembly. The nose of the spindle Is outside the headstock casting, and Is designed to accommodate the work−holding devices.

Example "Carriage"

The introductory statements mention that the carriage is intended to move the cutting tools; in other words to provide the setting and the feed motion in the turning operation.

Bearing in mind that the overall context is the generating of these two motions, the reader will look in vain for an explanation. Nowhere is any information given stating how the feed or setting motion is actually generated or controlled.

The paragraph on the “Apron” lists the main parts but is silent about their related functions and working principles.

The paragraph on the “Saddle” provides exotic details like “H−shaped casting having V−guide grooves”. Purpose unknown.

The paragraph on the “Cross slide” provides some details telling the reader that the cross slide “is moved by means of a screwed spindle fitted with a handle” and goes on to explain the use of the collar.

Unfortunately, there is no sectional view of the components to provide an insight supporting the text.

The illustration inserted at the bottom right, showing a similar mechanism linked to the spindle, may demonstrate what kind of illustration would be needed to link text and picture effectively.

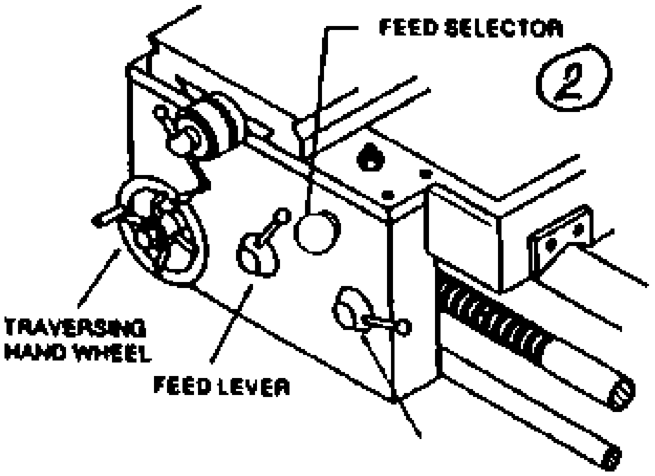
The overall conclusion must again be that either really comprehensive information producing real images in the reader’s mind should be presented, or this part of the training should be left to the workshop demonstration.

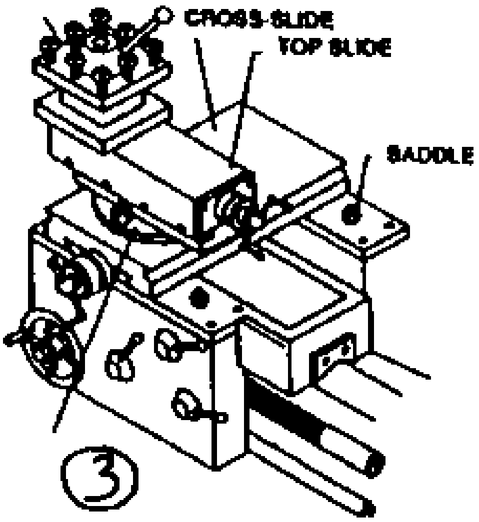
In combination with setting exercises for feed and depth of cut (at standstill), more comprehensive learning can be achieved through an experimental sequence with hands−on practice.

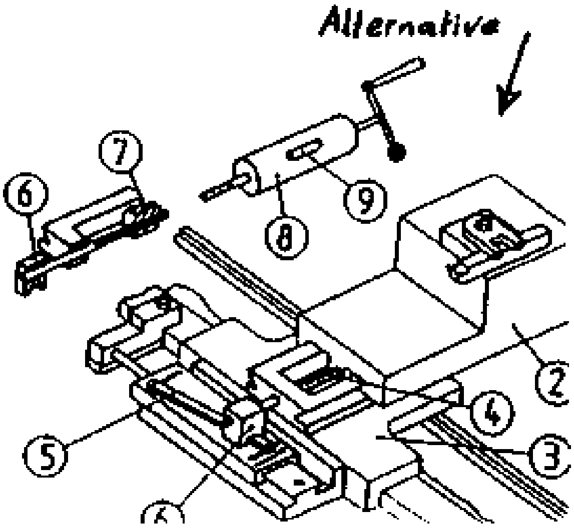
Unless it generates greater depth of understanding, there is little justification for such trade theory in classroom training.

The apron is boiled to the front of the saddle. It contains mechanisms for moving and controlling the carriage. The main parts of an apron are:

- traversing handwheel
- feed lever
- feed selector
- lead screw engagement lever.







Saddle (Fig 3)

It is a ‘H’ shaped casting having V guide grooves at the bottom face, corresponding to the lathe bed−ways for mounting on the lathe bed and for sliding.

Cross−slide

The cross−slide Is mounted on the top of the saddle, and It provides cross movement for the tool. This is fitted at right angles to the bed and Is moved by means of a screwed spindle, fitted with a handle. A graduated collar, mounted on the screw rod along with the hand wheel, helps to set the fine movements of the cross−slide.

EVALUATION CRITERIA FOR INFORMATION SHEETS

A) for text information

1. Is the text specific, generating concrete images either by itself or in connection with labelled details in illustrations? Are abstract statements avoided?

2. Does the text establish context by linkage to either preknowledge or other new information (in cause−effect context or via contrasting aspects in comparisons), using small steps? Have information gaps interrupting the context been avoided?

3. Is text information restricted to the scope defined by the related task bank?

B) for pictorial information

1. Are pictures actually needed either to illustrate part of a text (which cannot be visualized) or to replace text completely?

2. Are the graphics actually illustrative for the target group (e.g. in isometric representation rather than three view projection)?

3. Do illustrations establish context for cause−effect linked issues/topics and help to relate part of a text to a picture? Do the illustrations stress contrasting differences for comparisons?

4. Are the illustrations sufficiently simplified? Good for free−hand sketching? Are all unneeded components left out?

II.9 A SAMPLE SET OF PACKAGE COMPONENTS

The samples attached deal with the topic “brazing” because this is a topic appearing in the syllabi for the metal, the electrician and the automotive trades.

The major drawback is that the samples could not be tested due to time constraints, but it is hoped that the key message is demonstrated with the components.

Content:

P 0 – P 6	Practice material
Th 01 – 02	Theory analysis
D 1 – D 6	Discovery learning material
T 0 – T VIII	Task bank with validity

Justification for the skill sequence

For instructors and trainees alike it should be explained from which project or job the skill sequences originate.

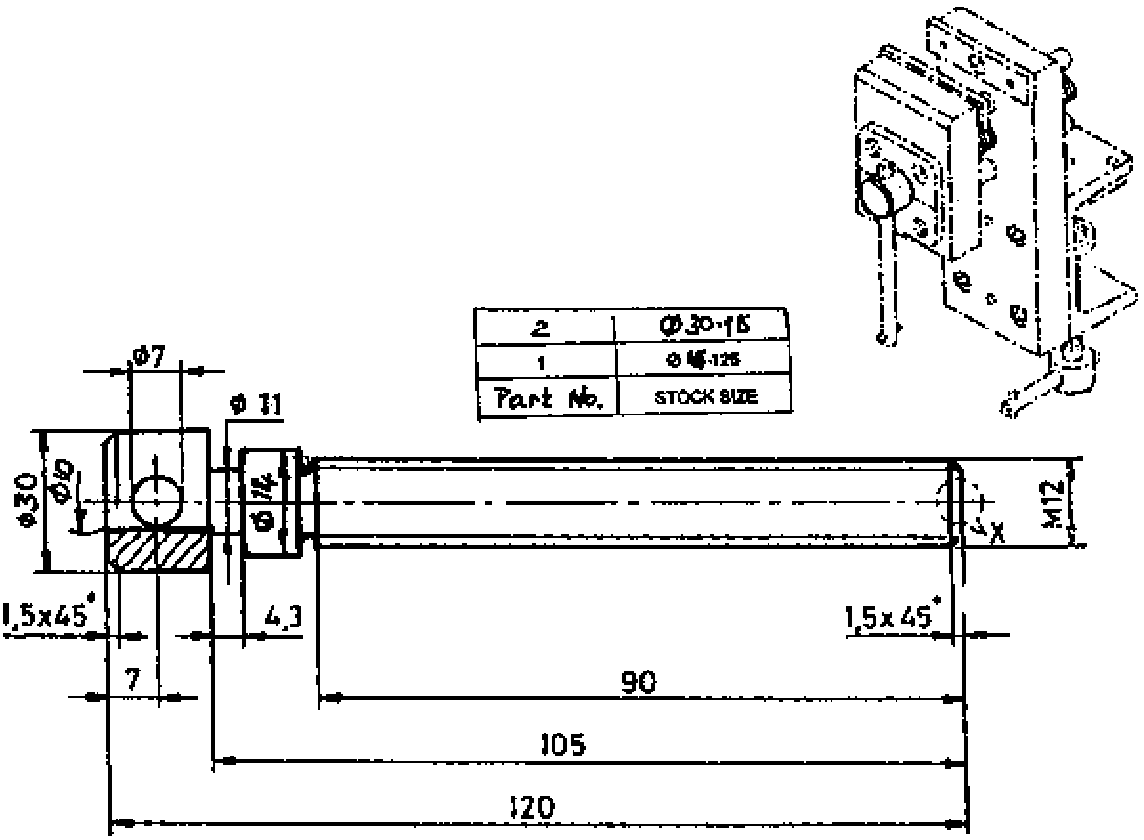
An introductory linkage of the skill sequence to the related project establishes the rational for the particular skills.

A few remarks concerning the design features will be a helpful hint for the instructor in planning his workshop demonstrations.

Page 1 of the sample is meant for the instructor only, but he could easily use excerpts from it for an OHP–tranparency.

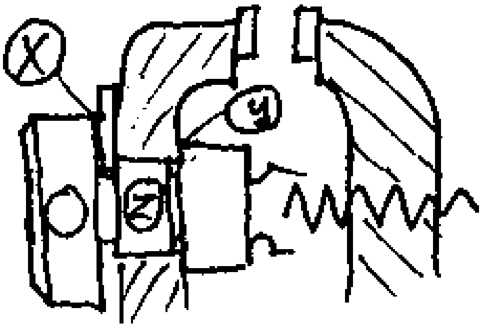
The pages 1 till 4 are meant to replace the pages 311 till 323. Instead of 12 pages there would be only 4 till 6 pages left.

Project:	Portable Vice
Job:	Making of vice screw rod
Skill:	Brazing



2	Ø30-15
1	Ø 16-125
Part No.	STOCK SIZE

Function of part: The jaws are moved by the screw rod. During clamping a considerable thrust force is applied causing high pressure between the flank (X) of the rod and the contact area of the jaw. A minimum size of the contact area is needed to prevent early wear of the thrust areas. The loosening of the screw takes less force so that a smaller area of contact is needed a section (Y) of the rod.



Another critical detail is the size of the rod portion (Z), since it is exposed to heavy bending stress enhanced by sharp corners (making it prone to cracking at these corners). It is therefore advisable to make section (Z) as big as the core diameter of the threaded part of the rod; e.g. some 11 mm minimum diameter.

The maximum diameter of the left end of the rod is therefore defined be the minimum diameter of part (Z) plus the minimum size of the contact area (X).

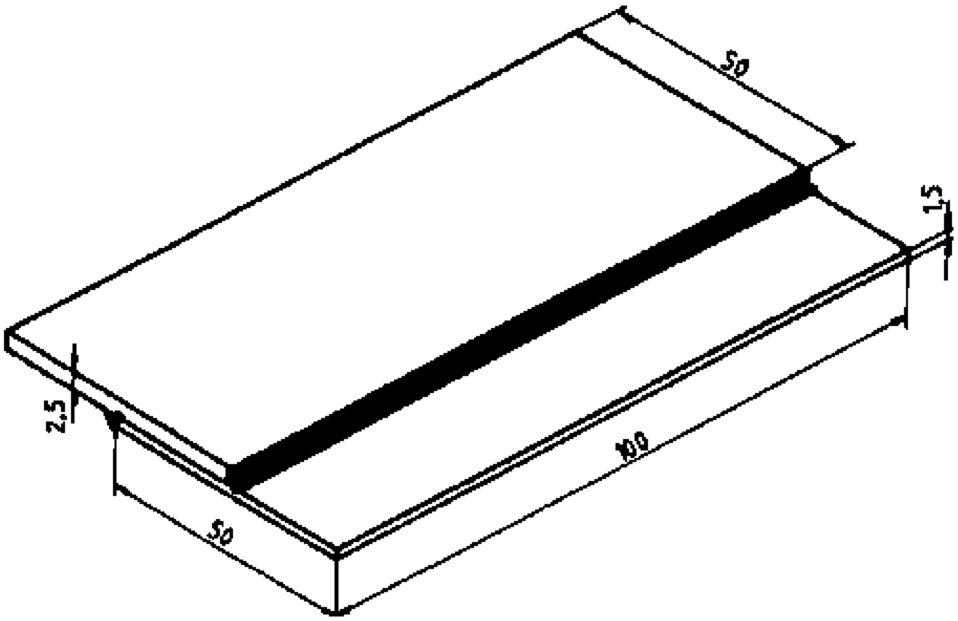
Assuming that a diameter of 30 mm would be sufficient this meant that a round bar of 30 mm is needed for making the screw rod resulting in excessive rough turning to reduce the right hand part of the rod to its nominal size for the thread.

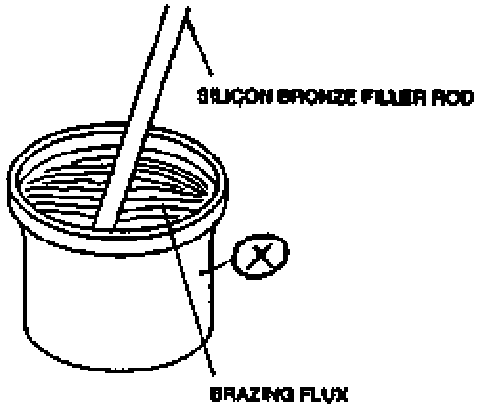
For cutting the thread a diameter of 14 mm will do. The thrust force for loosening the jaws can be held by a rod stepped from 14 mm large dia to 11 mm small dia.

A bush part with 10 mm bore and 30 mm external dia would fulfill the need of providing the necessary thrust area for the clamping. Joint to the rod by brazing it could save material cost and time. A fit with H7/e8 would be fine for the necessary clearance. The cross hole for the handle were to be drilled after brazing.

SKILL SEQUENCE: X

BRAZING OF SHEETMETAL / LAP JOINT OF UNEVEN THICKNESS





1. Get or prepare the mild steel plates as per drawing. If not available in the store take the next higher sheet thickness.

2. Clean the overlapping contact surface portions of the sheets to be brazed plus a strip of 10 mm. The minimum overlapping width is 3–times the thickness of the thinner sheet.

Use steel wire brush, emery cloth or file for cleaning. Ensure the complete removal of rust, mill scale, paint or slag.

3. Place the sheets as lap joint putting the thicker plate on top with an equal width of the overlapping portion. Put another strip if thin sheet under the opposite end of the to sheet for balance.

4. Use size 5 nozzle and lighten the gas welding flame. The nozzle needed is one number larger than the one used for welding the same sheet thickness, because the whole area to be joined must be brought to red hot before brazing can start.

5. Set the soft flame to neutral or carburising (yellow). Take bronze/brass filler rod of approximately 1,6 mm diameter.

6. Heat the complete lap section of the upper sheet to red colour before nearing the filler rod to the joint. Hold the blowpipe in position to provide more heat to the thicker sheet, but move the blowpipe to and fro along the joint section and take your time to distribute the heat evenly over the whole length of the joint.

7. Only after the whole area is of dull cherry colour dip the rod into the brazing flux pot (X) and then hold it to the open gap of the lap. Keep the flame away while the rod is pressed against the joint's corner. Never apply the flame directly towards the rod! Never let the sheet metal colour turn yellow or light red!

8. Watch the rod tip melting and spreading due to the heat stored in the sheets. Keep melting down brazing metal until the joint is filled (filler sucked in due to capillary action) and accumulates at both joint ends. Repeated dipping of rod into the flux can help

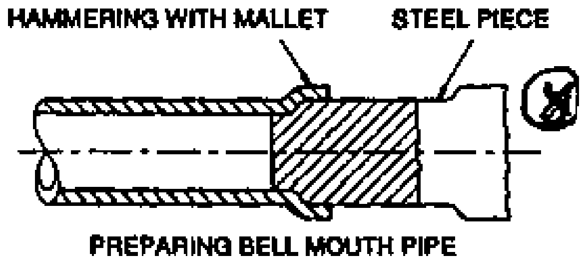
In case the rod does not melt or does not spread into the joint apply the flame towards the upper sheet metal again to and fro.

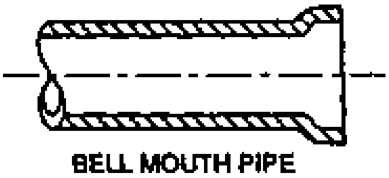
9. Take the flame away and allow the joint to cool for about 15 seconds before taking the sheets with a tong.

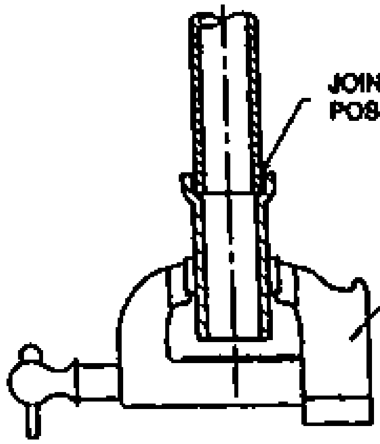
Turn them upside down for inspection of the lower side and check whether the brazing metal has appeared evenly at the lower end of the joint, too, indicating a complete filling of the gap.

10. Clean the joint on both ends with steel brush and emery cloth and check for smooth surface without pin holes along the seam..

SKILL SEQUENCE Y: SLIVER BRAZING OF COPPER PIPES







The working steps beyond 3 are the same like in SS BX:

1. Either prefabricated fittings are available that have the required clearance between pipe and fitting already or one pipe must get made a bell mouth end.

For that a bell shaped steel rod is used as a template and the copper pipe end is pushed over it by means of a mallet and hammer. (Y) In case the copper is too brittle a prior annealing of the pipe end (to red hot colour) will help to soften it.

2. Clean the joinig edges of the pipes (inside of the bell mouth end in particular!).

Check the clearance between the pipes (ideally 0,05 mm for silver alloy brazing).

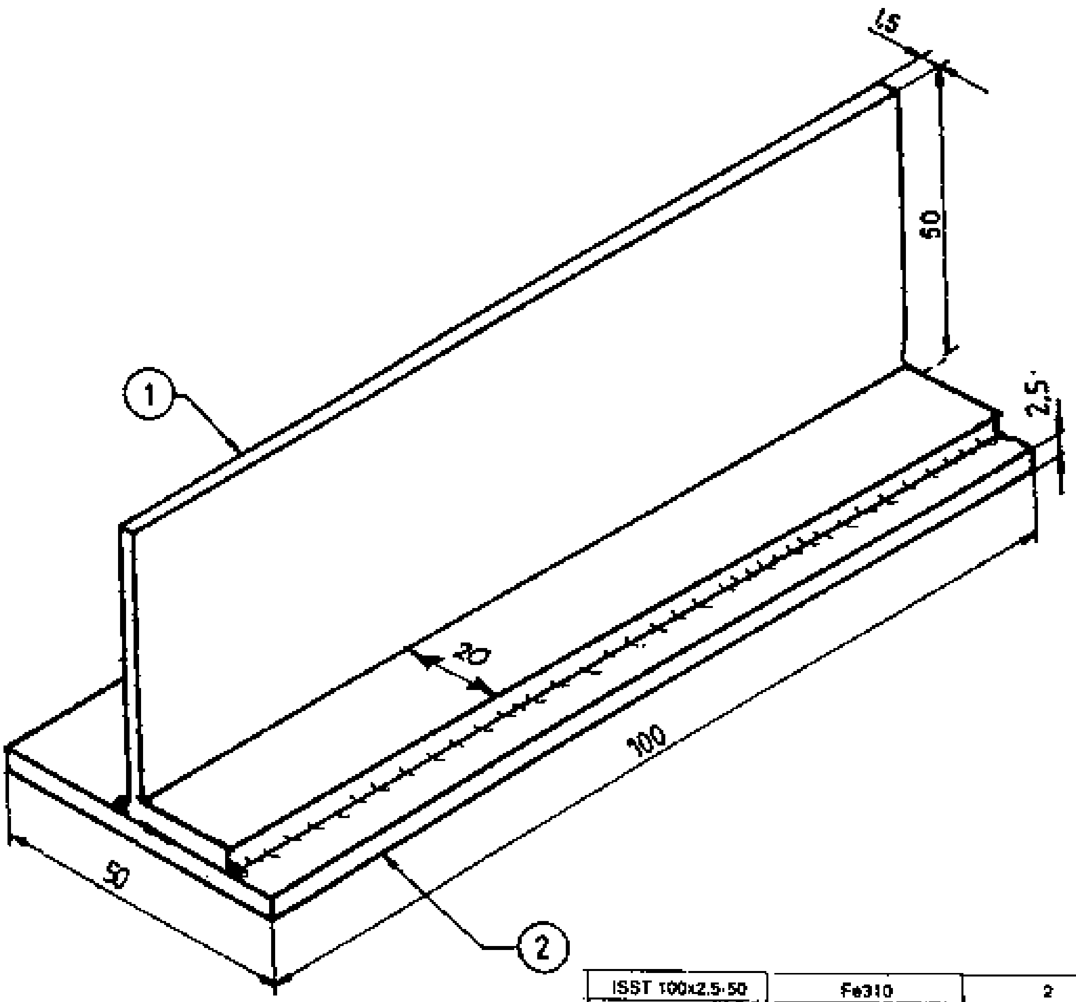
3. Clamp the pipes to be joined in a bench vice (Z)

4. Repeat all the steps of the SS BX above by taking into consideration that copper is a better heat conductor than steel and that a silver brazing rod type BA−Cu−Ag 12 of 1,6 mm dia is−used together with a silver brazing flux.

Heat to dull red colour again by plying the carburising flame gently around the joint.

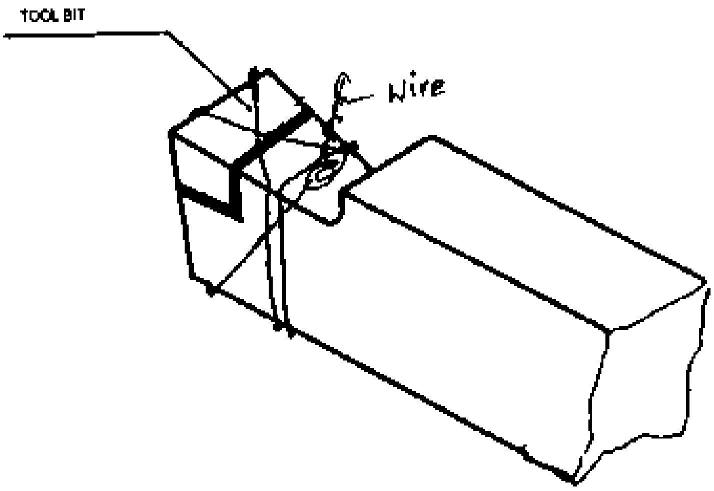
ADDITIONAL EXERCISES see next page!

The brazing of the tool tip to be done only as a reward for the best performers!



ISST 100x2.5·50	Fe310	2
ISST 100x1.5·50	Fe310	1
STOCK SIZE	MATERIAL	PART NO.

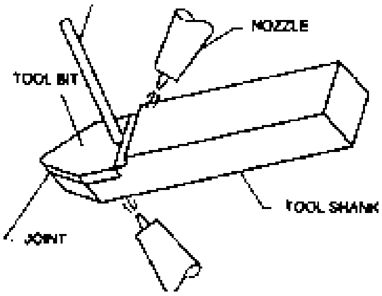
T–FILLET BRAZING



Tool bit	HSS
Tool shank machined	Fe310
SEMI-PRODUCT	MATERIAL

SILVER BRAZING OF TOOL BIT

Give more heat to the shank!

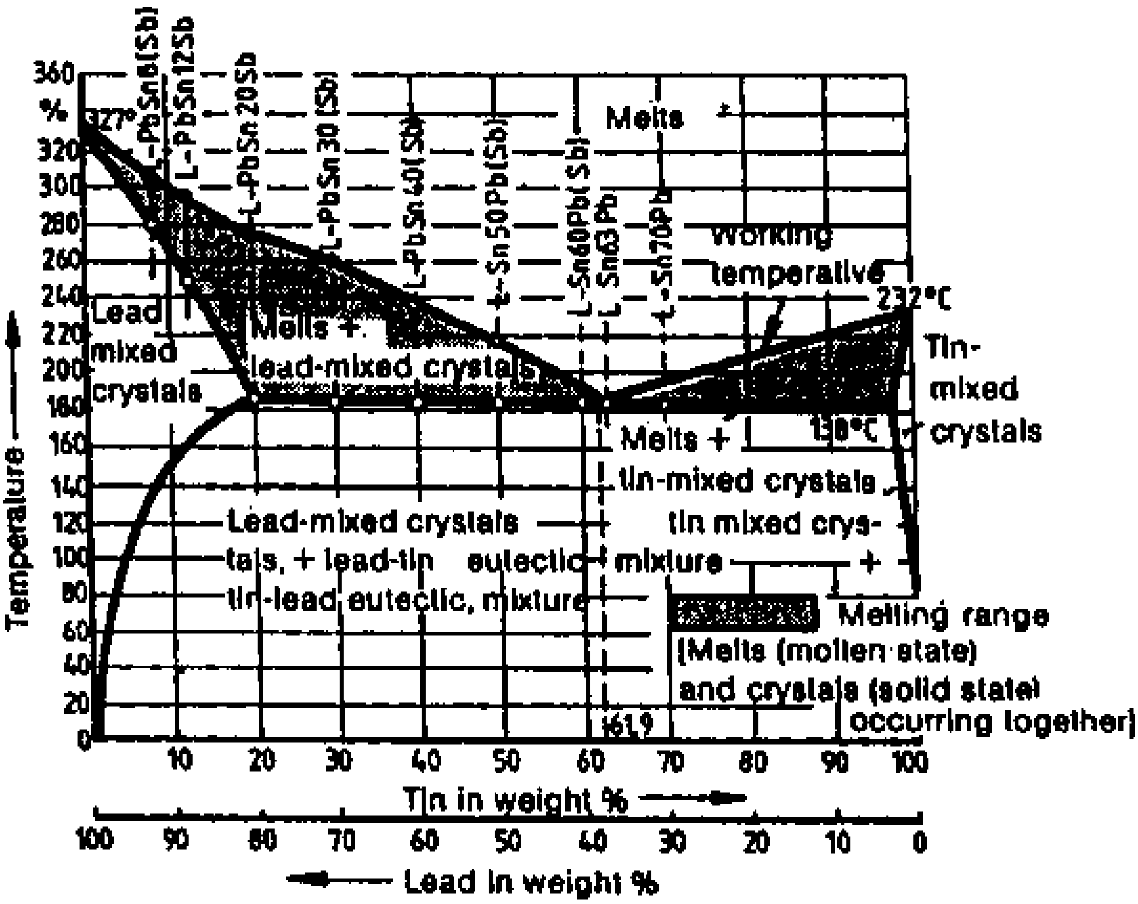


SILVER BRAZING OF TOOL BIT

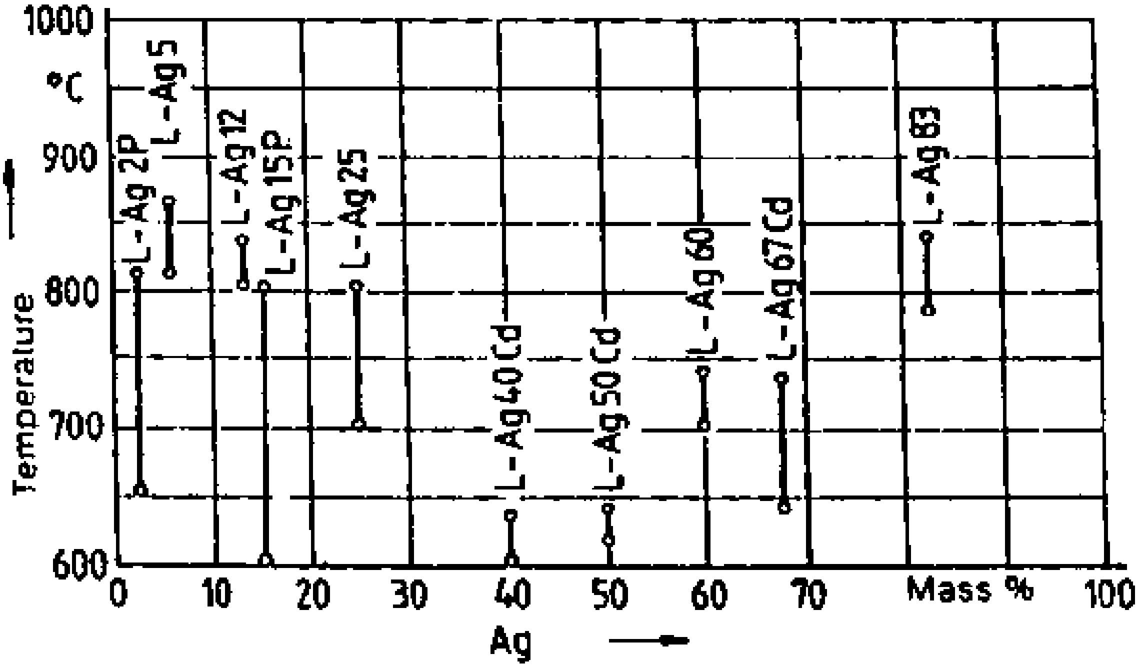
TABLE BOOK INFORMATION

Features of commonly used brazing metals

Braze metal	Composition	Heating source	Optimal gap clearance	Base metals
Brazing	60% Cu	Weld. flame	0,5 – 0,7 mm	Steel, Cu, Cu–alloy
brass	40 X Zn	Furnace, Dip		nickel, Cu–alloys
Silver	5–80% Ag	Weld. flame	0,04 – 0,05 mm	Steel, Cu, Cu–alloy
alloys	15–52% Cu	Furnace, Dip		Ni, Ni–alloys,
	Zn+Sn+Cd	Induction		Stainless steel



Equilibrium diagram for lead–tin



Melting range of hard solders containing silver

Topic: BRAZING

LIST OF PROBLEMS (Related theory)

A closer look at the critical steps of the skill sequence for “BRAZING” reveals the essential differences to welding. Typical problem areas are derived from the common defects in soldering/brazing jobs:

1. molten filler and solid base metal not forming alloys due to poor diffusion of filler atoms into solid base metal structure

2. dependance of diffusion on clean metal contacts and difficult control of working temperature

3. special heating patterns as different from welding resulting in special clamping needs until solidification took place

4. dissolution of oxides and working principle of fluxes and their temperature range

5. limited strength of filler metal and related enhancement of size of contact areas, making the lap joint the common version

6. dependance of capillary action (in lap joints) on surface roughness and width of the gap between sheets

This list leads to the following lists of tasks (next pages).

The application of the relevance check identifies some topics that seem suitable for discovery learning exercises.

Since there are two main fields for discovery learning two comparative exercises are meant to clarify the differences between welding, soldering/brazing and glueing, as well as the impact of the use or non−use of fluxes.

The four cause−effect structures address the impacts of clean surfaces, oxide layers, capillary action and the selection of solders.

The additional information to be covered in the information sheets are:

- conditions for diffusion of atoms into solid surfaces
- principle of capillary action and major factors on it
- design of lap joints with respect to enhanced contact area

RELEVANCE CHECK for topic BRAZING/SOLDERING

A. Linkage to workshop situations

1. Technique of joining sheet metals as lap joint and of fitting copper pipes with appliances

2. Joining tools like carbide tips on tool holders for turning or of joining ends of endless sawing blades

3. Making metallurgic joints in electric wiring like joining a copper cable with a brass thimble

B. Interlinkage of the content

1. base metal not molten − filler in liquid state − diffusion −any combination of base metals

2. unclean surface − no metal contact − no alloy formation−poor strength

3. Gap too wide − no sucking effect/capillary action − no filling of gap − poor strength

4. Equilibrium diagram for tin solders − selection of solder −working temperature − solidification range

C. Relation to other topics

1. Permanent joints like glueing oder welding

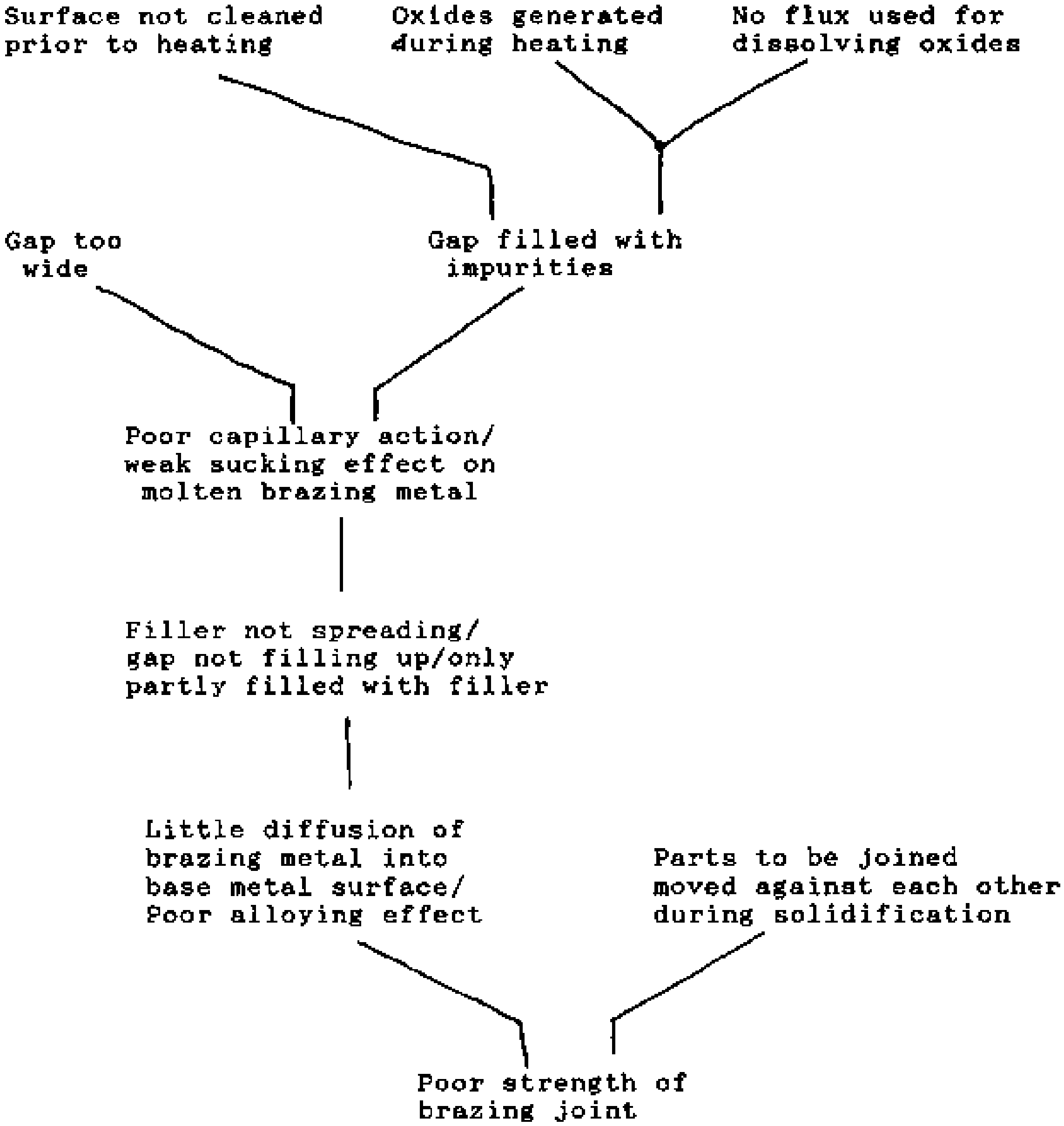
2. Overlap joints like riveting or spot welding

3. Joining of pipe systems with threading, sqeezing, glueing

4. Diffusion processes like case hardening of steel surfaces or decarburising of steel during annealing processes

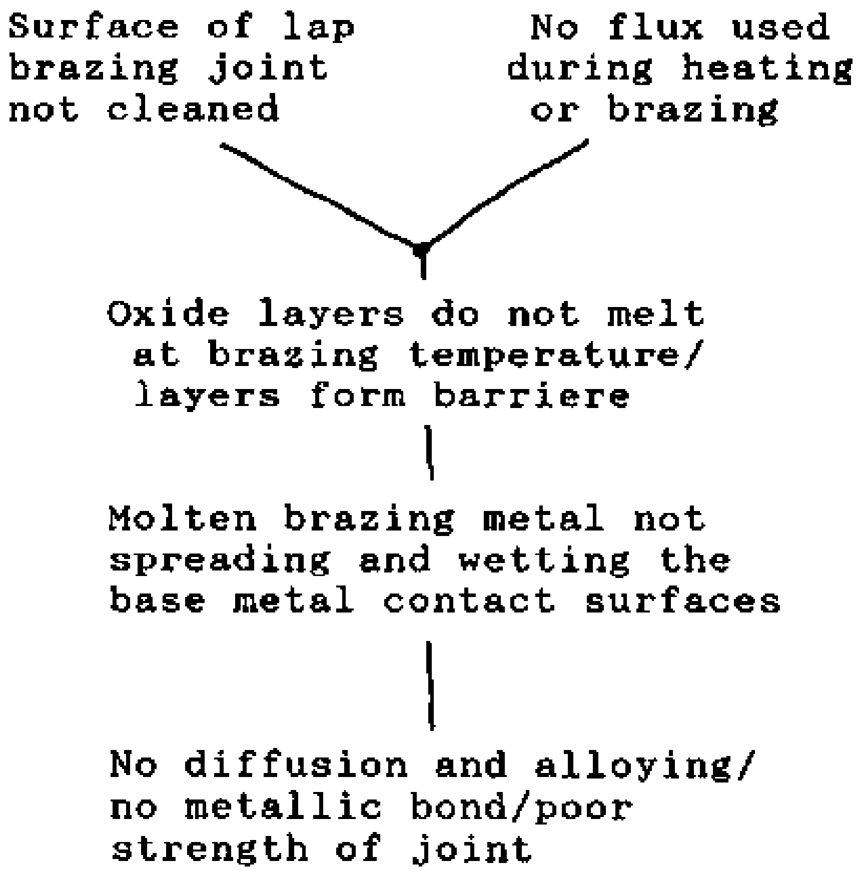
The above list proves the relevance of the trade theory contents for the topic soldering/brazing to justify a comprehensive coverage in the theory sessions.

It is worth trying to draft discovery learning exercises in addition to providing many common tasks of all three levels and the usual theory information sheets.



PROBLEM TREE (Complex logic structure for instructor)

Task: Why are clean surfaces essential for the strength of brazing joints?



Surface of lap brazing joint not cleaned

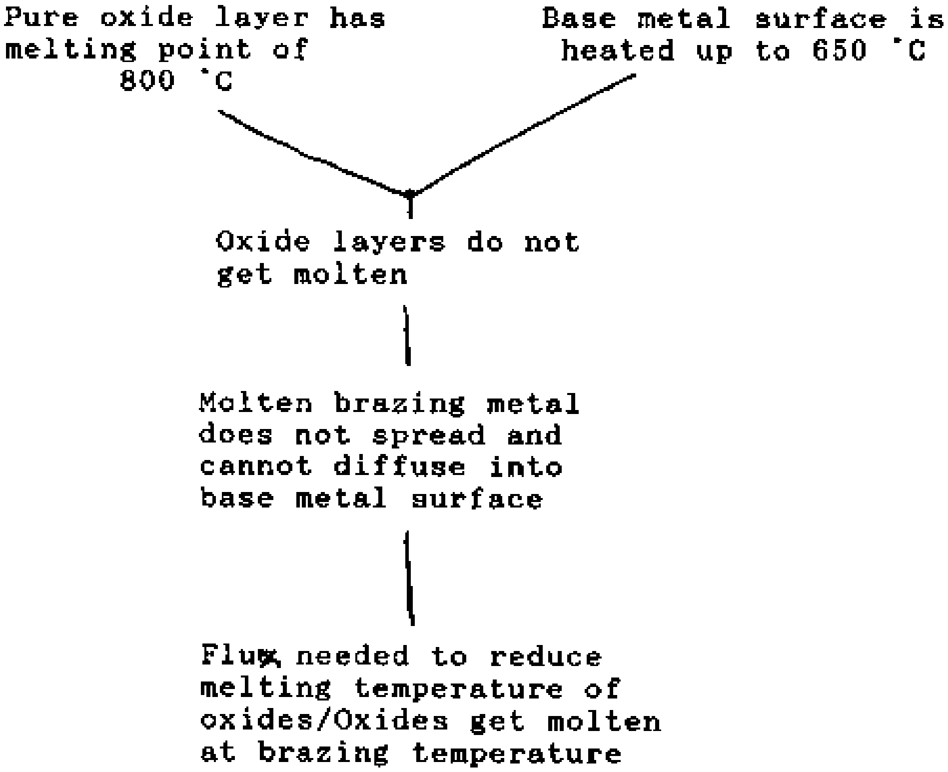
No flux used during heating or brazing

Oxide layers do not melt at brazing temperature/ layers form barriere

Molten brazing metal not spreading and wetting the base metal contact surfaces

No diffusion and alloying/ no metallic bond/poor strength of joint

Task: What is the effect of not using flux on the oxide layers?



Pure oxide layer has melting point of 800 °C

Base metal surface is heated up to 650 °C

Oxide layers do not get molten

Molten brazing metal does not spread and cannot diffuse into base metal surface

Flux needed to reduce melting temperature of oxides/Oxides get molten at brazing temperature

Task: Why is capillary action essential for the strength of the brazing joint?

Gap between contact surfaces of base metal too wide

Gap width allright,but base metal contact surfaces covered by oxides

Poor capillary action/ weak sucking effect on molten brazing metal

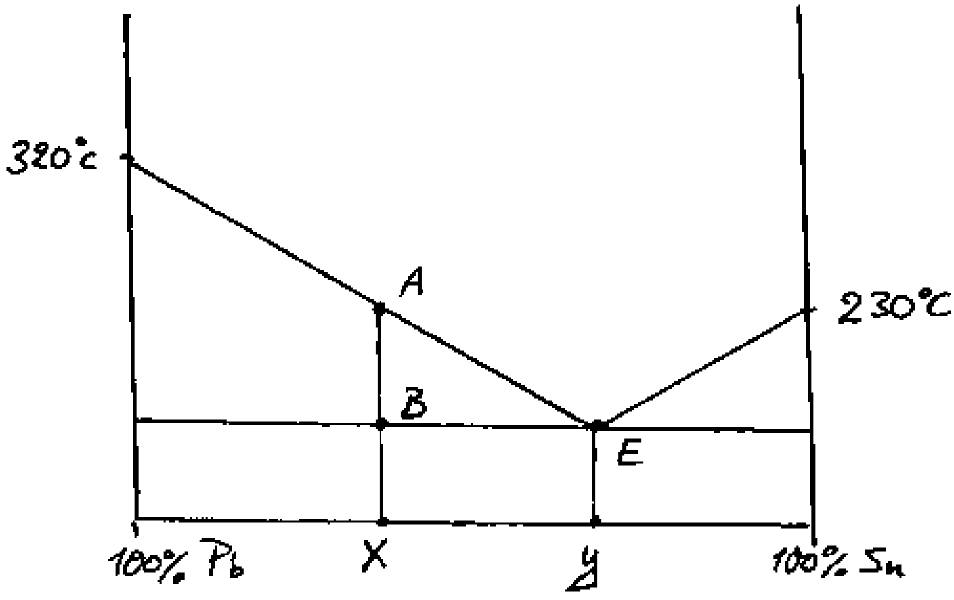
Only one side of the base metals heated to brazing temperature

Brazing metal not spreading and flowing into gap of lap

Molten brazing metal flows into gap but gets stuck half-way in lap

Only part of contact surface covered with brazing metal/ Poor strength of joint

Task: Why is tin solder of composition Y most suitable for soldering a copper wire?



Job: Copper wire to be soldered with brass thimble

Tin solder of composition X selected for use

Tin solder of composition Y selected for use

Longer heating time/ Period for solidification longer as well (from A to B)

Shorter heating time/ quick conversion from liquid to solid state, too

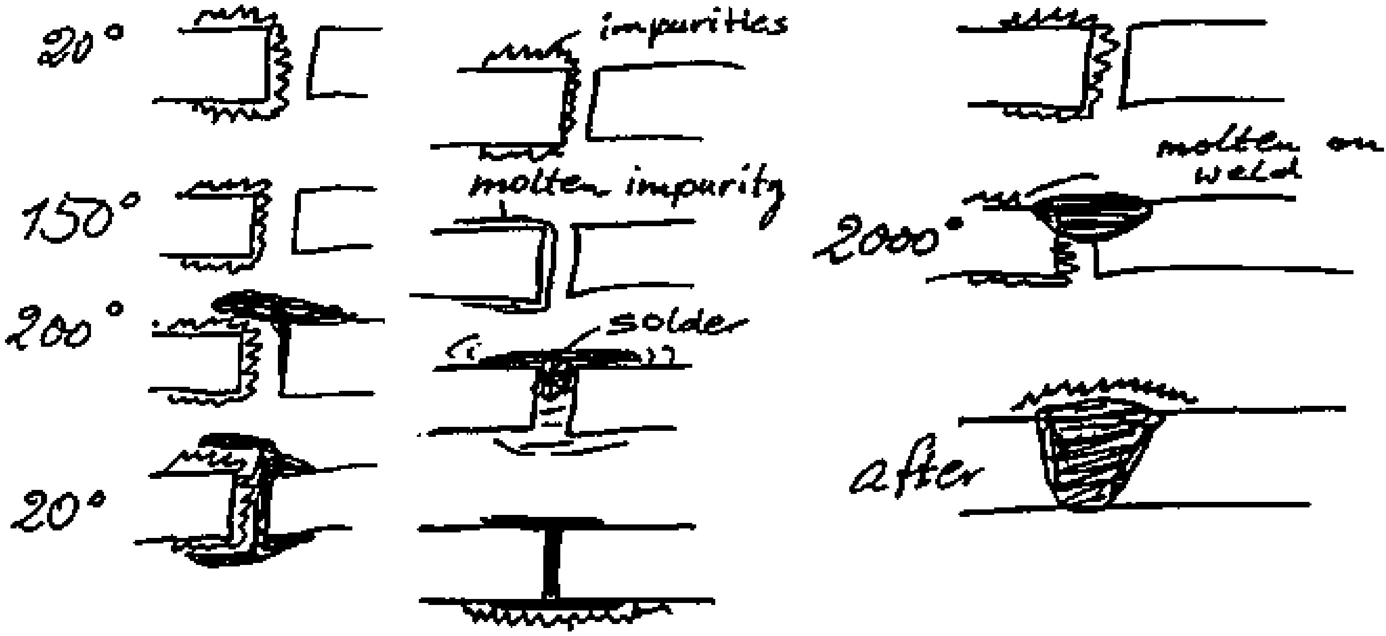
Higher risk of displacement of components during solidification period

TROUBLE SHOOTING CHART “BRAZING”

SYMPTOMS	DEFECTS	CAUSES	REMEDIES
1. Brazing metal rod does not melt when held against base metal surface	Rod not melting	a) Base metal not heated to working temper.	a) More warming up needed OR bigger torch
		b) Heat not distributed evenly in base metals. Working temp, only in parts of base	b) Flame to be moved to and fro across base metals. Bigger wall size needs heating longer
2. After melting the molten metal does not spread/not wet the surface accumulating at gap front	Brazing metal not wetting and spreading	a) Contact surfaces not clean/covered by oxides	a) Better cleaning prior to brazing
		b) New oxides occure during heating	b) Fluxes have to be used
3. Braze joint cracked under load. Broken lap surface shows poor spreading of brazing joint	a) like 2	a) like 2a/b	
	b) Poor capillary action/no filling of gap of lap	b) Gap too wide	b) Gap width to be adjusted acc. to table
4. Braze joint broken although broken surface shows good distribution of filler a) porous structure b) no porous str.	Lack of strength of joint	a) Filler overheated/alloy component burned b) Base parts not clamped firmly during cooling/solidification	a) Better check of temperature e.g. with color sticks or rod b) Clamping fixtures needed during cooling No moving of parts permitted

DLE: COMPARISON OF PROCESSES

A = Soldering without flux B = Soldering with flux C = Welding



While the filler is molten, the oxides remain solid	Reacts with oxides and reduces their melting point	Puddle temperature of molten base is double the base melting point
Melting point of oxides higher, than that of filler rod	Melting point of oxides lower than that of filler rod	Any impurities get molten and swim on top due to density
Wetting of contact surface cannot take place	Molten filler metal pushes away molten oxides	Surface layers of oxides melt during liquifying of edge
Impurities prevent direct contact between filler metal and base, no diffusion	Molten filler can spread on contact surface and diffuse into surface	After cooling and solidification the oxide layers are found as scale

DLE: Comparing types of permanent joints

A = glueing/adhesive bond	B = Soldering/Brazing	C = Welding
Surfaces need perfect cleaning	Definite clearance between mating parts to be joined a must	Gap size tolerance largest
Equal thickness of filler material on contact surface a must	Melting temperature of filler material lower than any base	Surface can be rough and covered with oxide layers
After spreading the filler material some time is needed for a chemical reaction	Base metals can be different as long as they react with filler	Base metal gets molten to a minimum depth
Surfaces pressed together once filler is ready (or warm)	A hot copper tip as well as a propane flame can be used for heating the joint	Filler and base metal usually equal
Lap joints possible exclusively	After heating up the base metal joint section the flame is pulled away	Fusion of all components, but molten puddle only in small locality
Temperatures above 250°C usually fatal for joint	Filler rod melts due to heat stored in the base metals	Flame or electric arc generate temperatures of more than 3000°C
Metal components can be joined with non−metal	Lap joint most common (biggest contact areas) but butt joint possible	Preheating of base metal only as exceptions
Joint can serve as electric insulation	Flux to be removed to prevent electrolytic corrosion	Quick cooling common with ensuing stress
	Components must be held together until joint is cooled and solidified	Butt and fillet joints common; lap joints lead to fillet joints at both sheet ends

VALIDITY CHECK FOR TASK BANK OF TOPIC “BRAZING”

The SUBJECT MATTER VALIDITY CHECK is carried out on the basis of 5 major issues within the topic brazing/soldering:

1. Soldering/brazing as different from welding and glueing Diffusion, pseudo−alloys, contact area size (overlapping)

2. Surface conditions for diffusion, oxidation problems, flux wetting and spreading action

3. Conditions for capillary action: temperature, gap width, surface features

4. Temperature ranges, equilibrium diagrams, heating patterns

5. Typical usage, corrosion aspects, miscellanious

Item No.	**Issues**					**Levels**			**Types**			**Pictures**	
	1	**2**	**3**	**4**	**5**	**I**	**II**	**III**	**SA**	**MA**	**MC**	**yes**	**no**
1		**X**					**X**		**X**				**X**
2		**X**					**X**		**X**				**X**
3		**X**				**X**			**X**				**X**
4				**X**			**X**		**X**				**X**
5				**X**			**X**		**X**				**X**
6					**X**		**X**		**X**				**X**
7					**X**		**X**		**X**				**X**
8					**X**		**X**		**X**				**X**
9				**X**			**X**		**X**				**X**
10	**X**							**X**	**X**				**X**
11	**X**					**X**			**X**				**X**
12		**X**	**X**					**3**		**X**		**X**	
13			**X**	**X**				**3**		**X**		**X**	
14		**X**	**X**					**3**		**X**		**X**	
15				**X**			**3**			**X**		**X**	
16	**X**			**X**				**3**		**X**		**X**	
17	**X**						**3**			**X**			**X**
18	**X**					**X**					**X**		**X**
19		**X**						**X**			**X**	**X**	
20		**X**		**X**				**X**			**X**	**X**	
21			**X**				**X**				**X**	**X**	
22	**X**						**X**				**X**	**X**	
23			**X**				**X**				**X**		**X**
24			**X**	**X**			**3**			**X**		**X**	
	6	**7**	**6**	**8**	**3**	**3**	**20**	**15**	**11**	**7**	**6**	**11**	**13**

dd

Comment:

a) subject matter coverage: The issue 5 is under−represented. Further items should address typical use of soldering/brazing.

b) levels of complexity: The ratio of levels I and II is o.k.

c) distribution of types: Not bad

d) ratio of pictorial items: Too poor. SA questions need pictures

Tasks derived from the skill sequences

1. Prior to brazing the contact surfaces must be freed from paint oil or grease. What other common impurity is to be removed?

Key: Rust or metal oxides

2. For the removal of oil or grease the use of emery cloth or other mechanical cleaning method is not advisable. Which other way of cleaning is more appropriate?

Key: chemical cleaning solvent e.g. petrol

3. For mechanical cleaning the emery cloth or files are used. What other mechanical cleaning tool is common?

Key: Wire brush

4. What is the temperature range for silver brazing? To what colour are steel sheets heated up before this filler rod is added?

Key: 650 °C till 850°C, dark sherry red

5. Why is the same nozzle size used for brazing as well as for gas welding steel sheets of the same thickness? Compare heat distribution and working temperature in your answer!

Key:

a) The whole brazing section is heated up thorougly (brought up to working temperature) simultaniously.

b) Temperature is brought up to double the brazing temperature for the molten puddle in welding.

6. Silver brazing is used for connecting electrical components (like cable end and thimble). What makes it superior to screw clamping?

Key: Better electrical conductivity

7. Why is it a workrule to remove the residual flux after the brazing or soldering is completed?

Key: Flux generates corrosion

8. What safety precaution is needed whenever chemical solvents like petrol are used to remove impurities from the contact surfaces?

Key: Venting of the workshop (ventilators or open windows)

9. Why is the torch moved to and fro pior to brazing of steel whereas it is common practice to focus the flame to one spot in welding? Refer to the desired temperature in your answer!

Key: For brazing the equal distribution of red hot temperature is essential. The steel melting temperature can be achieved only in a small spot in welding.

10. What will happen in case the two components are not fixed firmly until the filler is completely solidified?

Key: There will be cracks in the filler (inspite of a complete filling of the gap)

11. What is the minimum width for the overlapping of sheets in a solder/brazing joint?

Key: 3−times the sheet thickness

12 Tasks derived from Discovery Learning Exercises

1) Match the letters to structure!

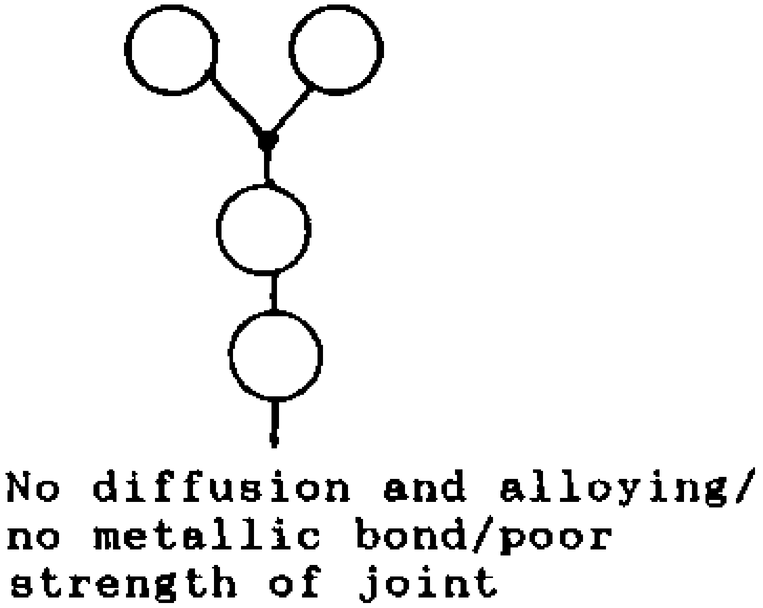
A = Surface of lap brazing joint not cleaned

B = Molten brazing metal not spreading and wetting the base metal contact surfaces

C = Oxide layers do not melt at brazing temperature/ layers form barriere

D = No flux used during heating or brazing

1) Why are clean surfaces essential for the strength of brazing joints?



13

A = Only one side of the base metals heated to brazing temperature

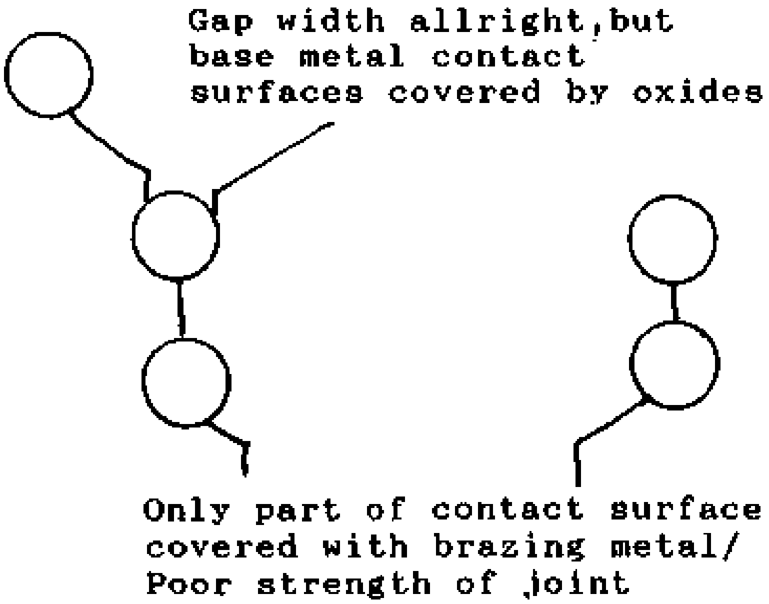
B = Brazing metal not spreading and flowing into gap of lap

C = Gap between contact surfaces of base metal too wide

D = Molten brazing metal flows into gap but gets stuck half−way in lap

E = Poor capillary action/weak sucking effect on molten brazing metal

2) Why is capillary action essential for the strength of the brazing joint?



14

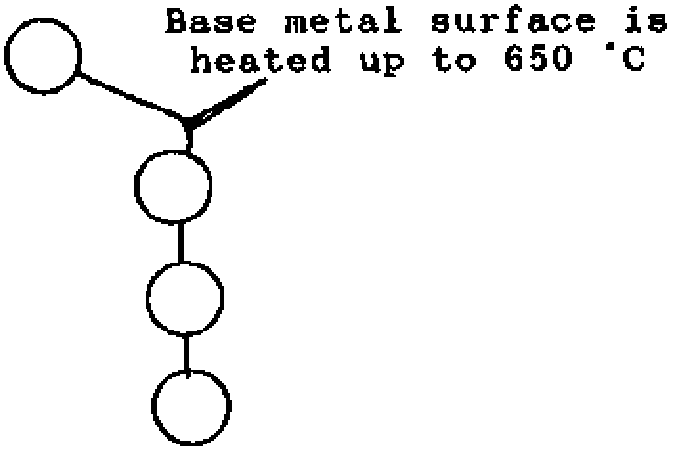
A= Flux, needed to reduce melting temperature of oxides/Oxides get molten at brazing temperature

B = Molten brazing metal does not spread and cannot diffuse into base metal surface

C = Pure oxide layer has melting point of 800 °C

D = Oxide layers do not get molten

3) What is the effect of not using flux on the oxide layers?



15

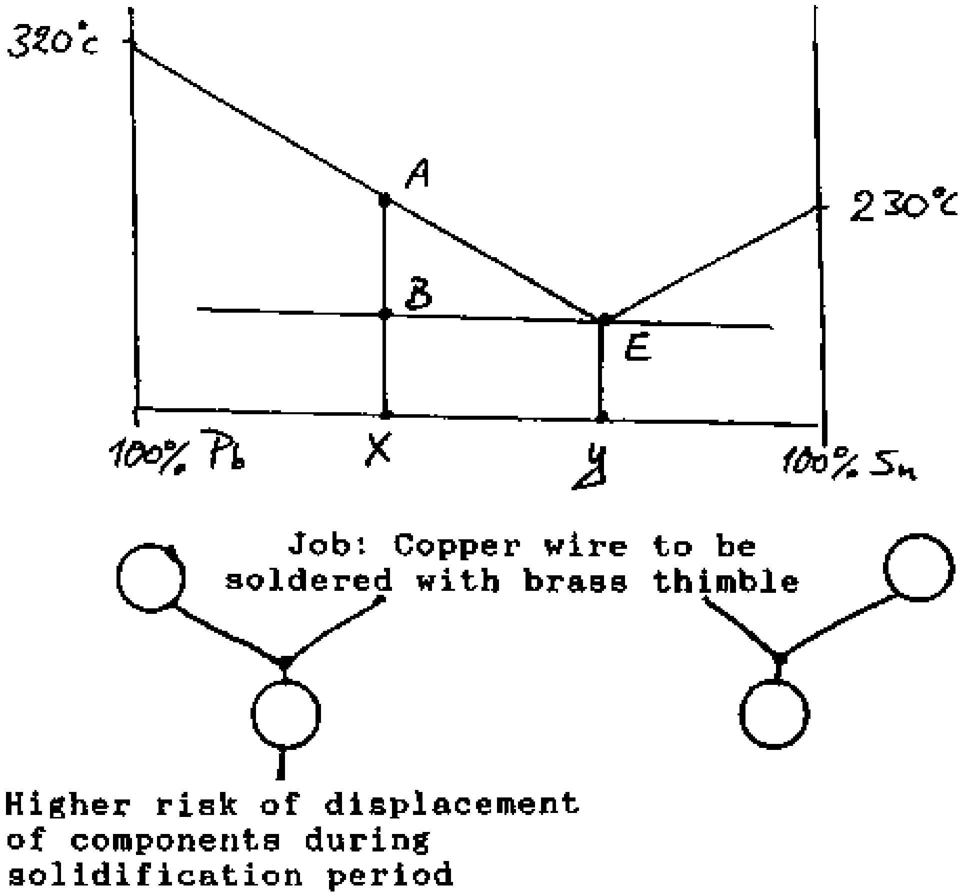
A = Tin solder of composition X selected for use

B= Shorter heating time/quick conversion from liquid to solid state, too

C= Longer heating time/Period for solidification longer as well (from A to B)

D = Tin solder of composition Y selected for use

4) Why is tin solder of composition Y most suitable for soldering a copper wire?



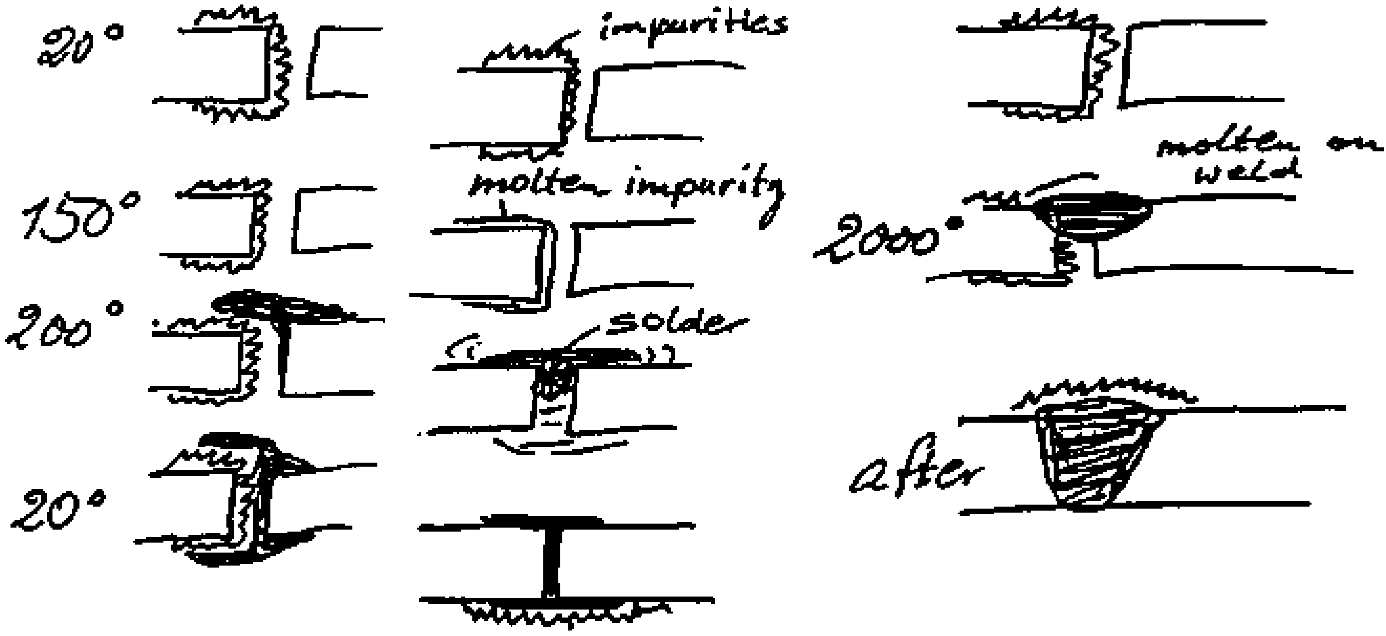
16

5) Match the letter A, B or C to the statements!

A = Soldering without flux

B = Soldering with flux

C = Welding



___ Molten filler can spread on contact surface and diffuse into surface

___ Reacts with oxides and reduces their melting point

___ Surface layers of oxides melt during liquifying

___ Impurities prevent direct contact between filler of edge

metal and base, no diffusion

___ Any impurities get molten and swim on top due to density temperature

___ Melting point of oxides lower than that of filler rod

___ Puddle temperature of molten base is double the base melting point

___ While the filler is molten, the oxides remain solid

___ Molten filler metal pushes away molten oxides

___ Wetting of contact surface cannot take place

6) Match the letter A, B or C to the statements!

17

A = glueing / adhesive bond B = Soldering / Brazing C = Welding

___ A hot copper tip as well as a propane flame can be used for heating the joint

___ Surface can be rough and covered with oxide layers

___ Quick cooling common with ensuing stress

___ Base metal gets molten to a minimum depth

___ Butt and fillet joints common; lap joints lead to fillet joints at both sheet ends

___ Components must be held together until joint is cooled and solidified

___ Equal thickness of filler material on contact surface a must

___ Molten puddle only in small locality

___ Surfaces pressed together once filler is ready (or warm)

___ Metal components can be joined with non–metal

___ Melting temperature of filler material lower than any base

___ Filler rod melts due to heat stored in the base metals

___ Temperatures above 250°C usually fatal for joint

___ Joint can serve as electric insulation

Other tasks

18

1. What is the typical feature for brazing as opposed to welding?

A During brazing only the brazing metal is heated up.

B The material ends to be joined and the filler are molten.

C The melting point of the brazing metal is below the melting temperature of the higher melting base metal.

D Only the brazing metal is melting.

19

2. What is a description fitting to picture B?

A The solder is in molten state and the base has reached working temperature.

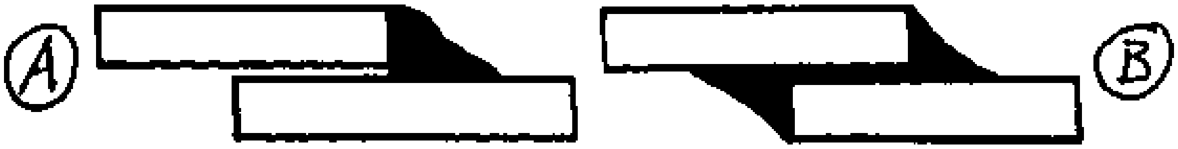
B The molten solder is wetting the base metal surface.

C An oxide layer on the base metal surface prevents the spreading of the molten solder.

D This is the state in which the diffusion (alloying) takes place

(20)

3. What is the description that fits best to picture A?



A The solder is molten but not yet wetting the base metal end.

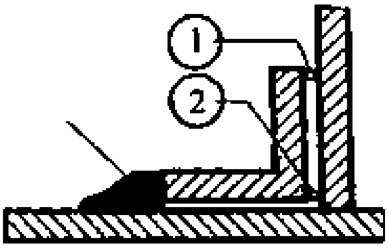
B The gap is too wide so that there is no capillary action.

C Oxide layers narrow the gap between the contact surfaces.

D The heating of the upper sheet metal is insufficient.

21

4. The picture shows a solder prior to entering the gap and spreading across the contact surfaces. Which statement refers to point (2)



A The gravity force prevents the solder from reaching here.

B Capillary action will take the solder up to this point.

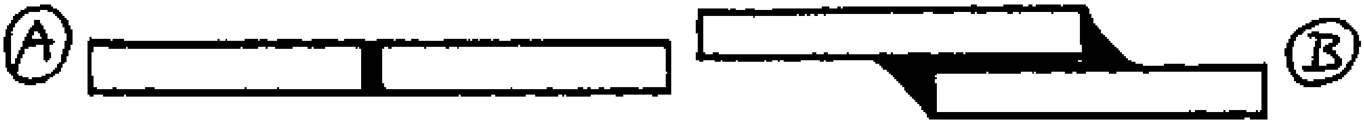
C The wider the gap the better the sucking effect at this point.

D Clean surfaces and flux let the solder reach here first.

Keys: 1D, 2C, 3B, 4B

22

5. What is the main justification for using the joint B for brazing and soldering, whereas A is typical for welding?



A The overlap joint hinders the oxidation of the contact surfaces because the air cannot enter the gap so easily.

B Control of an equal gap width is easier with overlap joint so that a better capillary action is achieved.

C An increase in overlapping width increases the strength of the brazing joint, whereas it does not in welding

D Removal of excess brazing metal and residual flux is more difficult in a butt joint.

23

6. A carburising flame is used for brazing with acetylene–oxygen torches. What is the reason?

A A higher flame temperature is achieved than with neutral flame

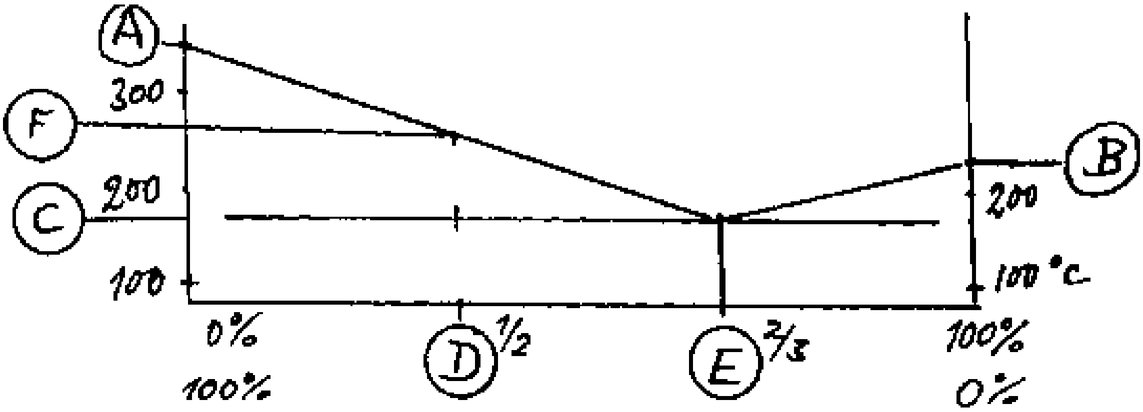
B The flame becomes softer and that causes better heat distribution

C Oxidation is made less likely since oxygen is swallowed by the flame more strongly.

D Copper attracts hydrogen from the C2H2 set free and that improves the strength of the brazing metal.

24

7. Match the letters to the statements!



___ This is the melting point of lead

___ At approximately 260°C this solder will melt.

___ Pure tin reaches liquid state here.

___ This is the melting point (liquidus line) for the solder of composition E.

___ That composition is not used for food tins because of the higher danger of lead contamination.

___ At this temperature the residual melt of the partly solidified solder will turn to solid state.

___ This composition is most common for connecting cables and thimble.

___ This composition has a temperature range of 70’C of being partly solid and partly molten.

___ Clamping time and waiting for solification is shortest with this solder.

___ Solder with 2/3 of lead will have a working temperature of some 50°C above this temperature.

Keys: 5C, 6C, A, F, B, C, D, C, F, D, E, F

TROUBLE SHOOTING CHART “BRAZING”

SYMPTOMS	DEFECTS	CAUSES + REMEDIES
1. Brazing metal rod does not melt when held against base metal surface	Rod not melting	○ ○
2. After melting the molten metal does not spread/not wet the surface accumulating at gap front	Brazing metal not wetting and spreading	○ ○
3. Braze joint cracked under load. Broken lap surface shows poor spreading of brazing joint	Poor capillary action/no filling of gap of lap	○ ○
4. Braze joint broken although broken surface shows good distribution of filler a) porous structure b) no porous str.	Lack of strength of joint	○ ○

A =	b) New oxides occure during heating	b) Fluxes have to be used
B =	a) Filler overheated/alloy component burned	a) Better check of temperature e.g. with color sticks or rod
C =	Gap too wide	Gap width to be adjusted acc. to table
D =	b) Base parts not clamped firmly during cooling/solidification	b) Clamping fixtures needed during cooling No moving of parts permitted
E =	a) Contact surfaces not clean/covered by oxides	a) Better cleaning prior to brazing
F =	a) Base metal not heated to working temper.	a) More warming up needed OR bigger torch
G =	b) Heat not distributed evenly in base metals. Working temp. only in parts of base	b) Flame to be moved to and fro across base metals. Bigger wall size needs heating longer