Machining of Material/Metal – Course: Manual working of metal. Methodical course–guide for instructors

Table of Contents

Machining of Material/Metal – Course: Manual working of metal. Methodical course–guide for instructors

Institut für berufliche Entwicklung e.V.
Berlin

Original title:
Lehrgang Methodische Anleitung für den Lehrenden
“Maschinelle Werkstoffbearbeitung/Metall”

First edition © IBE

Institut für berufliche Entwicklung e.V.
Parkstraße 23
13187 Berlin

Order No.: 90–32–0003/2

Introduction

The present guide shall help the instructor to accomplish the practical Locational training by giving practical recommendations as to the

– preparation,
– accomplishment and
– review of the practical vocational lessons.

At the beginning of the methodical guide the instructor is informed of the aims and contents of the course. The guide also states the previous knowledge required for acquiring the working techniques of machining of material. The emphasis is on the recommendations of didactic and methodology of the practical vocational lessons. The recommendations suggest the instructor how to plan and prepare the lessons. Possible forms and methods of accomplishing the instructions and exercises are also explained.

The last section deals with the peculiarities of the individual training units. It also contains a summary of the necessary teaching aids and working tools to facilitate organizing the course.

A methodically arranged complex of questions and answers shall help the instructor to test the know ledge of the trainees.

1. Aims and contents of the course

On completion of this training course the trainees should have the necessary knowledge, abilities and skills to work with

– engine lathes,
– horizontal or vertical milling machines,
– horizontal shaping machines and
– boring/drilling machines.

This implies that the trainees

– are able to decide on the purpose and application of the relevant machine and technique,

– are capable of setting up, operating, servicing and maintaining the machines and know the construction of the machines,

– have knowledge of how to determine the cutting values, such as speeds, feeds and stroke length,

– are able to select the proper tools and accessories for setting up the machines and know the construction of the different types of tools and accessories,

– have knowledge of how to meet the safety requirements in machining of material.

The course comprises the following training units (TU):

1st TU: Fundamentals of Fittings
2nd TU: Pinned Joints
3rd TU: Threaded Joints
4th TU: Feather Key Joints

To successfully acquire the skills of these working techniques, the trainees must have previous knowledge of and master the basic skills in the working techniques of manual working of material. In addition, they should have basic knowledge of engineering drawing to be able to “read” the working drawings.

2. Organizational preparation of training

In order to ensure that the instructions, demonstrations and exercises go off smoothly, the training must be well prepared. The following is to be made available:

Classroom and workshop

Though the instructions could be given in the workshop, it is better to do it in a room where the trainees have adequate facilities to sit and write.

If a daylight projector shall be used, a bright projection area and electric supply are required.

The demonstrations of the working techniques, followed by exercises, are to be done in the workshop directly on the relevant machine. One machine with the necessary cutting and operating tools, measuring and testing tools and accessories should be available for each trainee. The necessary working tools, related to the “Instruction Examples for Practical Vocational Training”, are summarized in the “Methodical Guide for Instructors”.

Teaching aids

Sufficient copies of the “Trainees' Handbook of Lessons” equalling the number of trainees are to be made available. The “Trainees' Handbook of Lessons” is mainly used in the introductory instruction for introduction and recapitulation. It explains the technical knowledge of one training unit, which is absolutely necessary for mastering the relevant technique, in a clearly arranged and easily conceivable way. Many illustrations add up to better understanding. Tasks and questions are included to recapitulate, strengthen and test the knowledge acquired. But they may also be used by the trainees for acquiring the knowledge by themselves. A summary of all questions is contained in a complex of questions and answers in the present methodical guide in the sub–section of the relevant training unit. Tasks and questions included in the “Trainees' Handbook of Lessons” are marked with “A”.

Sufficient copies of the “Instruction Examples for Practical Vocational Training”, depending on the number of trainees, are to be made available. They explain the technology for practising the examples, supplemented by working drawings. By means of the “Instruction Examples ...” workpieces can be produced and working algorithms practised to develop essential practical skills. Based on the “Instruction Examples ...”, the availability of the materials and necessary working tools can be checked and arranged by the trainees themselves.

The “Instruction Examples ...” of each training unit are arranged with increasing level of difficulty and should be followed in the sequence given.

The textbooks

– “Basic Vocational Knowledge – Working of Metal”
– “Formulas and Tables – Metal”
– “Machine Elements and Assemblies and their Installation”

can be used by the instructor for the instructions to consolidate knowledge and refresh basic knowledge.

The textbook “Formulas and Tables – metal” is particularly recommended for exercises of technical calculations.

All tools and accessories required for the working technique are to be made available as visual and/or demonstration aids. Various workpieces related to the conditions of the relevant factory are also to be made available for demonstration.

Blackboard drawings are to be prepared prior to the instructions.

If further teaching aids are available, the instructor can complete the Methodical Guide for Instructor.

This will give him a comprehensive survey and facilitate the preparations for the instructions.

Working tools and materials

The trainees' working places are to be checked for neatness, serviceability and completeness of the working tools and materials.

The completeness of the required technological documents (drawings, instruction examples for the relevant working technique) is to be ensured. Tests and/or recapitulations are to be prepared. The materials required for the exercises are specified in the relevant “Instruction Examples for Practical Vocational Training” – including the required dimensions. In a few cases the raw materials are to be made available in a certain stage of prefabrication that is to be prepared on advance.

3. Accomplishment of the training

3.1. General recommendations for the procedure of the course

The training course proceeds in the succession of the individual training units. The training units “Setting up and operation” should always be started with, since they will impart the basic knowledge required for the other training units. The training should then proceed with the training units according to the serial number of the training units. The knowledge and skills in the relevant working technique should be taught by an alternation of instructions and exercises. The instructions shall teach the knowledge required for accomplishing the working technique. In the exercises to follow the trainees shall put into practice the theoretical knowledge acquired. Practising of the work routines should take most of the time available for training and go on until a specified level of perfection has been reached. The practical exercises are to be considered the heart of the training. At the end of the exercises each trainee should be informed of the level of skills developed. Therefore, the following procedure of teaching a working technique is recommended to the instructor:

– introductory instruction,
– exercises with accompanying instructions,
– final instruction.

3.2. Introductory instruction

This lesson shall teach the theoretical knowledge required for the relevant working technique. It is to be given by the instructor at the beginning of each training unit. After that instruction the trainees should be able to carry out the exercises properly and with as good results as possible.

Related to the individual training units, the whole group of trainees is to be informed of

– the purpose and meaning of the relevant working technique,

– the construction, maintenance, types of machines, cutting tools, clamping tools, measuring and testing tools,

– the technological flow of work on the respective machine in the relevant working technique.

The instruction should also include labour safety instructions. This is absolutely necessary before each exercise is started in order to avoid accidents. The labour safety instructions should be as vivid as possible explaining accidents and incidents that actually happened in the factory. The trainees should be informed of general rules of labour safety and be referred to further specific hints to be given during the practical work. The trainees must be convinced that accidents cannot be avoided unless the labour safety instructions are strictly followed. A control book is to be prepared to give proof of labour safety instructions given outlining in brief the hints and explanations given to the trainees. Each trainee has to sign in the control book the labour safety instructions for ready reference in the event of any neglect.

General rules of labour safety:

– Wear close–fitting clothes! Loose clothes may be caught and pulled about by rotating machine parts.

– Never work at machines without protective headgear!

– Protect your feet by solid footwear!

– Never remove any protective devices from the machine!

– Do not reach into rotating machine parts! Switch off the machine first!

– Use tools in proper condition only!

– Clamp workpieces and tools safely and firmly!

– Use safety goggles (particularly with short–chip material) to avoid injuries of the eyes!

– Do not remove metal chips by hand! Use a chip hook, chip brush or hand broom!

– Keep naked hands off workpieces with burrs! Use protective gloves or a piece of cloth!

– Cover with sand and remove any oil slicks resulting from oiling of the machine!

– Never do any measuring or testing unless the machine is at rest!

– Do not set the speed or operate any switches unless the machine is at rest!

– Do not open any gear or motor covers until after switching off the main switch!

The introductory instruction may have the form of a lecture or dialogue or combination of these two forms.

The lecture by the instructor shall introduce the trainees into the new working technique and inform them of the aim of the instruction. Moreover, this is a way of teaching unknown knowledge, such as of the construction and operation of the relevant machine, of the construction and type of working tools to be used.

For more vividness of the lecture it is necessary to show and explain, e.g. to demonstrate, all working tools to the trainees. The construction and operation of the machine should be demonstrated in the workshop directly on the respective machine, the engine lathe, for example. The following steps are recommended for the demonstration of a working process:

– Demonstration at normal pace of work.

The instructor mentions the individual steps of work. The trainees get an idea of the entire process.

– Demonstration at decelerated pace

The process is disassembled into single components with the emphasis being on explanations.

– Repetition of difficult steps.

– Demonstration of the entire process at normal pace of work.

– One or two trainees repeat the demonstration of the working process.

– Evaluation of the demonstration.

It is important that all trainees can match the demonstration.

The lecture by trainees should be used as a means of recapitulating and consolidating knowledge already taught. For this purpose the trainees should be requested to deliver a continuous lecture, e.g. about the construction of vertical and horizontal milling machines.

The teaching dialogue shall serve to jointly elaborate (instructor with trainees) new knowledge, e.g. of technological processes. The dialogue is based on existing knowledge which is to be applied to new situations. For example, the dialogue may be preceded by reading some sections in the “Trainees' Handbook of Lessons”.

The elaboration of new knowledge in the dialogue can be considerably supported by the use of various visual aids, such as original cutting, clamping, measuring and testing tools, of the illustrations in the “Trainees' Handbook of Lessons”, of transparencies and models. The dialogue may also be used as a means of recapitulating known knowledge. All trainees can be involved in the recapitulation by the form of questions and answers of the dialogue. So the instructor can easily judge the level of knowledge of the trainees. The questions contained in the “Trainees' Handbook of Lessons” should be included in the teaching dialogue. Immediately upon elaboration of one or more key points, the trainees may requested to answer orally or in writing. In this way, the instructor can find out whether or not the trainees have understood everything. On the other hand, the questions in the individual sections of the “Trainees' Handbook of Lessons” are a means of control if the trainees had been requested to elaborate some technical key points on their own.

3.3. Exercises with accompanying instructions

Immediately before any exercises the trainees should be given specific hints for the workpiece to be practised.

According to the individual instruction examples, the trainees should be provided with information

– on the aim of the exercise,
– on the raw material of the workpiece,
– on the cutting, clamping, measuring and testing tools and accessories immediately required,
– on the steps of work (difficult steps should be demonstrated again),
– on certain dimensions and critical points of the workpiece,
– on criteria for judging the performance at the workpiece and on intermediate controls,
– on the time of the exercise to be kept.

A finished workpiece should be shown to the trainees to make clear the aim and key points of the exercise. It is useful when the instructor has previously made the workpiece himself so as to know the problems connected with its manufacture.

So he can clearly state the performance rating criteria and point out critical points of the workpiece. During such instructions each trainee should have the sequences of operations and the working drawings of the “Instruction Examples for Practical Vocational Training”. The trainees may then add necessary hints under headline “Comments” of the “Instruction Examples...”.

The aim of the exercises is to learn and to develop the skills of important operations in machining of metal workpieces up to an intended level of perfection. Therefore, the exercises must be repeated several times and be carried out purposefully. If the instructor is of the opinion that the first example of any training unit would make too high demands on the trainees' skills, preparatory exercises must be planned in terms of time and availability of material. Such preparatory exercises could comprise:

- Practising of the manipulation for setting up and operating the machines without workpieces.
- Practising of the possibilities of clamping of any blanks desired.

It is also possible to start immediately with the exercises based on the “Instruction Examples for Practical Vocational Training”. If the “Instruction Examples for Practical Vocational Training” offered are not used for the exercises, it is also possible to select other workpieces. In this case, attention should be paid to the fact that the workpieces selected lend themselves to practising of all working techniques already discussed. Before the trainees start practising, the instructor should make sure that the labour safety instructions and the instructions on how to behave in the workshop have been given. If not, they should be given now. For the exercises on lathes, the existing engine lathes should be assigned to the trainees according to their body height. The height of the machine can be compensated by footboards (gratings).

Upon assignment of the working places to the trainees including checking for completeness and serviceability of all cutting, measuring, testing tools and accessories, the trainees should receive their material. Each trainee should produce his workpiece himself, from cutting the blank until completion of the part. This is the only way of fair rating of the trainee's performance. The performance rating criteria are to be made known to the trainees before they start with the exercises. Each trainee should start practising based on the sequences of operations and working drawings.

All trainees should carry out the exercises on the same workpiece in the same sequence!

In this way the instructor keeps control of things. In the event of any difficulties the instructor must find out whether they face individual trainees only or the whole group. Individual trainees may be guided individually. If the whole group is facing the difficulties, the exercises should be interrupted for additional hints to be given to all trainees. The instructor should always walk from one trainee to another one to get exactly informed of the state of machining. He should praise good results and criticize bad results.

The instructor must always keep control of things.
The trainees must not practise unsupervisedly.

If the instructor finds out that the working techniques are carried out wrongly, he must make corrections immediately.

Since the trainees are working with machines, special attention is required. The trainees must not operate the machines unless they have first been instructed in the operation or the controls and in the hazards of injuries. One trainee only should work at the machine at a time.

In the event of waiting times because of occupied machines it is useful to keep the trainees busy with intermediate jobs, such as

- sharpening of worn–out cutting tools,
- repair of damaged working tools,
- refilling of coolant and lubricant.

With increasing level of intricacy of the exercises intermediate controls are recommended. This is an opportunity for the instructor to rate the performance already prior to the completion of the exercise. Workpieces of bad workmanship can be eliminated already in this stage if reworking is required or a good final result cannot be expected any more. This is all the more important if single parts are to be matched and one part cannot be made fit because of pour quality of machining.

It is a waste of time if trainees continue machining of parts which are of no use.

In this case it is more useful if the trainee stops the exercise and starts again with new raw material.

Intermediate controls, which are announced to the trainees in advance, stimulate the trainees and make them feel confident to go on with the exercises.

The instructor should note down the results and observations of the intermediate controls to take them into account for the final control.

Upon completion of each exercise the workpiece must be rated.

It is important that the rating is based on the rating criteria stated before the beginning of the exercise.

In preparation of the control and evaluation of the results the instructor must ensure that

- each trainee is informed of the rating criteria,
- a sheet of paper is prepared to fill in the results of rating.

Experience showed that the trainees are stimulated by seeing and comparing their performances on a rating sheet visible for anybody.

This rating sheet may have the form of a clearly arranged table:

Table 1: Example of a rating chart

Training unit 1

	1st instruction example				2nd instruction example				3rd instruction example			
Rating criteria	**accuracy to size**	**surface finish**		**time of exercise**	**accuracy to size**	**surface finish**		**time of exercise**	**accuracy to size**	**surface finish**		**time of exercise**
1st name												
2nd name												
3rd name												

The rating sheet should be open to inspection by all trainees. During the controls, whether intermediate or final, the trainees should have the opportunity of self−assessment of their performance. In this way, the trainees learn to exercise self−control. Observations and results of the intermediate controls noted down during the exercises are to be taken into account for the rating. Irrespective of the form of rating (mark, point or percentage system), general rules of rating the quality of the workpieces and the way of working are to be observed. The following rules of rating are recommended:

Very good performance

The workpiece is faultless. All specified sizes have been complied with. The workpiece surfaces are clean. Full use of the workpiece is ensured. The workpiece has been produced within reasonable time and with no additional help by the instructor. The trainee has a good command of the working techniques and properly uses the tools and accessories.

Good performance

The workpiece shows minor faults in terms of compliance with specified sizes and cleanness of the workpiece surfaces. The use of the workpiece is ensured. No reworking is required. The trainee basically works on his own. With certain reservations the trainee has a good command of the working techniques.

Fairly good performance

The workpiece shows several faults which can be removed by reworking, such as deviations from specified sizes, unclean surfaces. The use of the workpiece is ensured.

The trainee works with little help. He has no good command of the working techniques.

Satisfactory performance

The workpiece shows major faults in terms of accuracy to size and quality. It can just be used. Reworking is necessary.

The trainee needs the help of the instructor because he has a poor command of the working technique and doss not always find faults himself.

Unsatisfactory performance

Specified sizes have not been complied with. The workpiece is of no use. The trainee is not able to work on his own. He has no command of the working techniques.

3.4. Final instruction

At the end of each exercise and immediately on completion of each training unit the results must be evaluated. Such evaluation should have the form of discussions with the whole group of trainees to find out:

To which degree did each trainee achieve the aims envisaged? It is recommended to guide the trainees, based on the rating criteria made known before the exercise, to assess their results themselves. The instructor should

– complete the trainees' assessment,
– rate the results,
– generalize the experience gathered by the trainees,
– point out typical faults made by the trainees in their work and the causes,
– show to the trainees ways of removing and avoiding faults in preparation of the next exercise.

The results of the evaluation should be recorded in a table (see table 1). At the end of a training unit it is useful to have a prepared test. In this may the instructor will get a comprehensive survey of the trainees' knowledge actually acquired and of their practical experience. The complex of questions and answers of each training unit (see section 4) facilitates the preparation and evaluation of such tests.

Fundamentals of Fitting

1. Objectives and Subject Matters of the Practical Vocational Training in the Techniques of “Fitting”

On completion of the training the trainees are supposed to have a good command of the manual techniques of fitting component parts, in order to produce simple units. To achieve this, the following is required:

Objectives of training

– The trainees have knowledge of the purpose, types and use of the fitting of component parts and sub–assemblies (units).

– They know the various methods used for manual fitting works in preparation of assemblings.

– They are able to produce the correct type of fit according to the use and function of the component parts and sub–assemblies.

– The trainees are able to properly select the tools and auxiliaries and to suitably apply them by strictly observing the health protection, labour safety and fire protection rules.

To meet these objectives, the instructor or teacher should emphasize the following points of content:

Subject matters of training

Knowledge

– purpose, types and methods of manual fitting works
– types and fields of application of the tools, testing instruments and auxiliaries
– selected basic terms of the ISA System of Fits, representation and designation of fits
– principal technological sequences of fitting works on plane and curved surfaces
– hints on labour safety

Skills

– selection and handling of the tools, testing instruments and auxiliaries for manual fitting works

– selection and implementation of the appropriate technique according to the demands made on the work–pieces:

• narrow, plane surfaces by filing
• broad, plane surfaces by filing and scraping
• curved surfaces by scraping
• bores by reaming
• quality control and function test.

2. Organizational Preparations

All instructions, demonstrations and exercises should be prepared thoroughly and meticulously. This requires the following measures:

2.1. Planning of the Practical Vocational Training in the Techniques of "Fitting"

Draw up a time schedule and set an approximate number of hours in which you expect to complete the instruction on the various techniques of fitting. Plan an appropriate number of hours for the theory instruction on each subject, the practical demonstration, the instruction in preparation of a particular job, especially the exercices, the proper execution of the exercises, for recapitulations and controls.

When elaborating your time schedule, remember the level of know–how of your trainees, the conditions of trainees, the jobs which your trainees will take on in future and the degree of difficulty of the respective training stage.

The mephasis at each stage of training is always on the impartment of high craftsmanship and teaching of mechanical skills with the help of practice–related exercises which should be given the biggest chunk of time your schedule.

2.2. Preparation of the Labour Safety Instructions

A short labour safety instruction should precede every practical exercise, where the main points of the safe handling of all tools, auxiliaries, etc. are explained to avoid injuries.

The directions which are binding on the safe handling of drills, countersinks and reamers should be repeated as they apply to the techniques of fitting. The following focal points should be repeated several times:

– Make sure that all tools are clean, sharp and undamaged.

– Make sure that the workpiece is clamped securely and safely. Never apply excessive force. This may damage the workpieces.

– Put all measuring and testing means aside at their proper place. Use pads, supports, etc. where provided, to protect them against impact, shock and corrosion.

– It is regarded as good workmanship to keep one's workplace tidy and always to put down individual components together with their matching parts.

Have a notebook or file at hand where you keep minutes of these instructions. All trainees shall certify with their signature that they were instructed accordingly.

2.3. Preparing the Teaching Aids

– The “Trainees' Handbook of Lessons – Fundamentals of Fitting” has to be given to each trainee.

– Surveys can be prepared in form of blackboard drawings prior to the beginning of the instructions.

– Component parts, assemblies and models of guides can be made available as demonstration aids.

2.4. Preparing the Working Materials

– Each trainee has to be given the “Instruction Examples for the Practical Vocational Training – Fundamentals of Fitting” as theoretical basis for the exercises to be done.

– The starting material necessary for the exercises has to be prepared with the help of the material contained in the “Instruction Examples...” and made available in a sufficient number.

– The workshop has to be checked for complete equipment with tools, measuring and testing means and auxiliaries according to the planned exercises.

– Recommended basic equipment:

• hand hacksaws, files of various forms, scrapers, hand reamers with and without angular momentum

• steel scriber, pencil, centre punch, hammer, aluminium hammer

• limit gauges for external and internal dimensions

• form gauges and feeler gauges, centre squares

• steel tape, vernier caliper, external, internal and depth micrometers, protractor

• marking devices

• marking colour, chalk, cutting oil, tap wrench, machine grease

• vice with protective jaws, special clamping devices

– A bench or upright drilling machine with pertinent clamping devices is required for the necessary preparatory works (boring and countersinking).

– Prior to the beginning of the exercises, the serviceability of this machine has to be controlled with regard to the aspects of labour safety.

3. Recommendations for the Practical Vocational Training in the Techniques of “Fitting”

The following paragraphs make suggestions for the theory instructions, demonstrations of the techniques of fitting, as well as for checking and assessing the trainees' knewly acquired know–how.

3.1. Introductory Instruction

The trainees should be instructed on the basics of the subjects. For this, use a room where they can sit down and take notes. The trainees should be asked to enter the answers to the questions in the “Trainees' Handbook...”. The trainees are supposed to have a good command of the techniques of filing, scraping and reaming before they are instructed in the techniques of fitting. The essentials of these techniques should be repeated occasionally. The contents of the “Trainees' Handbook...” follow the system of the introductory demonstrations and instructions. The focal points in that “Handbook” can be discussed in the order given there.

Purpose, types and methods of manual fitting works

To start with, explain to the trainees the necessity of fitting works in preparation of mounting sub–assemblies. It is advisable, to show examples of interference and clearance fits by means of visual aids available and to explain the use of these types of fits.

Since the methods applied in manual fitting works differ strongly in individual and series production these differences have to be illustrated by examples.

In doing so the manufacturing condition of “exchangeability” of series–manufactured component parts has to be especially pointed out.

Tools, testing means and auxiliaries

Introduce the tools, testing means and auxiliaries, as well as the fields of their application. The trainees will have some knowledge from their instructions on the manual techniques of material working. Discuss these points again with your trainees. Ask them questions to find out what they remember. The following instruments are to be recapitulated:

- files, scrapers, hand reamers
- matching pieces, testing instruments, measuring instruments
- marking devices
- special clamping devices, vice with protective jaws.

Selected basic terms of the ISA System of Fits

The worldwide use of the ISA System of Fits, particularly in countries which have adopted the metric system of units makes it necessary to enable the trainees to work with ISA–standardized sub–assemblies. With the help of the respective section in the “Trainees' Handbook...” basic terms can be explained which have to be known for reading an engineering drawing with fit specifications.

Only selected terms from this extensive field are to be mentioned:

- nominal size and actual size
- dimensional limits, dimensional variations and fit sizes
- tolerance and tolerance zone.

Accordingly, the representations of fits in engineering drawings have to be shown, and “fit specifications with dimensional variations” and “fit specifications with ISA symbols” have to be presented.

Imparting of this knowledge should be aimed at recognizing fit specifications in engineering drawings and deducing their fabrication with corresponding tools and testing means.

For the practical work it is not necessary to calculate the dimensional limits by means of ISA tables. However, the trainees should be shown such a way of determining a dimensional limit by the example of a “fit size symbol”.

This focal point has to be concluded with the explanation of the advantages of the ISA System of Fits. It should be especially emphasized how simply precision bores can be worked manually using ISA−standardized hand reamers and testing instruments the dimensions of which have been coordinated accordingly.

Fitting works on plane and curved surfaces

The various techniques are to be explained proceeding from the description of the working surfaces of component parts and sub−assemblies. The “Trainees' Handbook...” contains pertinent examples:

Fitting works on narrow plane surfaces are described by the example of a mitre angle gauge, the working of broad plane surfaces is explained by examples of a square−box wrench and a lock screw. Precondition for this is the good command of the techniques of “filing” and “scraping of plane surfaces”.

When explaining these works the different test methods are to be dealt with. It is important to show the trainees the limits of the light gap test method and to explain to them the drag mark and the touching−up method as supplementary and more exact test methods.

Recommendation:

Here, the instructions can be finished and followed by exercises in the working of plane surfaces (1st and 2nd Instruction Examples).

Subsequently, the instructions have to be continued be the following focal point:

Fitting works on curved surfaces are also described by means of examples.

The fitting in by scraping of a slide bearing and the reaming of a gear bore for the reception of a shaft are explained. The latter example requires the recapitulation of the knowledge of the point “ISA System of Fits” and an explanation of the practical application. It is recommended to determine a fit size as example to designate tools and testing means with concrete specifications.

Hints on labour safety

The main points of safe filing, scraping and reaming should be discussed once more. These main points can be taken from the “Trainees' Handbook of Lessons”.

3.2. Exercises

The necessary hints on labour safety have to be given, on principle, before the beginning of the exercises. Afterwards, the workshop and the available technical equipment are to be shown to the trainees and their operation is to be demonstrated. It is recommended that the instructor begins each exercise with a demonstration in connection with instructions related to the given instructional example. The trainees are to be motivated to perform the exercise in good quality. Expected difficulties have to be pointed out.

The exercises can be done either as a compact whole according to the recommendations mentioned in Section 3 or in two exercise stages.

By means of the “Instruction Examples for the Practical Vocational Training – Fundamentals of Fitting” four exercises can be performed by using different techniques of fitting.

The “Instruction Examples for the Practical Vocational Training – Fundamentals of Fitting” contain a list of the material (starting material, tools, measuring and testing means and auxiliaries), the sequence of operations for doing the exercises and a comprehensible workshop drawing. This provides the trainees with the information necessary to perform the exercises purposefully.

If the course of the exercises shows that the quality of the practising workpiece is insufficient, more extensive exercises will have to be done. In this case, any waste products should be used. After the trainees have sufficiently proved their skills with these products, the envisaged Instruction Example can be manufactured.

It is necessary that the instructor previously produced the practising workpiece by himself so that he knows all the problems of the manufacturing process.

Thus it is possible to name clear main points for evaluating the performances – problematic points of the practising workpiece can be pointed out. During the task–related instructions the sequences of operation and workshop drawings should lie on the tables so that the trainees can take down notes into their handbooks.

The individual Instruction Examples are shortly described in the following to give a survey of the practising workpiece to which the previously imparted knowledge should be applied:

Instruction Examples

Instruction Example 31.1. Mitre Angle Gauge

A testing means is made of a 2–mm–thick steel sheet by filing an angle sector of 135°. The fit test is performed with the light gap test method by means of an available angle gauge or a protractor.

(Figure 1)

Instruction Example 31.2. Square Bolt for a Three–jaw Chuck Wrench

A square with a wrench opening of 12 mm is filed to a round stock with a diameter of 16 mm. The accuracy of the fit is tested with a square bush of corresponding size of a three–jaw chuck. The drag mark method is used as test method.

(Figure 2)

Instruction Example 31.3. Lock for Three–jaw Chuck Wrench

The pre–fabricated square bolt is now being equipped with a head and a lock. The fitting work is performed by reaming with ISA–standardized hand reamers. The required pin joints are to have clearance and interference fits. Limit gauges are used to test the fit.

(Figure 3)

Instruction Example 31.4. Pulley and Shaft to be Fitted together

An available pulley is joined with a pre–fabricated shaft. The bore of the shaft has to be adjusted according to the desired fit size – the subsequent mechanical treatment is performed by reaming. The feather key is to be inserted into the shaft keyway, if necessary it has to be pre–worked by filing true to size.

(Figure 4)

All trainees can do the exercises simultaneously, provided that the material prerequisites are guaranteed (availability of a sufficient number of devices).

In this case, the trainees can individually carry out the exercises–each trainee should be given as much time as he needs.

If there are not enough working tools available, the trainees will have to be split up in groups. It is favourable to divide them into groups according to the use of the various tools, measuring and testing means.

If the suggested Instruction Examples are not used for the exercise, it will also be possible to select other practising workpieces. The instructor should take care that all techniques previously discussed can also be practised with these pieces.

Major points as to practical work

It is advisable for the instructor to select certain aspects which he will give his particular attention when supervising and evaluating the trainees' exercises. Here are a few suggestions:

– Do the trainees carefully prepare the workplaces?
– Do they select the proper tools (size, form) for the fitting works?
– Do the trainees recognize the fit sizes from the engineering drawing?
– Do the trainees adhere to the correct sequence of the fitting works?
– Do the trainees correctly apply the test methods?
– Do the trainees meet the quality requirements?
– Are the trainees able to correctly assess the quality of their work?
– Do the trainees observe the labour safety rules?

The main points of evaluation have to be made known to the trainees prior to the beginning of the exercise!

3.3. Examples for Recapitulation and Control

This section contains tasks for consolidating and testing the acquired knowledge and skills; the answers to each task are also given:

1. What is the purpose of fitting?
(To assemble component parts, according to their function, to sub–assemblies.)

2. Which types of fits are mainly distinguished?
(Interference and clearance fits, cylindrical and flat fits.)

3. Which methods can be applied in fitting works?
(Individual or single–piece production and series production.)

4. Which manufacturing condition is good for an efficient economic assembling?
(The elements belonging together according to their function have to be exchangeable.)

5. Which tools are used for manual fitting works?
(Files, scrapers, hand reamers.)

6. Why has the internationally valid ISA System of Fits been adopted?
(To render possible the international exchange of ready–to–assemble component parts and sub–assemblies.)

7. Which specifications have to be recognizable in an engineering drawing?
(The permissible dimensional variations have to be given inform of numbers or symbols.)

8. How is the specification of an ISA fit size marked?
(Nominal size specification, tolerance zone and quality number.)

9. Which practical importance does the application of the ISA System of Fits have for testing?
(Standardized gauges make possible a time–saving testing of the quality of the fit without determining the actual size.)

10. Which recommendation has to be paid attention to during the testing?
(Testing means and workpiece must have the same reference temperature.)

11. What does “shift–fitting” mean?
(A symmetrical element has to fit into the matching piece also in case of a rotation of 90° or 180°.)

4. Teaching Aids

For a better understanding by the trainees it is recommended to make available demonstration objects.

These can be component parts and smaller sub–assemblies of machines, but also self–made models of flat tracks, dovetail guides and cylindrical guides. It is also favourable to use prepared practising workpieces in the instructions (on the basis of the “Instruction Examples...”) to demonstrate good and bad fitting work.

If the trainees are to be familiarized more profoundly with the ISA System of Fits, it is recommended to prepare blackboard drawings or transparencies for overhead projection with extracts from ISA tables and representations of fits.

Likewise, such teaching aids can also be derived from national standards.

Pinned Joints

1. Objectives and Subject Matters of the Practical Vocational Training in the Techniques of Making Pinned Joints

The trainees who have completed the course are supposed to have a good command of the techniques of making pinned joints. To achieve this, the following is required:

Objectives of training

– The trainees will have a ready knowledge of the purpose and the types of pinned joints and the stresses in pinned joints.

– The trainees will master the various techniques of making joints by use of fitting cylindrical or taper pins.

– The trainees are in a position to select the right type of pin for a particular joint.

– They select the right type of tool and aids and use them in the proper way. They keep strictly to all safety regulations.

To meet these objectives, the instructor or teacher should emphasize the following points of content:

Subject matters of training

– Knowledge

- Purpose and types of pins and pinned joints
- Stresses in pinned joints
- Types of tools and auxiliary accessories, fields of their application
- The technological steps of fitting cylindrical and taper pins, grooved pins and dowel pins
- Undoing pinned joints
- Labour safety regulations

– Abilities

- Preparing the component parts for assembly
- Assembling the component parts and inserting the pins
- Checking the component parts prior to and after assembly
- Undoing pinned joints

2. Organizational Preparations

All instructions, demonstrations and exercises should be prepared thoroughly and meticulously.

2.1. Planning the Practical Vocational Training in the Techniques of Making Pinned Joints

Draw up a time schedule and set an approximate number of hours in which you expect to complete the instruction on the various techniques of making pinned joints. Plan an appropriate number of hours for the

theory instruction on each subject, the practical demonstration, the instruction in the preparation of a particular job, especially the exercises, the proper execution of the exercises, for repetitions and checks.

When planning your time schedule, remember the level of know–how of your trainees, the conditions of training, the jobs which your trainees will take on in future and the degree of difficulty of the respective training stage.

The emphasis at each stage of training is always on the impartment of high craftsmanship and teaching of mechanical skills with the help of practice–related exercises which should be given the biggest chunk of time in your schedule.

2.2. Preparing Labour Safety Instructions

A short labour safety instruction should precede every practical exercise, where the main points of the safe handling of all tools, auxiliaries, etc. are explained to avoid injuries. The directions which are binding on the safe handling of drills, countersinks and reamers should be repeated as they apply to the techniques of pinning. The following focal points should be repeated several times:

– Make sure that all tools are clean, sharp and undamaged.

– Use hammers, drifts, punches, etc. which are in good condition.

– Make sure that the workpiece is clamped securely and safely. Never apply excessive force. This may damage the workpieces.

– Put all measuring and testing means aside at their proper places. Use pads, supports, etc. where provided, to protect them against impact, shock and corrosion.

– Drive in pins only when the component parts are securely clamped and cannot slip.

– It is regarded as good workmanship to keep one's workplace tidy and always to put down individual components together with their matching parts.

Have a notebook or file at hand where you keep minutes of these instructions. All trainees shall certify with their signature that they were instructed accordingly.

2.3. Preparing the Teaching Aids

– Each trainee should have a copy of the “Trainees' Handbook of Lessons–Pinned Joints”.

– Prepare surveys and tables which you can write at the blackboard prior to theory struction periods.

– Make available a sufficient number of pins, pinned joints, as well as samples or functional assemblies with pinned joints for demonstration.

2.4. Preparing the Working Materials

– Each trainee should have a copy of the “Instruction Examples... –Pinned Joints” for theoretical reading.

– Make sure that a sufficient number of tools, measuring and testing means and auxiliary accessories are available as specified in the “Instruction Examples.... –Pinned Joints”.

– Check that there is a sufficient supply of tools, measuring and testing means and auxiliary accessories for the practical exercises at hand.

– The following is recommended as a basic stock:

- Marking gauges, steel scribers, centre punches
- Locksmith's hammers, light metal hammers, drifts, punches
- Vernier callipers, plug limit gauges, try squares

- Drills, cylindrical and taper reamers, countersinks, triangular scrapers
- Cutting fluid, machine grease, tap wrenches
- Vices with protected jaws, specific clamping devices

– A bench–type or column–type drilling machine and the required work–holding devices are needed for preliminary operations (drilling, boring, countersinking).

– Check the safe and reliable operation of these machines before your trainees use them.

3. Recommendations for the Practical Vocational Training in the Techniques of Making Pinned Joints

The following paragraphs make suggestions for the theory instructions, demonstrations of the techniques of making pinned joints as well as for checking and assessing the trainees' knewly acquired know–how.

3.1. Introductory Instruction

The trainees should be instructed on the basics of the subject. For this, use a room where they can sit down and take notes. The trainees should be asked to enter the answers to the questions in the “Trainees' Handbook”. The trainees are supposed to have a good command of the techniques of boring, drilling and reaming before they are instructed on the techniques of making pinned joints. The essentials of these techniques should be repealed occasionally.

The contents of the “Trainees' Handbook” follow the system of the introductory demonstration and instructions. The focal points in that “Handbook” can be discussed in the order given there.

Purpose and types of pins and pinned joints

To start with, explain to your trainees the advantages of joining parts with pins. Use visual aids to demonstrate the mechanical details and functions of the different kinds of pinned joints. This way, jour trainees will understand the difference of pinned joints used. Discuss with them the various kinds of joints and their applications. Explain the designations of all pins to enable them to identify the nominal diameter of a pin in order to select the right size of drill for making a hole. Where no pins or pinned joints are available, use the Figures in the “Trainees' Handbook” to make your trainees familiar with them.

Stresses in pinned joints

Make frequent use of the blackboard to explain the stresses in pinned joints. Your trainees must understand that a positive connection in a properly pinned joint can only be achieved if the preworked bore holes are of the right size and match the diameter of the pin. Use a drawing on the blackboard to discuss, in addition to friction, the shearing stress in pinned joints, which can be so strong that the pins shear off.

Tools and auxiliary accessories

Introduce the tools and auxiliary accessories, and their applications. Your trainees will have some knowledge from their instructions on the manual techniques of material working. Discuss these points again with your trainees. Ask them questions to find out what they remember. Repeat the details of the following tools:

– Drills, countersinks, reamers
– Locksmith's hammers, light metal hammers
– Non–ferrous metal punches, drifts
– Clamping devices, supports, pads.

Technological process of making pinned joints

Pinned joints, generally, are made by using two different technological methods. It is recommended to explain and illustrate the differences in these methods. Joints which use cylindrical pins or taper pins typically involve the operation of reaming. Ask your trainees as many questions as you think are needed to make sure that they remember the details of this technique. Refer to the “Trainees' Handbook”, where the technique is described and the formulae are given for calculating bore hole and countersink dimensions. Use practical exercises to illustrate your explanations. Ask several trainees to demonstrate the calculations at the

blackboard. Be very particular about pointing out the details of fitting taper pins. Emphasize the importance of using taper pins of the right length.

Joints which use grooved pins or dowel pins need not be reamed. The technological operations for these joints can be explained with reference to the points using cylindrical or taper pins.

Undoing pinned joints

There are essential differences in undoing pinned joints, depending on whether the hole is a through hole or a blind hole. Discuss these differences with your trainees. The loosening and dismantling of pinned joints is a most requisite procedure. However, the fact must be stressed and explained several times that seized pins and pins in blind holes must be removed with a drill. This is in most striking contrast to what the trainees were told about the specifics of pinned joints. It is a major point to make them understand that some way out of a given situation must always be found, even if it involves destroying the pin. It is more important not to damage the component parts of the joints. The trainees should be told that this is a rule, and follow it.

Safety at work

The main points of safe boring, drilling, countersinking and reaming should be discussed once more. These main points can be taken from the “Trainees' Handbook of Lessons”.

3.2. Exercises

Instruct your trainees to observe all safety regulations. This should be done before the practical exercises are begun. Then show every trainee his place of work and check that the machines and other pieces of equipment in the workshop are in good condition.

Begin each exercise by explaining the theoretical background and follow it with the practical performance of the exercise. Tell your trainees to go about their work with a sense of good craftsmanship.

Also tell them where to expect difficulties. The practical exercises can be done in the sequence in which they are given in the “Instruction Examples....”. Using the “Instruction Examples .... – Pinned Joints” your trainees can do four exercises in different techniques. The “Instruction Examples....” contain a list of materials for each exercise, tools, measuring and testing means, auxiliary accessories, the details of the technological operations and a workshop drawing.

The trainees will find there the information they need to execute the exercises properly and thoroughly. The instructor is advised to make the trainees aware of weak spots, where there may be difficulties and enable them to correctly assess the results of their work.

The instructor will do good to previously do the exercises himself. To make the instructor more aware of the points which his trainees are to achieve in their practical training, we will describe now the instruction examples for practical vocational training.

Instruction Examples

Instruction Examples 32.1.: Making a Pinned Joint for Fastening

Two square bars are to be joined successively by using a grooved cylindrical pin, a taper pin and a cylindrical pin. Check each pin for tight fit. Undo the joint. Then fasten a suitable piece of sheet metal to the square bar by means of a grooved drive stud (round head) and a grooved drive stud (countersunk).

(Figure 1)

Instruction Example 32.2.: Making a Support Plate

Grooved pins are inserted according to half length reserve taper grooved dowel pins into specific locations on a 10 mm steel plate. Another piece of plate is to be located on the first, which serves as a support. The shape and the size of the second plate can be varied by the instructor.

(Figure 2)

Instruction Example 32.3.: Making a Swivel Joint

A simple swivel joint is to be made from flat steel pieces and pins. One and is made pivotable by a cylindrical pin with a loose force fit. A fixed joint is produced at the other end using a grooved cylindrical pin. The joint is to be secured against torsion by a grooved taper pin.

(Figure 3)

Instruction Example 32.4.: Making a Container with Lid

A container is to be made from 8 mm plate metal. The plates are held together by grooved taper pins. The lid is removably connected to the body by close–tolerance grooved pins.

(Figure 4)

All trainees can do the exercises together if sufficient numbers of component parts are available. This will give every trainee a chance of doing all exercises himself. Allow the trainees as much time as they need to complete the exercises. If not enough component parts, tools, etc. are available, the trainees can work in groups. Each group should practise the use of a particular type of pin. Other exercises can be done instead of those suggested above. In that case the instructor should make sure that the techniques taught in this course can be practised extensively.

Major points as to practical training

It is advisable for the instructor to select certain aspects which he will give his particular attention when supervising and evaluating the trainees' exercises. Here are a few suggestions:

– Do the trainees prepare their workplaces with sufficient care and circumspection?
– Do they select the appropriate types and sizes of tools for the exercise they want to do?
– Will they do the job in the correct sequence of operations?
– Do they grease the pins before inserting them?
– Are the trainees able to meet the quality requirements?

In particular:

• Do the pins fit the holes exactly and tightly?
• Are the heads of the pins flush with the surface of the work–piece (except pins for holding)?
• Do the pins serve the intended purpose in a joint?

– Are the trainees able to assess their own work correctly?
– Have all labour safety regulations been observed?

3.3. Recapitulation and Checks

A list of questions has been compiled for this paragraph. They are intended to check the trainees' know–how. A question is followed by the correct answer in brackets. The letter “Q” indicates that the question has already been asked in the “Trainees' Handbook....”.

1. What are pinned joints?
“Q” *(Pinned joints are disconnectable joints, whereby two or more individual parts are held together by pins. Several different types of such connections are known.)*

2. Name the main types of pins.
“Q” *(Cylindrical pins, taper pins, grooved pins, dowel pins)*

3. How are pinned joints specified?
“Q” *(Pinned joints are specified as to the function of the pin in the joint.)*

4. What types of pinned joints are produced?
“Q” *(Pinned joints for fastening, driving, holding, swivelling, fitting, securing and shearing.)*

5. What is typical of a pinned joint for fastening?
“Q” *(Pinned joints for fastening hold together two or more component parts without frictional connection.)*

6. What is typical of pinned joints for holding?
(One component part is held at another component part by a pin.)

7. What is typical of a pinned joint for swivelling?
(The component parts of the joint are movably or swivably connected with one another.)

8. What is typical of a pinned joint for fitting?
“Q” *(The component parts of this joint are fixed in a definite position relative to one another.)*

9. What is typical of a pinned joint for securing?
(The component parts of this joint are protected against becoming loose accidentally under dynamic loads.)

10. What is typical of a pinned joint for shearing?
(Pinned joints of this type secure their component parts, which are connected directly with each other, from overloads. The pin will break when the load becomes too heavy.)

11. Identify stresses which the pin in a joint is exposed to.
“Q” *(Frictional forces between the walls of the bore hole and the surface of the pin, external forces that act on a component part of the joint, shearing stresses by the parts of the joint.)*

12. Name important tools and accessories for making pinned joints.
“Q” *(Locksmith's hammers, light metal hammers, non–ferrous metal punches and drifts, drills, countersinks, reamers, clamping devices and supports.)*

13. What is the sequence of operations when making a joint by using a cylindrical pin?
(Setting up and clamping the component parts, drilling, countersinking, reaming, checking, cleaning the hole, pinning.)

14. What holes will you drill for a cylinder pin having a diameter of 26 mm?
“Q” *(Rough–drill a 24 mm diameter hole and countersink it to 25.8 mm diameter.)*

15. How will you produce bore hole for taper pins?
“Q” *(Use a drill of the nominal diameter of the taper pin. Large holes are made stepwise.)*

16. What is the taper per unit length of taper pins and what does it mean?
(A taper per unit length of 1:50 means that the diameter is reduced by 1 mm for every 50 mm of length)

17. What type of countersink will you use to deburr a bore hole?
“Q” *(Use a 90–degree included angle countersink.)*

18. What should be taken into consideration when reaming a taper pin joint?
“Q” *(When reaming a hole for a taper pin joint, test the fit of the pin before you drive it in.)*

19. What condition must be satisfied with respect to the length of a taper pin?
“Q” *(The length of the taper pin must be 2 mm shorter than the thickness of all parts of the proposed joint.)*

20. How will you shorten the length of a taper pin?
“Q” *(Saw off the thicker end of the pin with the hacksaw and file a new head.)*

21. How do you insert a pin?
(Drive the pin in with an aluminium hammer or a locksmith's hammer and a non–ferrous metal punch. Proceed from the end at which you applied the reamer.)

22. How should a pin fit its hole?
“Q” *(The upper edge of the pin must be flush with the edge of the bore. More specifically, both*

ends of a cylindrical pin must be flush with the edge of the bore. Taper pins, on the other hand, have their thicker end flush, the thin end is 2 mm inside the hole.)

23. What are the differences in the technological operations when producing a joint by using a grooved pin or a cylindrical or a taper pin?
"Q" *(The bore hole for the grooved pin is made in accordance with the nominal diameter of the pin. Bores for cylindrical pins must be reamed, those for grooved pins need not be reamed.)*

24. How can you remove a pin from a through hole?
"Q" *(Apply several blows on a drift of a nominal diameter somewhat thinner than that of the pin. Apply the drift to that end of the pin which is opposite to the driving–in end.)*

25. How can you remove a drive stud?
(Apply a flat chisel sideways between the head of the grooved pin and the surface of the component part and slightly lift the drive stud by a few blows with a hammer. Remove it with a pair of longs.)

26. How can you remove seized pins?
(They have to be removed with a drill.)

4. Teaching Aids

Use visual aids to reinforce the trainees' understanding of your instructions. Such aids can be pins, pinned joints or components or assemblies of machines with pinned joints. Instructors are advised to use sample joints made by the trainees during their practical exercises and demonstrate good and bad joints.

Threaded Joints

1. Objectives and Contents of the Practical Training in the Techniques of Making Threaded Joints

Trainees who have completed the course are supposed to have a good command of the techniques of making threaded joints. To achieve this, the following is required:

Objectives of training

– The trainees will have a ready knowledge of the purpose and the types of threaded joints and the stresses in these joints.

– The trainees will master the various techniques of making direct and indirect screwed joints for fastening purposes.

– The trainees are in a position to select those joints which serve an intended purpose.

– They can choose the right type of tools, auxiliaries and aids and use them properly, strictly keeping to all regulations on health and labour safety as well as fire protection.

To meet these requirements the instructor or teacher should emphasize the following points of content:

Content of training

Know–how

– Purpose and types of bolts, screws, nuts, locking devices, washers and threaded joints

– Stresses in threaded joints

– Types of tools and their uses

– The technological steps of making direct and indirect bolted and screwed joints for fastening purposes

– Undoing threaded joints

– Safety regulations

Abilities

– Preparing the component parts for assembly
– Assembling the component parts and inserting bolts, screws, nuts and locking devices
– Checking the component parts before and after assembly
– Undoing a threaded joint.

2. Organizational Preparations

Instructions, demonstrations and exercises should be prepared thoroughly and meticulously. This includes:

2.1. Planning the Practical Training in the Techniques of Making Joints

Set an approximately appropriate number of hours in which you want to complete the instruction in the individual techniques of making threaded joints. Plan an appropriate number of hours for the theoretical introduction into each technique, the practical demonstrations, the task–related instructions in preparation of the exercises, the proper execution of the exercises for recapitulations and controls.

When planning your time schedule, remember the level of knowledge attained by your trainees, the conditions of training, the future jobs which your trainees will take on, the degree of difficulty of this training.

The emphasis at each stage of training is always on the teaching of manual skills. They must be given the biggest chunk of time in your schedule.

2.2. Preparing Labour Safety Instructions

A short labour safety instruction should precede any practical exercise, where the major points of the safe handling of all working tools are explained to avoid injuries. The details of the safe handling of drills, countersinks and thread cutting dies will be explained.

These main points should be repeated several times:

– Make sure that the tools are of the right type and size and in proper working order.

– Make sure that the workpiece is clamped tightly and safely. Do not use excessive force in clamping a workpiece as it will cause damage.

– Use assembly tools of the right size for tightening or loosening bolted and screwed joints. Tools of the wrong size tend to damage the workpiece and may slip off causing injuries.

– Make sure that large parts cannot drop to the ground when the bolts and nuts or screws are removed.

– Always keep your workplace in order, store all tools properly and place individual parts always together with their matching parts.

A notebook or file should be at hand to keep minutes of these instructions. All trainees are required to certify with their signature that they were instructed accordingly.

2.3. Teaching Aids and Materials

– Every trainee should be given a copy of the “Trainees' Handbook of Lessons – Threaded Joints”.

– Surveys and tables should be prepared as blackboard drawings prior to the instructions.

– Different kinds of tools, bolts and screws, a number of threaded joints, as well as functional models of assemblies using threaded joints should be used in the demonstrations.

2.4. Working Tools

– Each trainee should have a copy of the “Instruction Examples for Practical Vocational Training – Threaded Joints” as a theoretical basis of the exercises.

– Make a sufficient number of component parts and joints always available for practical exercises, as described in the “Instruction Examples...”.

– Make sure that a sufficient number of tools, measuring and testing means as well as auxiliaries are available as specified in the “Instruction Examples... – Threaded Joints”.

The following basic stock of tools, measuring and testing means as well as auxiliary accessories is recommended:

– Marking gaugers, steel scribers, centre punches
– Locksmith's hammers, flat chisels
– Vernier callipers, try squares
– Drills, countersinks, thread taps, die stocks, dies
– Screw drivers, wrenches and spanners of different types and sizes
– Cutting fluid, machine grease, tap wrenches
– Vice with protected jaws, suitable types of clamping devices.

– A bench–type drilling machine or column–type drilling machine and the required work–holding devices should be available for necessary preparatory work, such as drilling, boring and countersinking.

– Check the safe and reliable operations of these machines before your trainees use them.

3. Recommendations for the Practical Training in the Techniques of Making Threaded Joints

The following paragraphs make suggestions for the theory instructions, the demonstration of the techniques of bolting and screwing as well as for checking and assessing the trainees' newly acquired know–how.

3.1. Introductory Instruction

The trainees should be instructed on the fundamentals of the subject. For this, use a room where they can sit down and take notes, or answer the questions in the “Trainees' Handbook...”. The trainees are supposed to have a good command of the techniques of boring, drilling, countersinking and thread cutting before they are instructed in the techniques of making threaded joints. The essential details of these techniques should be explained occasionally.

The contents of the “Trainees' Handbook ...” follow the system of the introductory demonstration and instruction. The main points in that “Handbook” can be discussed in the order given there.

Purpose, Types of Bolts, Screws, Nuts, Locking Devices, Washers and Joints

To start with, explain to your trainees the advantages of joining component parts by bolting or screwing. Use demonstration models to explain the mechanical details and functions of the different kinds of threaded joints. From this, your trainees will understand the uses of the different joints discussed. Discuss with them the various kinds of joints and their uses. Explain the designations of all bolts and screws to enable your trainees identify the right type of bolt or screw from a piece list. They should be able to identify the nominal diameter and the length of engagement in order to select the right kind of drill and know the depth of the hole to be drilled. Where no original bolts, nuts, screws or joints are available, use the figures in the “Trainess' Handbook...” to make your trainees familiar with them.

Stresses in Threaded Joints

Make frequent use of the blackboard drawings to explain the stresses in threaded joints. Your trainees should understand that in order to make a properly bolted or screwed joint, they must choose two component parts, one having an external thread, the other with an internal thread, and screw them together by turning in opposite directions.

Illustrate the details of positive and non–positive joints and what they have in common. Explain to them the details of all stresses that may occur in a threaded joint and make them understand how to take them into account when assembling the component parts. Discuss and compare the various ways stresses can act in a joint, i.e. prestressing, service stress, tensile and compressive stresses as well as shearing stress. Say why there is a self–retaining effect in threads for joints that are made for fastening purposes.

Tools

Introduce the tools and explain their uses. Your trainees will have some knowledge of that from the instruction in techniques of manual material working. Discuss these points again with your trainees. Ask them questions to find out what they remember.

Explain the following tools to your trainees:

- Drills, countersinks, thread taps, die stocks, dies
- Screw drive for screws with cross slots and intersecting slots.
- Open ended wrenches, ring spanners, box spanners
- Hexagon pin–type wrenches, adjustable wrenches
- Torque spanners, electrically actuated wrenches

Use the figures in the “Trainees' Handbook...” to illustrate your points. When you describe the tools, always tell your trainees how to use them properly and safely: Tell them what may happen when they use the wrong type or size of tool, such as a screw driver, spanner or wrench. Show them damaged bolts, screws and nuts to reinforce their understanding. Do not forget to mention the bodily injuries that can be caused by slipping tools.

The Technological Steps of Making Threaded Joints

The differences in bolted and screwed joints lie mainly in the preparations for making them. It is recommended to illustrate these differences by examples.

Direct and indirect threaded joints should be dealt with separately.

A screwed pipe joint is a good example to illustrate a direct screwed joint. A detailed explanation of a screwed pipe joint is given in the section on the cutting of external thread in the “Trainees' Handbook...”. The example of a pipe joint there will be understood clearly by your trainees. It is that of a simple screwed joint using a piece of pipe and joining it to another piece by a short thread. Another typical example of a pipe joint is joining pipes by a bell piece and a long thread. This technique is mainly used in permanent pipe installation systems whose position cannot be changed. The technique is practised in the example no. 33.4., but it is good to explain it now to give the trainees a full picture of all techniques.

Most parts that are made for fastening purpose are indirectly bolted or screwed. The details of indirect joints are explained in the “Trainees' Handbook...”. The two examples are those of a joint comprising a bolt, component parts and a nut, and of a bolt, component parts and another component part with a receiving

thread. It is recommended to repeat the details of these joints when discussing the technique of thread cutting.

(A good time is when the calculation of the drill diameter and the bore depth from the available kind of screws is the topic.)

Give examples in figures. Use blackboard drawings on the basis of the respective diagram in the “Trainees' Handbook...” and enter dimensions for the calculation. Require your trainees to describe by exactly calculated values the techniques of drilling, boring, countersinking and thread cutting. Then give them the most important details of the assembly operations.

Tell them that these are “rules”. A summary of these rules is given in the “Trainees' Handbook...”. The trainees should give the answers to the questions in their “Handbooks”.

Undoing Threaded Joints

The undoing of threaded joints should be explained with particular reference to safety aspects. Emphasize the need of using tools of the right type and size, the safe handling of all dismantled components and their identification for re–assembly. The loosening and dismantling of bolted or screwed joints is certainly a most requisite procedure. However, the fact should be stressed and repeatedly explained that bolts and screws and nuts which cannot be loosened despite the use of rust solvents, must be removed with a drill (bored out). This is in most striking contract to what the trainees were told about the specifics of bolted and screwed joints. It is a main point to make them understand that some way out of a given situation must always be found, even if by destruction.

It is most important that the component parts in the joint remain undamaged. The trainees should be told that this is the rule, and follow it.

Safety at Work

The main points of safe boring, drilling, counterboring and thread cutting should be discussed again.. These main points can be taken from the “Trainees' Handbook...”.

3.2. Exercises

Instruct your trainees to observe the labour safety regulations, before they start doing practical exercises. Then show every trainee his place of work and check that the machines and equipment in the workshop are in working order.

Begin each exercise by explaining the theoretical background and follow it with the practical execution of the exercise. Tell your trainees to go about their work with a sense of good craftsmanship. Also tell them where to expect difficulties. The practical exercises can be done in the order in which they are given in the “Instruction Examples...”.

Using the “Instruction Examples for Practical Vocational Training – Threaded Joints” the trainees can do four exercises in different techniques.

The “Instruction Examples...” contain lists of component parts (material), tools, measuring and testing means, auxiliary accessories and a workshop drawing. The trainees will find there the information they need to exercise the examples properly and thoroughly. The instructor is advised to make the trainees aware of the weak spots, where they may be facing difficulties, and enable them to assess the results of their own exercises correctly.

The instructor will do good to do the exercises himself, using the same tools his trainees will have to use, before he asks them to do the exercises themselves.

To make the instructor more aware of the major points which his trainees are to achieve in practise, we will now describe the exercises of the “Instruction Examples...”.

Instruction Example 33.1. Making a threaded joint

Different kinds of bolts and screws are screwed into two flat pieces of metal, the choice being open. The flat component part which is on top has through holes, the holes in the bottom component part are tapped. The purpose of the exercise is to practise the use of different types of tools for heads of different shapes. Further practice in the techniques of cutting internal thread is intended.

(Figure 1)

Instruction Examples 33.2. Making a threaded joint with locking devices

Different kinds of bolts and screw with locking devices are screwed into two flat pieces of metal, the choice of the metal being open. The purpose of the exercise is to practise the proper use of different kinds of locking devices. Further practice in the techniques of cutting internal thread and making threaded joints is intended.

(Figure 2)

Instruction Example 33.3. Making a container with lid

A container is made of 8 mm plate sections, the joints are made with countersunk screws. The lid is fitted on stud bolts and knurled nuts and can be screwed on the container.

(Figure 3)

Instruction Example 33.4. Making a pipe joint

Two pieces of a 1–inch pipe are to be joined by a pipe bell on a long thread. The purpose of the exercise is to practise the use of the die stock for cutting pipe thread and making the joint of the two pieces of pipe by a pipe bell without turning the pipes.

(Figure 4)

All trainees can do the exercises together if sufficient pieces of metal, bolts, tools, etc. are available.

This will give every trainee a chance of doing all exercises himself. Allow them as much time as they need to complete the exercises.

Where not enough component parts, bolts, tools, etc. are available, the trainees can work in groups. Each group should do one exercise at a time.

Other exercises can be done without prejudice to those suggested above. In that case the instructor should make sure that the techniques previously taught in this course can be practised extensivily.

Major Points for Practical Training

We recommend that the instructor selects certain aspects which he will give his particular attention. Here are a few suggestions:

- Do the trainees prepare their places of work with sufficient care and circumspection?
- Do they select the right type and size of tools for a particular assembly job?
- Will they do a job in the correct sequence of operation?
- Do they grease the bolts before they screw them in the metal component?
- Are the trainees able to meet the quality requirements?

In particular:

- Are all screws properly tightened?
- Have the locking devices been properly used?
- Will the threaded joint perform the intended task?
- Have the holes been tapped properly?
- Are the trainees able to asses their own work correctly?
- Have all labour safety regulations been observed?

3.3. Recapitulation and Controls

A list of questions has been compiled for this paragraph, which are to check the trainees' newly acquired knowledge. Most of these questions have been asked in the “Trainees' Handbook of Lessons...”.

1. What is a bolted or screwed joint?
(Bolted or screwed joints are detachable joints where two or more individual component parts are joined by bolts, screws and nuts, directly with each other.)

2. What conditions must be satisfied by a threaded joint which is exposed to dynamic stress?
(Suitable locking devices are used where detachable joints have to be secured against accidental loosening due to the action of dynamic stress.)

3. Give uses of countersunk bolts and screws.
(They are used in industrial plant and machinery, where safety requires that no screw head projects from the surface of a component part.)

4. What is the difference in the length of engagement of a cheese head bolt or screw and a countersunk bolt or screw?
(As to cheese head bolts or screws the threaded shanks are inserted into a component part. As to countersunk bolts and screws the heads are flush with the surface of the part into which they are screwed.)

5. Where does the shape of a sheet metal screw differ from that of a wood screw?
(On sheet metal screws, there is thread on the entire cylindrical portion of the screw, with a tip, whereas on wood screws the thread is only as long as the tapered portion of the shank.)

6. What conditions must be satisfied by the materials of which nuts, bolts and screws are made?
(Bolts, screws and nuts must be made of the same material and have the same kind of coating.)

7. Identify uses of knurled nuts and wing nuts.
(Knurled nuts nad wing nuts are used for producing detachable joints of component parts by hand.)

8. Identify elements of locking devices which must be used once only.
(Cotter pins, spring rings and out–bent locking devices are used once only.)

9. Suggest an effective way of locking when the shank of a bolt projects the nut.
(The locking effect can be enhanced on bolts which have their shanks projecting beyond the nut by screwing a counternut onto the projecting portion of the shank. Both nuts must be screwed tight.)

10. Give uses for washers.
(Washers are used on bearing faces when the latter are not properly machined, where bolts, screws and nuts are to be tightened on oblong holes and where slopes of the bearing face must be compensated.)

11. Name different types of threaded joints.
(There are direct joints, indirect joints, fastening joints and adjustable joints.)

12. Identify a critical specification of a thread for fastening purpose.
(It must have a high self–retaining effect.)

13. Name different kinds of stress in threaded joints for fastening purpose.
(There are prestressing and service stress, which act as tensile or compressive forces, and shearing stress.)

14. What may happen when the blade of a screw driver is too narrow?
(The clearance between the blade and the slot is too big, the blade may slip and damage the screw head. Injuries can be caused.)

15. What may happen when an extension is used on an open ended wrench for tightening a bolted or screwed joint?
(The joint will be overly prestressed, the threaded bolt will fail either when being tightened or later, under the action of the service stress.)

16. Name applications of the torque spamnner.
(The torque spanner is used on high−strength bolted and screwed joints which require a specific torque or where there are several bolted or screwed joints on one component part and their prestressing is the same.)

17. Give details of making a tapped hole for a screw.
(For blind holes, consider the length of thread engagement and the run−out depth of the thread tap. The tap hole must be made deeper by that dimension.)

18. Where several component parts are to be joined by a screw, which part must have a receiving thread?
(The receiving thread must be in the part which is the last as seen from the head of the screw.)

19. How is a trainee to proceed in tightening a joint which comprises a bolt and a nut?
(Grip the bolt head tightly and tighten the nut.)

20. Where should the locking element be placed in a joint consisting of a bolt and a nut?
(At the side where the nut is applied.)

21. How will you proceed in tightening several screws or bolts in the lid of a container?
(Start from the middle and proceed outwards, crosswise.)

22. Give important details of dismantling component parts.
(Use a suitable support so that the parts cannot drop to the ground. Mark the parts for re−assembly. Loosen the joints before you dismantle the parts fully.)

23. What general requirements must be met by assembly tools?
(The tools must be of the right type and size for the job in hand, and they must be in proper working order.)

4. Teaching Aids

Use visual aids to reinforce the trainees' understanding of your instruction. Visual aids, or other illustrative material, can be bolts, screws, nuts, locking devices, threaded joints or component parts or assemblies of machines with threaded joints. Instructors are advised to use the sample joints made by the trainees during their practical exercises and illustrate good and bad joints.

Feather Key Joints

1. Aims and Contents of Vocational Training in the Field of Techniques for Manufacturing Feather Key Joints

After having completed the vocational training, the trainees shall master the techniques for manufacturing feather key joints.

For this purpose, the following aims must be reached:

Aims

– The trainees have thorough knowledge of the purpose and kinds of and stress on feather key joints.

– They master the various techniques used for manufacturing fitting key and sliding key joints.

– They are able to choose the suitable fastening devices according to the function of the respective feather key joint.

– The trainees are able to choose the right tools and auxiliary means and to use them according to the regulations on health and labour safety and fire protection.

In order to achieve these aims, the following contents must be imparted by the instructor:

Contents

Knowledge

– Purpose of feather key joints, kinds of feather key and profile shafts as well as kinds of feather key joints

– Stress on feather key joints

– Kinds and fields of application of tools, devices and auxiliary means

– Technological processes for manufacturing feather key joints and profile shaft joints

– Detachment of feather key joints

– Labour safety

Abilities

– Preparation of the parts for assembly
– Assembling the parts and putting the feather keys in
– Checking the parts before, during and after assembly
– Detachment of feather key joints

2. Organizational Preparations

In order to ensure that the instructions, exercises and demonstrations go off smoothly, the instructions must be carefully prepared.

This includes the following measures.

2.1. Planning of the Training in Techniques for Manufacturing Feather Key Joints

Starting from the total number of teaching hours, the individual sections of this lesson should be planned separately.

Time planning is recommended for the following sections:

– Introduction into the techniques in the form of an instruction.
– Required demonstrations.
– Task–related instruction in preparation of the exercises.
– Carrying out of the exercises.

– Recapitulation and tests.

With the planing of the time, following factors should also be considered:

– The level of education of the trainees;
– The conditions of training;
– The future field of working of the trainees;
– The difficulties the respective section may offer.

The focal point of each section of training is the acquisition of skills by practical exercises, which, therefore, must be given the major portion of time.

2.2. Preparation of the Instruction on Labour Safety

Before the beginning of the exercises, a brief instruction is held on the appropriate use of the working means and on accident–free working.

The same hints are applicable which have to be observed with filling, scraping, drilling, reaming, milling and shaping. Special attention has to be paid to the following points:

– Use only clean, undamaged and sharp tools.

– Clamp the tools firmly and safely – but so that they are not damaged.

– Measuring and testing tools must be kept carefully and protected against damage due to shock and corrosion.

– The workshop place has to be kept in order, individually manufactured elements of a component are kept only together with their counterpart.

The trainees confirm the instruction on the above points by their signatures in a book especially started for this purpose.

2.3. Preparation of the Teaching Aids

– The “Trainees' Handbook of Lessons – Feather Key Joints” is distributed according to the number of trainees.

– Surveys and especially meaningful illustrations from the “Trainees' Handbook of Lessons” may be prepared as blockboard drawings before the lessons.

– Various feather keys, different feather key joints as well as models or serviceable components may be used as illustrative material, as far as they are available.

2.4. Preparation of the Working Means

– As a theoretical basis of the exercises that have to be done, the “Instruction Examples for Practical Vocational Training – Feather Key Joints” are distributed among the trainees.

– The materials which are required for the exercises must be prepared and placed at the disposal in sufficient quantity according to the enumeration in the “Instruction Examples for Practical Vocational Training”.

– The workshop has to be inspected as to the complete supply of tools, devices, measuring and testing tools and auxiliary equipment corresponding to the planned exercises.

– Recommended basic equipment:

• Steel scriber, centre punch
• Locksmith's hammer, light metal hammer, non–ferrous metal drift pins
• Finishing files, triangular scrapers
• Vernier caliper, dial gauge and stand, external limit gauges, plug limit

gauges
• Drills, countersinking cutters, thread taps, reamers, tap wrenches
• Screw drivers, adjustable pliers, pliers for shaft snap rings in various sizes
• Cutting oil, machine grease, soluble oil emulsion
• Vice with protective jaws, special clamping mens
• Hand screw press, pullers.

– For the necessary preparatory work – drilling and countersinking – a bench–type or upright drilling machine with the corresponding clamping means is required.

– The serviceability of this machine is to be tested before the beginning of the exercises and taking into consideration the regulations on health and safety at work.

3. Recommendations for Vocational Training in the Techniques for Manufacturing Feather Key Joints

The following sections contain suggestions for the structuring of the instructions, the demonstrations of the techniques as well as of the exercises and tests.

3.1. The Introductory Instruction

If possible, the introductory instruction should be held with the trainees in a classroom. During the instruction pay attention that the trainees write down supplements or answers of questions in the “Trainees' Handbook of Lessons”.

An essential presupposition for manufacturing the various kinds of feather key joints is also the knowledge and mastering of the techniques of manual working and machining of material. This knowledge should be reactivated when the opportunity arises. The instruction can be held according to the focal points indicated in the “Trainees' Handbook of Lessons”.

Purpose of feather key joints, kinds of feather keys and profile shafts as well as kinds of feather key joints

In the form of a lecture the trainees are explained what is understood by feather key joints, what tasks the feather key joints have to fulfill and what are the advantages and disadvantages of feather key joints.

It is recommendable to explain different kinds of feather key joints on the basis of the available illustrative material; in this context, also the differentes in the use of the various feather keys can be demonstrated.

The various feather keys should be shown and their special fields of use be explained.

After this, it should be pointed to the manufacture of the joints by profile shafts. It should be emphasized that these joints follow the principle of feather key joints, although no additional connecting elements are used.

The trainees should understand that this kind of joints is especially used for highly stressed machine parts.

Stress on the feather key joints

This is best explained with the help of a blackboard drawing according to Figure 9 from the “Trainees' Handbook of Lessons”. The trainees should understand that the positively connected joint is only stressed when the rotating movement starts and that the power transmission is only enabled by the exact fit of feather key and keyway. By the blackboard drawing the trainees are explained the acting forces and the shearing stresses to be derived thereform.

Tools, devices and auxiliary means

Starting from the knowledge in the fields of manual working and machining of material, these working means are presented in connection with their fields of use.

This focal point should be developed in the form of a talk with the trainees, the instructor testing the level of knowledge of the trainees by systematic questions.

The following working means must be mentioned:

- Shank cutters and side milling cutters
- Internal broaches and keyway cutting tools
- Files and scrapers
- Presses and screwing fixtures
- Hammers and non–ferrous metal drift pins
- Pliers and screw drivers
- Pullers (extractors)

Technological processes for manufacturing feather key joints and profile shaft joints

Since the steps of work with the manufacture of the various kinds oft feather key joints differ only slightly, it is recommendable to describe in detail the manufacture of one commenly used fitting key joint. In the “Trainees' Handbook of Lessons”, this sequence of operations is described in great detail by 8 partial steps. This should be follow by a supplementary explanation of the sliding key and profile shaft joints. For the consideration of already imparted knowledge it is important that the trainees realize the relation of cause and effect. This can be achieved by constantly drawing their attention to the consequences which an omitted or wrong step of work may have for the serviceability of the feather key joint. In doing so, the instructor may point to the development of qualities such as accuracy, conscientiousness and perseverance in working.

Detachment of feather key joints

The detachment of feather key joints must be explained to the trainees by two essential steps. One thing is to explain how shaft and hub can be separated.

Starting from their knowledge, the trainees should answer the question how very tight interference fits between shaft and hub can be detached. The methods suggested by the trainees my be discussed, then the correct suggestions are confirmed and/or supplemented by the instructor. In conclusion, the individual steps for removing the keys out of the keyways of the shafts are explained.

Hints on health and safety at work

While repeating the instructions on health and safety at work from the fields of manual working and machining of material, special points are emphasized which are especially applicable in the present field. These focal points are to be found in the “Trainees' Handbook of Lessons”.

3.2. Exercises

On principle, the necessary instructions on labour safety must be given before beginning the exercises. Then, the workshop places are allocated to the trainees and the technical equipment of the workshop is checked as to its serviceability. It is recommendable to begin every exercise by a demonstration by the instructor in connection with explanations related to the respective instruction example. In doing so, the trainees are motivated to carry out the exercise in a good quality. In this context, the focal points for assessment are mentioned and it is pointed to problems to be expected with the respective workpieces for exercise.

The instructor must have manufactured the workpiece which is the subject of the exercise himself before!

The exercises can be done in succession in the order of the instruction examples offered.

According to the “Instruction Examples for Practical Vocational Training – Feather Key Joints” – 4 exercises in different techniques can be carried out. The material “Instruction Examples for Practical Vocational Training” gives a list of the required initial material, working tools, measuring and testing tools and auxiliary means as well as the sequence of operations for doing the exercises and a clear working drawing. Thus, the trainees are provided with all required information for implementing the exercises systematically. The initial materials must be prefabricated by machines before beginning the exercises. It is necessary that the shafts and hubs are available true to size in accordance with the dimensions indicated in the working drawing, otherwise the individual operations belonging to the exercise cannot be observed correctly. If no feather keys from standardized assortments are available, these must be manufactured too. The corresponding dimensions are to be found in the working drawing.

In order to give a survey by what exercises the imparted knowledge shall be put into practice, the individual instruction examples are briefly described below.

Instruction examples

Instruction example 34.1. Fitting key joints I

A hub is to be connected with a shaft by a round–end flat key as a fitting key. The axial displacement of the hub is prevented by two shaft snap rings.

(Figure 1)

Instruction example 34.2. Fitting key joint II

A hub is to be connected with a stepped shaft by a Woodruff key as a fitting key. The axial displacement of the hub is prevented by one shaft snap ring.

(Figure 2)

Instruction example 34.3. Sliding key joint I

A hub is to be slidably mounted on a shaft using a straight–ended flat key, which is to be fixed in an ending key way of the shaft by locking screws.

(Figure 3)

Instruction example 34.4. Sliding key joint II

A hub is to be slidably mounted on a shaft using a round–ended flat key, which to be fixed in a closed keyway of the shaft.

(Figure 4)

After having fulfilled these tasks, the trainees detach the joints. All trainees can carry out the exercises at a time, if materials and tools can be provided in sufficient quantity. In this case, the trainees can do the exercises individually – each trainee shall take the time he needs.

If not enough working means are at the disposal, tasks and trainees are divided into groups. It is recommendable to proceed according to the field of use of the various feather keys. If the instruction examples offered are not used for any exercise, other pieces for the purpose of exercise may be chosen. In doing so, pay attention that all the techniques that had been discussed previously can be practised by these pieces for exercise.

Criteria in practical exercise

It is recommendable to fix criteria for assessing the exercises. These can be the following:

- Do the trainees prepare their workshop places carefully?
- Are the appropriate tools – size and form – chosen for the assembly?
- Do the trainees observe the correct order of the individual steps of work?
- Do the trainees slightly grease the parts before assembling them?
- Do the trainees fulfill the quality standards of work?
    - Do the feather keys exactly fit in the keyways?
    - Are shaft and hub exactly assembled corresponding to the given fits?
- Are the joints detached in the correct way?
- Are the trainees able to judge their own work correctly?
- Do the trainees observe the regulations on health and safety?

3.3. Examples for Recapitulation and Tests

For consolidating and testing the acquired knowledge and skills, this section contains questions which are also included in the “Trainees' Handbook of Lessons”.

1. What are feather key joints?
(Detachable joints where parts that shall do rotating movements are positively connected.)

2. What are the special advantages of feather key joints?
(Guarantee of true running of the parts, stability of the joints even with higher rotary powers.)

3. What is the disadvantage of feather key joints?
(They do not stand often changing shock–like stress.)

4. What kinds of feather keys are distinguished?
(Flat keys and Woodruff keys)

5. What kinds of feather key joints are distinguished?
(Fitting key joints, sliding key joints, profile shaft joints.)

6. What kind of stress is a feather key in a joint exposed to during the transmission of power?
(– Surface pressing between the side faces and the machine parts;
– Shearing stress due to opposite forces applied.)

7. What technique is used for making the keyways in the shafts?
(Milling)

8. What techniques are used for making the keyways in the hubs?
(Broaching or shaping.)

9. What techniques are used for reworking of feather keys?
(Filing, scraping)

10. What are the criteria for checking the individual parts, if a fitting key joints shall be made?
(Surface quality of shaft and bore hole in the hub; length, width, depth and alignment of the keyway of the shaft and of the hub, fit size of shaft and hub.)

11. How tight must be the fit of feather key in the keyway of the shaft?
(The lateral surfaces of the key must perfectly fit to the keyway of the shaft; there can be a slight interference fit.)

12. How can a hub be placed on the shaft, if there is an interference fit between the two parts?
(The hub is shoved on the shaft in hot condition.)

13. What are criteria for checking after a fitting key joint has been made?
(Clearance between feather key back surface and keyway of the hub, firm fit of hub and shaft, firm fit of the fitting key, fit of the hub in the right place on the shaft, exact true running of the hub on the shaft.)

14. How can the axial displacement of the hubs on the shaft be prevented?
(Shaft snap rings or retainer rings are mounted on the left and on the right sides of the hubs.)

15. What enables the firm fit of the sliding key in the keyway of the shaft?
(The sliding key is fixed by locking screws in the keyway of the shaft.)

16. What kind of fit is required between shaft and hub with a sliding key joint?
(Easily sliding clearance fit.)

17. How is a fitting key joint detached, if there is an interference fit between shaft and hub?
(The parts are drawn apart by an appropriate pulling device; if the fit is too tight, the hub must be heated for a short time, then, the fitting key is lifted out with the help of adjustable pliers.)

4. Explanations to the Teaching Aids

In order to facilitate the understanding on the part of the trainees, it is recommendable to use illustrative objects. These may be individual parts of components or machines, which include feather key joints. Also, work–pieces from exercises held before – according to the “Instruction Examples 1 to 4” – may be included in the instruction to show well made or inferior feather key joints.