The Structure of Technical English
A. J. Herbert
Preface

This practice book is intended for foreign engineers or students of engineering who have already mastered the elements of English, and who now want to use their knowledge of the language to read books on their own subjects. Readers should understand, however, that the purpose of the book is to teach language, not to teach engineering.

The language in which scientific and technical facts are expressed is certainly not a different language from that of everyday life, but all the same it presents the foreign student with a number of special problems. The most obvious and the most widely recognised of these problems is the vocabulary. Fortunately a number of excellent dictionaries of scientific and technical terms exist. There is, of course, a vast vocabulary of technical words, but the problem is not so frightening as it looks. In the first place, many of these highly technical words are fairly international; and in the second place, they usually have very specialised meanings. In any case, they are not the concern of this book. Much more difficult are the semi-scientific or semi-technical words, which have a whole range of meanings and are frequently used idiomatically. One of the aims of this practice book is to present as many of these words as possible, and as often as possible: words such as work and plant and load and feed and force. Words like these look harmless, but they can cause a lot of trouble to the student.

And then there is another kind of word which is important: the verbs, adjectives and adverbs which are not specifically scientific, but which belong to the phraseology of science. These are usually formal, dignified and foreign-sounding words, like extrude and propagate and obviate and negligible, which are partly responsible for the slightly fossilised appearance of the typical scientific statement. A wide selection of these words will be found in this book.

But more than anything else, I have tried to describe the technical statement: that is, the completed sentence rather than the individual word. Many of the structures illustrated in the book are found also in ordinary language though not so commonly. But they are essential to the expression of technical facts and ideas – at least for the present. Perhaps it is a more amiable way of writing will emerge, and in fact technical writers are already conscious of the obscurity and pomposity of a great deal of technical writing. But there is a justification for many of their tricks of style, and I have not attempted to criticise them at all, merely to analyse them. The structures and practice sentences in this book are intended to familiarise the foreign student with the
kind of writing and the kind of statements he is likely to find in his reading of scientific and technical literature.

In writing technical sentences at all, one is forced to assume that the reader knows a certain amount of the subject. But the knowledge assumed here is not very great. I have taken for granted a knowledge of the terms of elementary mechanics and physics of the kind that would be studied in High Schools. The majority of the sentences in the exercises refer either to common knowledge or to the material contained in the preceding reading sections. This may explain the lack of diversity in the exercise statements, but the only alternative was to assume a wide knowledge of all branches of engineering, which did not seem a good idea. It is expected that the teacher will provide further illustrative material in the subject which his students are taking.

The reading passages which begin each section have been specially written to illustrate features of technical style, and for no other purpose. But I hope that they are reasonably accurate from the engineering point of view, and for this I must express my grateful thanks to a number of lecturers in the University of Birmingham who had read sections of the book and corrected a number of mis-statements: to Dr. J. W. R. Griffiths of the Department of Electrical Engineering; to Mr. K. E. Porter of the Department of Chemical Engineering; to Mr. F. D. Hobbs the Graduate School in Highway and Traffic Engineering; and above all to Mr. P. D. Allen of the Department of Mechanical Engineering, who has given me a great deal of help and answered a layman's questions with endless patience.

A. J. Herbert

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Section 1

Reading: Iron and Steel

The earth contains a large number of metals which are useful to man. One of the most important of these is iron. Modern industry needs considerable quantities of this metal, either in the form of iron or in the form of steel. A certain number of non-ferrous metals, including aluminium and zinc, are also important, but even today the majority of our engineering products are of iron or steel. Moreover, iron possesses magnetic properties, which have made the development of electrical power possible.

The iron ore which we find in the earth is not pure. It contains some impurities which we must remove by smelting. The process of smelting consists of heating the ore in a blast furnace with coke and limestone, and reducing it to metal. Blasts of hot air enter the furnace from the bottom and provide the oxygen which is necessary for the reduction of the ore. The ore becomes molten, and its oxides combine with carbon from the coke. The non-metallic constituents of the ore combine with the limestone to form a liquid slag.

![Cross-section of blast furnace](image)
### Exercise

Table: 

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>How many substances are present in iron ore?</td>
<td></td>
</tr>
<tr>
<td>What proportion of countries use electricity from nuclear power stations?</td>
<td></td>
</tr>
<tr>
<td>How much carbon does wrought iron contain?</td>
<td></td>
</tr>
<tr>
<td>How much power do you need to drive a large liner through the water?</td>
<td></td>
</tr>
<tr>
<td>Are there many gold-fields in the world?</td>
<td></td>
</tr>
<tr>
<td>How much petroleum is pumped out of the ground every year?</td>
<td></td>
</tr>
<tr>
<td>What percentage of people in your country work in factories?</td>
<td></td>
</tr>
<tr>
<td>Are any metals besides ferrous metals used in industry?</td>
<td></td>
</tr>
<tr>
<td>How much oxygen is needed to burn a ton of coal?</td>
<td></td>
</tr>
<tr>
<td>How much soil do the rivers carry down to the sea in a year?</td>
<td></td>
</tr>
<tr>
<td>What proportion of passengers flying in aircraft are killed in crashes?</td>
<td></td>
</tr>
<tr>
<td>How much of your country's electrical supply is derived from water power?</td>
<td></td>
</tr>
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### Contents

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
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<tbody>
<tr>
<td>The packet</td>
<td>20 cigarettes. 1</td>
</tr>
<tr>
<td>The gas</td>
<td>contains about 34% of carbon monoxide.</td>
</tr>
<tr>
<td>The alloy</td>
<td>5% nickel and 5% iron.</td>
</tr>
<tr>
<td>The tank</td>
<td>100 gallons of oil.</td>
</tr>
<tr>
<td>The carbon monoxide</td>
<td>was about 5%.</td>
</tr>
<tr>
<td>The moisture</td>
<td>content of the cylinder increased.</td>
</tr>
<tr>
<td>Part of the heat</td>
<td>content of the gases is lost.</td>
</tr>
<tr>
<td>He emptied out the contents of the box.</td>
<td></td>
</tr>
<tr>
<td>A tank is a large container for holding liquids.</td>
<td></td>
</tr>
<tr>
<td>The class consists of twenty-four students.</td>
<td></td>
</tr>
<tr>
<td>The atmosphere comprises a number of gases.</td>
<td></td>
</tr>
<tr>
<td>The machine is composed of several different parts.</td>
<td></td>
</tr>
<tr>
<td>Cast-iron is made up of about six different substances.</td>
<td></td>
</tr>
<tr>
<td>The factory produces components for aircraft.</td>
<td></td>
</tr>
<tr>
<td>The resultant force acting on an aircraft wing may be resolved into a vertical component and a horizontal component.</td>
<td></td>
</tr>
<tr>
<td>The composition of cast-iron is different for different purposes.</td>
<td></td>
</tr>
</tbody>
</table>

| A certain proportion of the world's coal lies in this country. |

---

1 Students unfamiliar with this way of presenting alternatives will find an explanation on page xii.
This floats on top of the molten iron, and passes out of the furnace through a tap. The metal which remains is pig-iron.

We can melt this down again in another furnace—a cupola—with more coke and limestone, and tap it out into a ladle or directly into moulds. This is cast-iron. Cast-iron does not have the strength of steel. It is brittle and may shatter under tension. But it possesses certain properties which make it very useful in the manufacture of machinery. In the molten state it is very fluid, and therefore it is easy to cast it into intricate shapes. Also, it is easy to machine it. Cast-iron contains small proportions of other substances. These non-metallic constituents of cast-iron include carbon, silicon, and sulphur, and their presence in these substances affects the behaviour of the metal. Iron which contains a negligible quantity of carbon, for example wrought-iron, behaves differently from iron which contains a lot of carbon.

The carbon in cast-iron is present partly as free graphite and partly as a chemical combination of iron and carbon which we call cementite. This is a very hard substance, and it makes the iron hard too. However, iron can only hold about 2% of cementite. Any carbon content above that percentage is present in the form of a flaky graphite. Steel contains no free graphite, and its carbon content ranges from almost nothing to 1%. We make wire and tubing from mild steel with a very low carbon content, and drills and cutting tools from high carbon steel.

**WORD STUDY**

Negligible, Considerable, Substantial, etc.

A **negligible** amount of something is very small.
It is so small that we can neglect or ignore it.

A **considerable** amount of something is quite large.
An **appreciable** amount is large enough to be worth appreciating or noticing.
A **substantial** amount is large enough to be worth considering or noticing.
A **material** amount is large enough to be noticed, like a material.

Melt, Molten, Smelt

Ice cream melts in the sun.
Ice melts in the summer.
The melted ice comes down the mountain in rivers.

At a certain temperature, metals melt. They become molten. The molten iron passes out of the furnace into moulds.

We smelt iron ore by heat, and change the ore into its metal state.

During smelting, the temperature in the furnace is raised and the iron melts.
When the ore is smelted, it becomes pig-iron.

**Property**

Every metal possesses certain properties, or characteristics or qualities which we can find by experiment; these properties may make the metal suitable or unsuitable for any particular purpose. Designers of high-speed aircraft need new materials with special properties such as heat resistance and strength at high temperatures.

Here are some of the properties which metals may have:

The metal is fluid. It flows easily when it melts.

- plastic.
- plasticity.
- elastic.
- elasticity.
- ductile.
- ductility.
- malleable.
- malleability.

It can be stretched without breaking.

It can be hammered out of shape without breaking.

**PATTERNS**

1. Mako + Noun + Adjective

<table>
<thead>
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<th>Renders</th>
<th>The Problem</th>
<th>Easy, Difficult, Interesting</th>
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<tbody>
<tr>
<td>This</td>
<td>makes</td>
<td>the metal</td>
<td></td>
</tr>
<tr>
<td></td>
<td>renders</td>
<td></td>
<td></td>
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<table>
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<th>Renders</th>
<th>The Metal</th>
<th>Harder, Softer, Stronger, Weaker</th>
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<td>This</td>
<td>makes</td>
<td>the metal</td>
<td></td>
</tr>
<tr>
<td></td>
<td>renders</td>
<td></td>
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<table>
<thead>
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<th>Renders</th>
<th>The Screw</th>
<th>Tighter, Looser, Flatter</th>
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<td>This</td>
<td>makes</td>
<td>the screw</td>
<td></td>
</tr>
<tr>
<td></td>
<td>renders</td>
<td></td>
<td></td>
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<table>
<thead>
<tr>
<th>Makes</th>
<th>Renders</th>
<th>The Hole</th>
<th>Wider, Deeper, Broader</th>
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<tbody>
<tr>
<td>This</td>
<td>makes</td>
<td>the hole</td>
<td></td>
</tr>
<tr>
<td></td>
<td>renders</td>
<td></td>
<td></td>
</tr>
</tbody>
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1 Students unfamiliar with this form of substitution table will find an explanation on page xii.
Expand, Contract

Most substances expand when they are heated. = They grow bigger or longer. Most substances contract when they are cooled. = They grow smaller or shorter.

When substances are heated, expansion takes place. When substances are cooled, contraction takes place.

The coefficient of expansion, which tells us how much a substance will expand for each degree rise in temperature, is different for different substances.

Relieve (= to make less severe)

When the pressure in a boiler becomes too great, we can relieve it by allowing some of the steam to escape. We can relieve the stresses in a steel bar by tempering it.

Critical

1. = decisive (point or stage) and therefore important or serious.
   The sick man is going through a crisis. He is in a critical condition.
   There is a political crisis. The political situation is critical.

2. = a decisive point in temperature, pressure or angle at which something is about to happen.
   The critical temperature of steel: above or below this temperature the molecular structure changes.
   The critical temperature of a gas: above this temperature it cannot be liquefied by pressure.
   The critical pressure: the pressure at which a gas can be liquefied.

Help, Assist, Facilitate

1. Annealing helps to remove (helps or assists in removing) internal stresses from the metal.
2. Safety devices help to prevent (help or assist in preventing) accidents in the machine shop.
3. A good transport system facilitates rapid erection of houses.
4. The use of standard components facilitates the distribution of goods.
5. Prefabrication of the walls makes replacing when they are worn easier.

Conducive

1. Regular maintenance is conducive to better performance of the machine.
2. Good labour relations are conducive to improved production.
3. Turbulence in the cylinder is conducive to more efficient burning of the gases.

WORD STUDY

Likely, Li likely, Susceptible

1. The work is likely to start early next year.
2. The new engine is likely to be a good one.
3. An explosion is likely to occur at any minute.
4. The new engine will probably be very expensive.
5. An explosion may unfortunately occur at any minute.
6. The metal may unfortunately become overheated.
7. The work may be delayed until next year.
8. There is a risk of an explosion occurring.
9. There is a risk that an explosion will occur.
10. The region is liable to frost damage. (noun)

Bring about, Produce, Cause, Give Rise to

1. Changes in temperature may bring about changes in the length of the bar.
2. The high temperature can give rise to cracks in the furnace walls.
3. These experiments will produce new methods of construction.
4. A drop in pressure will cause cylinder condensation.

Complete these statements with the proper ‘Content’ word:

1. The metals which we find in the earth ...... iron, lead and copper.
2. The carbon ...... of wrought-iron is very low.
3. We know the chemical ...... of the liquid from previous analysis.
4. Smelting ...... of heating the iron ore in a furnace and removing the slag.
5. The ...... of moulding sand ...... quartz, felspar and mica.
6. The atom ...... a nucleus, and electrons moving round it in space.
7. All matter ...... of atoms.
8. Metals which we use widely in industry ...... aluminium and steel.
9. We can discover the ...... gases of a fuel by chemical analysis.
10. The total floor space of the factory ...... 20,000 square feet on two floors.
11. The moisture ...... of the gas can be reduced by condensation.
12. Chromium is a necessary ...... of stainless steels.
13. This concrete ...... 1 part lime, 2 parts sand and 4 parts aggregate.
14. Most fuels ...... a mixture of different substances.
15. This company does not manufacture the engine itself, but only certain ...... of it.
16. The compound strip ...... two strips riveted together, one of iron and the other of copper.
17. It is easy for any faulty ...... to be taken out of the machine and replaced.
18. A flask of water, a glass rod and a rubber bulb ...... the only equipment which we need for the experiment.
19. The flask ...... a very small amount of water.
20. The 30,000 books in the library ...... a substantial number of books on engineering.

Section 2

Reading: Heat Treatment of Steel

We can alter the characteristics of steel in various ways. In the first place, steel which contains very little carbon will be softer than steel which contains a higher percentage of carbon, up to the limit of about 11%. Secondly, we can heat the steel above a certain critical temperature, and then allow it to cool at different rates. At a critical temperature, changes begin to take place in the molecular structure of the metal. In the process known as annealing, we heat the steel above the critical temperature and permit it to cool very slowly. This causes the metal to become softer than before, and much easier to machine. Annealing has a second advantage. It helps to relieve any internal stresses which exist in the metal. These stresses are liable to occur through hammering or working the metal, or through rapid cooling. Metal which we cause to cool rapidly contracts more rapidly on the outside than on the inside. This produces unequal contractions, which may give rise to distortion or cracking. Metal which cools slowly is less liable to have these internal stresses than metal which cools quickly.

On the other hand, we can make steel harder by rapid cooling. We heat it up beyond the critical temperature, and then quench it in water or some other liquid. The rapid temperature drop fixes the structure of the steel which occurred at the critical temperature, and makes it very hard. But a bar of this hardened steel is more liable to fracture than normal steel. We therefore heat it again to a temperature below the critical temperature, and cool it slowly. This treatment is called tempering. It helps to relieve the internal stresses, and makes the steel less brittle than before. The properties of tempered steel enable us to use it in the manufacture of tools which need a fairly hard steel. High carbon steel is harder than tempered steel, but it is much more difficult to work.

These heat treatments take place during the various shaping operations. We can obtain bars and sheets of steel by rolling the metal through huge rolls in a rolling-mill. The roll pressures must be much greater for cold rolling than for hot rolling, but cold rolling enables the operators to produce rolls of great accuracy and uniformity, and with a better surface finish. Other shaping operations include drawing into wire, casting in moulds, and forging.
9. Alcohol is not often used in thermometers; mercury is used very often in thermometers.

10. Alcohol boils at 78°C; water boils at 100°C.

11. The new car does 35 miles per gallon; the old car did only 30 miles per gallon.

12. Aluminium has a coefficient of expansion of 0.000025; copper has a coefficient of expansion of 0.000017.

13. The steel workers receive 30 shillings per shift; the coal miners receive 30 shillings per shift too.

4. This engine needs servicing every 3 months; the latest engine needs servicing every 5 months.

3. Maximum and Minimum

1. The maximum temperature is 35°C (Centigrade).

2. The upper temperature limit is 40°C (Centigrade).

3. The minimum temperature is 0°C (Centigrade).

4. The average temperature is 17°C.

5. The temperature range is 35°C.

6. The temperature in this country ranges from 35°C to 0°C.

2. a. In summer the temperature rises. There is an increase in temperature.

b. In winter the temperature falls. There is a decrease in temperature.

c. By heating a substance, we can raise its temperature to boiling point.

d. By cooling a substance, we can lower its temperature to freezing point.

3. a. The maximum pressure in the boiler is 500 lb/in².

b. The maximum speed of the aircraft is 800 m.p.h. (miles per hour).

c. The maximum fuel consumption of the engine is 30 m.p.g. (miles per gallon).

d. The maximum speed of the turbine is 8000 r.p.m. (revolutions per minute).

e. The maximum diameter of the tube is ¾ inch.

Section 3

Reading: Lubrication of Bearings

The machine tools in a workshop sometimes have their own electric motors, or they may take the power they need from a motor which feeds several machines. The shafts which carry the power from the motor to the machines need some kind of support to keep them steady. We call these supports bearings.

There are different types of bearings for different purposes. We can classify them according to whether they take the load on the

(a) Thrust bearing

(b) Journal bearing

(c) Roller bearing
PATTERNS

1. Enable, Allow, Make, etc. + Infinitive

Note: Enable really means to make possible, but it is often used in the same sense as allow and permit. Let is spoken, but not often written in this sense. With let and make, the word 'to' is not used before the infinitive.

<table>
<thead>
<tr>
<th>Pattern</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enable</td>
<td>Scientists enable to examine very small objects.</td>
</tr>
<tr>
<td>Allow</td>
<td>The doctor allows to measure body temperature.</td>
</tr>
<tr>
<td>Make</td>
<td>Helicopters enable to land in the city centre.</td>
</tr>
<tr>
<td></td>
<td>Good production methods enable to manufacture more cars.</td>
</tr>
<tr>
<td>Permit</td>
<td>Expansion joints permit the pipes to expand or contract.</td>
</tr>
<tr>
<td>Allow</td>
<td>Safety valves allow the steam to escape from the boiler.</td>
</tr>
<tr>
<td>Permit</td>
<td>The heat permits the metal to cool slowly.</td>
</tr>
<tr>
<td>Cause</td>
<td>Weakness in the metal causes the metal to fracture under tension.</td>
</tr>
<tr>
<td></td>
<td>Weakness in the metal makes the metal melt.</td>
</tr>
</tbody>
</table>

EXERCISE

Complete these statements using the verbs shown above:

1. The rise in temperature ... the mercury ... rise up the tube.
2. The motorway ... motorists ... travel from London to Birmingham much more quickly than before.
3. The use of tractors ... more food ... be produced more cheaply.
4. The presence of oxygen ... the mixture ... burn rapidly.
5. The failure of both engines ... the aircraft ... crash.
6. The increase in exports ... the country ... import more raw materials.
7. The risk of an explosion ... the workers ... leave the factory.
8. The speed of the train ... it ... leave the rails on the curve.
9. The fluidity of cast-iron ... it ... be cast into intricate shapes.
10. The use of a pressure gauge ... the engineer ... read the boiler pressure.
11. The sharp rise in temperature ... the engine ... overheat.
12. The presence of non-metallic constituents in iron ... it ... behave in various ways.
13. Rapid cooling ... unequal contractions ... occur in the metal.
14. The growth of industrial towns ... many people ... leave the countryside.
15. The differential gear ... the two rear wheels ... turn at different speeds.

2. Comparative

Here are some of the most useful patterns for comparing two things:

<table>
<thead>
<tr>
<th>Material</th>
<th>Property</th>
<th>Relative to Cast-Iron</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel</td>
<td>Stronger</td>
<td>Stronger</td>
</tr>
<tr>
<td></td>
<td>Far stronger</td>
<td>Far stronger</td>
</tr>
<tr>
<td></td>
<td>Slightly stronger</td>
<td>Slightly stronger</td>
</tr>
<tr>
<td></td>
<td>More expensive</td>
<td>More expensive</td>
</tr>
<tr>
<td></td>
<td>Much more expensive</td>
<td>Much more expensive</td>
</tr>
<tr>
<td></td>
<td>A much more expensive material</td>
<td>A much more expensive material to produce</td>
</tr>
<tr>
<td></td>
<td>Cast-Iron</td>
<td>Cast-Iron</td>
</tr>
<tr>
<td>Cast-Iron</td>
<td>Lower</td>
<td>Lower</td>
</tr>
<tr>
<td></td>
<td>Less expensive</td>
<td>Less expensive</td>
</tr>
<tr>
<td></td>
<td>Much less expensive</td>
<td>Much less expensive</td>
</tr>
<tr>
<td></td>
<td>A much less expensive material</td>
<td>A much less expensive material to produce</td>
</tr>
<tr>
<td></td>
<td>Not so expensive</td>
<td>Not quite so expensive</td>
</tr>
<tr>
<td></td>
<td>Not quite such an expensive material</td>
<td>Not quite such an expensive material to produce</td>
</tr>
<tr>
<td></td>
<td>As useful</td>
<td>As useful</td>
</tr>
<tr>
<td></td>
<td>Almost as useful</td>
<td>Almost as useful</td>
</tr>
<tr>
<td></td>
<td>Almost as useful a material</td>
<td>Almost as useful a material</td>
</tr>
</tbody>
</table>

EXERCISE

Join the two statements in each line, by comparing one with the other. Turn the comparison round both ways:

E.g. A is larger than B

1. The carbon content of mild steel is 0.2%; the carbon content of cast-steel is 1.2%.
2. Wrought-iron contains 0.02% of carbon; it contains 0.02% of manganese.
3. The British engine weighs 3 tons; the French engine weighs 3 1/2 tons.
4. The electric heater costs a penny an hour to run; the gas heater costs twopenny an hour.
5. Cast iron contains up to 3.0% of silicon; it contains up to 1.5% of phosphorus.
6. The temperature in this room is 28° C; the temperature outside the room is 22° C.
7. My radio works very well; my brother's radio works very badly.
8. The journey takes four hours by day; it takes five hours at night.
2. Capability (Will, Can, Capable, Are able to)

will fly
can fly
are capable of flying

These planes are capable of flying at 800 miles per hour.

3. What always happens (Will)

This solid will vaporise when we heat it.
Friction will cause the bearings to become heated.
Good lubrication will reduce the friction.

4. What sometimes happens (May, Can)

Metal which cools rapidly may fracture.
Unguarded belts or chains may cause accidents.
The testing of new planes can take a long time.

5. Ability (Can)

Work on the new engine can start in a few weeks.
We can easily calculate the frictional losses.

Note: The uses shown above can have both active and passive forms (see Section 5).
But the use which follows is nearly always in the passive form.

6. Possibility (Can, May)

Low-speed bearings can be lubricated with grease.
This problem can be approached in several ways.
The steel may be quenched in either water or oil.
The thermo-couples may be used to measure high temperatures.

Exercise

Decide on the meaning of these statements, and add will, can, etc. Where there is more than one possibility, show whether there is a difference of meaning or not:

1. This type of disease (cause) death.
2. A number of metals (carry) electric current.
3. The tank (hold) ten gallons of petrol.
4. The drive to a machine (obtain) from a shaft.
5. The bridge (take) about eighteen months to complete.
6. The docks (handle) more than twenty ships at a time.
7. Severe storms (occur) in the Atlantic during winter.
8. The winds in the centre of the storm (be) up to 130 miles per hour.

9. Heat-treated steel (give) strengths as high as 120 tons per square inch.
10. A flexible belt (twist) in more than one plane.
11. The new motorway (have) three traffic lanes in each direction.
12. An error of judgement on the part of the pilot (be) disastrous.
13. A magnetic needle (point) towards the magnetic north pole.
14. Castings (contract) slightly as they cool.
15. Iron and steel at a high temperature (oxidise) in the air.
16. A bright surface (reflect) sunlight, but a dull surface (absorb) it.
17. This metal (resist) temperatures of 600° Centigrade.
18. The factory (take) on a number of skilled workmen in the autumn.
19. The boiler (feed) with any type of solid fuel.
20. Above a certain critical temperature, the structure of the steel (change).

2. Prevention, Protection, etc.

<table>
<thead>
<tr>
<th>Good lubrication</th>
<th>prevents overheating.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>damage to the bearings.</td>
</tr>
<tr>
<td>prevents keeps</td>
<td></td>
</tr>
<tr>
<td></td>
<td>the bearings from becoming overheated, being damaged.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>water in.</th>
<th>out.</th>
</tr>
</thead>
<tbody>
<tr>
<td>up.</td>
<td>down.</td>
</tr>
<tr>
<td>screws right.</td>
<td>air clean.</td>
</tr>
<tr>
<td>This keeps the pressure</td>
<td>This prevents the pressure from falling.</td>
</tr>
<tr>
<td>from escaping.</td>
<td>entering.</td>
</tr>
<tr>
<td>screws from working loose.</td>
<td>air from getting dirty.</td>
</tr>
</tbody>
</table>

A thin film of oil protects the bearings from corrosion.
A guard on the machine protects the workers from injury.

Workers should avoid wearing loose overalls in the factory.
Using these materials wastefully.

By taking precautions in the factory we can reduce the risk of accidents.
shaft or the thrust along the axis of the shaft. The former type is known as a journal bearing, and the latter type as a thrust bearing.

The rotating shaft bears on a stationary bush or tube. We therefore have two metal surfaces in close contact with each other, and sliding over each other often at high speed. This will cause friction and the bearing will become heated. So we have to protect the metal surfaces from overheating and damage.

First of all, we avoid making the shaft and the bush of the same material. The shafting itself is generally of steel, but we use another metal such as cast-iron or bronze or white metal for the bush. At a certain temperature, the metal in the bush will seize or run, and this will prevent damage to the shaft. But of course it will not prevent overheating from occurring.

However, we can reduce the danger of overheating by lubrication. We have a thin film of oil between the two metallic surfaces to keep them apart. The internal friction of oil is much less than the friction between two solids, and generates less heat. Lubrication also offers another advantage. A film of oil on the metal surfaces will prevent them from corroding by protecting them from the air.

The sort of lubricant which we use depends largely on the running speed of the bearing. We can use grease in low-speed bearings, but grease offers more resistance to the turning movement of the shaft. A lighter oil causes less friction, and so an oily lubricant is better for high-speed bearings. The rotation of the shaft carries the film of oil round the inside of the bearing and keeps the shaft from contact with the bush which houses it. We can feed the oil into the bearing in several ways. Sometimes we allow it to drip down under the influence of gravity. More commonly, a pump or gun feeds it in under pressure. In motor-car and other engines, we half cover the bearing in an oil-bath, and oil splashes up into it.

We can reduce the amount of friction even more with rolling bearings. The hardened steel balls in this type of bearing roll round in a finely-ground ball race, and make little more than point contact with the race.

**WORD STUDY**

*contact* (= touch)

1. When the platinum points are in contact with each other, a current flows.

2. The pistons do not come in contact with the cylinder cover.

3. The water which is in close contact with the steam will evaporate first.

4. The various departments are in close touch with each other all the time.

5. The leaves of the spring are not in contact with each other. They are separated or kept apart by strips of rubber.

---

**House, Accommodate**

1. The university houses most of its students in hostels.
2. An aluminium bush houses the bearing.
3. The cylinders accommodate a certain volume of steam.
4. The air cannot hold any more steam without a rise in temperature.

---

**Resist, Withstand**

1. High-speed aircraft need metals which can resist very high temperatures.
2. Turbine blades must be able to withstand creep and corrosion.
3. Curved rails offer resistance to the movement of the train.
4. Some materials offer resistance to the passage of electric current.
5. Silicones offer resistance to moisture and heat.
6. Thick grease offers more resistance to motion than thin oils.
7. Silicones are resistant to moisture and heat.

---

**Advantages**

The advantage of rolling bearings is that they cause less friction.

This type of bearing offers several advantages over the sliding bearing.

Its low cost confers a great advantage on this type of engine.

The earlier type of engine suffers from the disadvantage of being expensive to run.

---

**PATTERNS**

1. The Use of Will, Can and May

These are the most important uses of these three words:

1. **Future (Will)**

   Note: We do not often use the form is going to in technical writing or speech to show the future.

   Production of the new machine will commence next year.
   Work will shortly begin on the new motorway.
   The new aircraft will fly for the first time on Monday.

---
Section 4

Reading: The Lathe

The lathe is one of the most useful and versatile machines in the workshop, and is capable of carrying out a wide variety of machining operations. The main components of the lathe are the headstock and tailstock at opposite ends of a bed, and a toolpost between them which holds the cutting tool. The toolpost stands on a cross-slide which enables it to move sideward across the saddle or carriage as well as along it, depending on the kind of job it is doing. The ordinary centre lathe can accommodate only one tool at a time on the tool-post, but a turret lathe is capable of holding five or more tools on the revolving turret. The lathe bed must be very solid to prevent the machine from bending or twisting under stress.

The headstock incorporates the driving and gear mechanism, and a spindle which holds the workpiece and causes it to rotate at a speed which depends largely on the diameter of the workpiece. A bar of large diameter should naturally rotate more slowly than a very thin bar; the cutting speed of the tool is what matters. Tapered centres in the hollow nose of the spindle and of the tailstock hold the work firmly between them. A feed-shaft from the headstock drives the tool-post along the saddle, either forwards or backwards, at a fixed and uniform speed. This enables the operator to make accurate cuts and to give the work a good finish. Gears between the spindle and the feed-shaft control the speed of rotation of the shaft, and therefore the forward or backwards movement of the tool-post. The gear which the operator will select depends on the type of metal which he is cutting and the amount of metal he has to cut off. For a deep or roughing cut the forward movement of the tool should be less than for a finishing cut.

Centres are not suitable for every job on the lathe. The operator can replace them by various types of chucks, which hold the work between jaws, or by a front-plate, depending on the shape of the work and the particular cutting operation. He will use a chuck, for example, to hold a short piece of work, or work for drilling, boring or screw-cutting. A transverse movement of the tool-post across the saddle enables the tool to cut across the face of the workpiece and give it a flat surface. For screw-cutting, the operator engages the lead-screw, a long screwed shaft which runs along in front of the bed and which rotates with the spindle. The lead-screw drives the tool-post forwards along the carriage at the correct speed, and this ensures that the threads on the screw are of exactly the right pitch. The operator can select different gear speeds, and
EXERCISE

Complete these statements with a suitable verb from those used above, or the corresponding noun:

1. Coal miners wear safety helmets to ...... them from falling rock.
2. The lock on the door ...... the thieves from entering the office.
3. The noise from the street ...... him from sleeping.
4. The doctors ...... the patient alive with drugs.
5. Lack of capital ...... the company from buying the new machinery.
6. We have to ...... the steel from contact with air when we heat or cool it.
   This ...... oxidation from taking place.
7. These drugs do not afford complete ...... from the disease, but they ...... the likelihood of catching it.
8. We normally ...... having two similar metals sliding over each other.
9. The non-return valve ...... the steam from escaping.
10. A refrigerator ...... food fresh for a long time.
11. The filter ...... grit from getting into the engine.
12. The use of helium rather than hydrogen ...... the possibility of explosion.
13. Good planning ...... the production costs down.
14. The ...... of fire in a mine is of the greatest importance.
15. Working in shifts ...... shutting down the boilers at night.
16. Cooling the metal in oil rather than water ...... the risk of cracking.

3. Classification

<table>
<thead>
<tr>
<th></th>
<th>two</th>
<th>three</th>
<th>several</th>
<th>many</th>
</tr>
</thead>
<tbody>
<tr>
<td>types</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>kinds</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>sorts</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>classes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>varieties</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>of bearings</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Bearings</th>
<th>are</th>
<th>of</th>
<th>two, etc.</th>
<th>types, etc.</th>
<th>(of = belonging to)</th>
</tr>
</thead>
<tbody>
<tr>
<td>We can classify</td>
<td>bearings</td>
<td>according to</td>
<td>their position on the shaft: whether they take the load on the shaft or the end thrust.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>We can divide</td>
<td>bearings</td>
<td>into several</td>
<td>classes</td>
<td>categories</td>
<td>groups</td>
</tr>
</tbody>
</table>
10. He teaches all the children of the neighbourhood, ..... whether they are rich or poor.
11. The passengers ..... the pilot and navigator for their safety.
12. Progress with nuclear reactors will ..... solvency many engineering problems.
13. The velocity of the liquid flow ..... the diameter of the pipe it flows through.
14. A number of different tools are available ..... the amount of money you can spend on them.
15. The number of tools which you can buy ..... the amount of money you can spend.

2. Movements

1. a. A trip-lever actuates operates the valve. (= makes it move).
    b. A flexible belt drives the motor. (= makes it turn round).

2. a. The piston moves forwards, backwards, up, down.
    b. The pendulum oscillates, or moves, etc.
    c. The cross-slide traverses, or slides, the carriage.
    d. The wheels rotate, turn, revolve.
    e. The liquid circulates through the pipes.

3. The machine is at rest, stationary, in motion, moving.

3. Velocity

<table>
<thead>
<tr>
<th>The velocity speed of the aircraft fluid gas, etc.</th>
<th>increases, rises, decreases, falls.</th>
</tr>
</thead>
<tbody>
<tr>
<td>The aircraft increases speed, speeds up, accelerates.</td>
<td></td>
</tr>
<tr>
<td>There is an increase in speed.</td>
<td></td>
</tr>
<tr>
<td>Opening the throttle of a car makes it go faster, accelerates it.</td>
<td></td>
</tr>
<tr>
<td>Applying the brake of a car makes it go slower, retards it.</td>
<td></td>
</tr>
</tbody>
</table>

A reciprocating engine.
A oscillating movement.
this will alter the ratio of spindle and lead-screw speeds and therefore alter the pitch of the threads. A reversing lever on the headstock enables him to reverse the movement of the carriage and so bring the tool back to its original position.

WORD STUDY
Machine, Motor, Work, Tool, etc.

An engine e.g. a steam engine
A turbine
An aero-engine, etc.

A motor e.g. a small (electric) motor

A tool e.g. a hand-operated tool, a hammer, drill, chisel

A machine e.g. a lathe, power press, etc.

These produce power.

We roll metal in a rolling-mill.
We draw metal in a die.
We forge metal in aforge or drop-forgi.
We hammer metal with a hammer, etc.

We work or form the metal.

We turn metal on a lathe.
We grind metal on a grinding machine.
We polish metal.
We bore metal, etc.

These use power.

Gears, Teeth, etc.

We connect the machine to the motor by a driving belt or chain.
We link (there may be four forward gears and one reverse gear.)

We engage the gear by letting (putting) in the clutch.
We disengage the gear by letting out the clutch.

Incorporate
The pulley incorporates (has) a brake.
The headstock incorporates (contains) the gears and driving mechanism.
The solder incorporates (including) a fluxing material.
The vessel incorporates (has) a number of new constructional features.

PATTERNS
1. Dependence
You should pay special attention to the constructions used with this word. Notice that the first meaning (to) is slightly different from the rest.

a. The aircraft is dependable (reliable). You can depend (rely on) it. It will not break down.
b. The aircraft depends on its wings and engines to provide lift.
c. Sweden is dependent on her hydro-electric resources for power.
d. Our customers rely on our completing their order by the agreed date.

2. a. The size of the motor
depends on the amount of power it has to produce.

b. The rise in pressure
is dependent on the speed of rotation of the pump.
c. The hardness of the steel
is dependent on the proportion of carbon it contains.

3. a. The steel will be mild or hard depending on the proportion of carbon it contains.
b. The metal will expand or contract according to whether the temperature rises or falls.

4. The climate remains the same, independent of (irrespective of) the season of the year.

EXERCISE
Complete these statements with the appropriate word or words.

1. The amount of expansion which takes place …… the coefficient of expansion of the metal.
2. The saturation pressure of a vapour …… its temperature.
3. The building work will start this month or next, …… how soon enough labour is available.
4. The depth of the road surface will …… the volume of traffic it carries.
5. This country …… imports from abroad for more than half its food.
6. The motor may be large or small …… the amount of power it has to give.
7. The research programme will continue …… the cost.
8. The angle of refraction of light …… the angle of incidence.
9. The value of a metal …… whether it is rare or abundant.
2. (Comparative)

The temperature in the boiler is

slightly above normal (505° C).
rather above normal (520° C).
slightly higher than it should be.
rather higher than it should be.

Note: rather, not fairly, is used with comparatives, whether they indicate an advantage or a disadvantage.

PATTERNS

I. The Impersonal Passive

In the first four sections, we added using the passive type of statement, and concentrated on the types of statement which are frequently made in the active form. But you must remember that the majority of statements in technical writing are in the passive form, because the technical writer wants his object to be objective and impersonal. He does not usually start a sentence with I or you or the operator, etc. From this section on, we shall be using the passive form very often.

Here are a few examples of the change from active into passive.

<table>
<thead>
<tr>
<th>Action</th>
<th>Passive</th>
</tr>
</thead>
<tbody>
<tr>
<td>The driver starts the engine.</td>
<td>The engine is started.</td>
</tr>
<tr>
<td>He welds the plates together.</td>
<td>The plates are welded together.</td>
</tr>
<tr>
<td>The furnace smelts the ore.</td>
<td>The ore is smelted in the furnace.</td>
</tr>
<tr>
<td>The man sharpened his tool.</td>
<td>His tool was sharpened.</td>
</tr>
<tr>
<td>He welded the plates together.</td>
<td>The plates were welded together.</td>
</tr>
<tr>
<td>They will start the work soon.</td>
<td>The work will soon be started.</td>
</tr>
<tr>
<td>We must lubricate bearings.</td>
<td>Bearings must be lubricated.</td>
</tr>
<tr>
<td>A lathe can cut screws.</td>
<td>Screws can be cut on a lathe.</td>
</tr>
</tbody>
</table>

As you see, Passive constructions require this pattern:

(pro)noun + a form of be + past participle

EXERCISE

Change these active statements into impersonal passive statements.

1. We can cast this type of metal into very complicated shapes.
2. We smelt the ore in a blast furnace and reduce it to pig iron.
3. A skilled operator can carry out many operations on a lathe.
4. We clamp two metal plates together.
5. Coal miners produce millions of tons of coal every week.
6. The company marketed several new products every year.
7. They will start production on the new type of reactor soon.
8. We can generate heat for welding in several ways.
9. We pass an electric current across the electrodes.
10. Welders normally prefer a vee-shaped weld.
11. That country does not produce any heavy industrial machinery.
12. This allows the cross-slide to move across the saddle.
13. The operator selects the appropriate gear for the job.
14. We call these supports bearings.
15. This will prevent damage to the shaft.
16. This will prevent the metal surfaces from coming into contact.
17. We can use a thin grease as a lubricant in rolling bearings.
18. We can alter the characteristics of steel in various ways.
19. We must heat the steel above its critical temperature.
20. You must take care not to damage the machinery.

II. Methods

1. a. Welding is one method of joining pieces of metal together.

b. There are many methods of joining pieces of metal together.

c. One of the best methods of joining pieces of metal together is to weld them.

Note. Means, as a noun, is the same in both singular and plural (see Section 8).
Without the 's', means is an adjective (see Section 2).

2. New methods of production were adopted a few years ago.

3. Should

This word is used very often in technical writing, with several slightly different meanings.

1. Instructions to operators, employers, etc.

These machines should be handled with great care.
Safety precautions should be observed at all times.
The results of the experiment should be plotted on a graph.
N.B. This is sometimes used for politeness when must be is really meant.
Section 5
Reading: Welding

There are a number of methods of joining metal articles together, depending on the type of metal and the strength of the joint which is required. Soldering gives a satisfactory joint for light articles of steel, copper or brass, but the strength of a soldered joint is rather less than a joint which is brazed, riveted or welded. These methods of joining metal are normally adopted for strong permanent joints.

The simplest method of welding two pieces of metal together is known as pressure welding. The ends of metal are heated to a white heat — for iron, the welding temperature should be about 1300° C — in a flame. At this temperature the metal becomes plastic. The ends are then pressed or hammered together, and the joint is smoothed off. Care must be taken to ensure that the surfaces are thoroughly clean first, for dirt will weaken the weld. Moreover, the heating of iron or steel to a high temperature causes oxidation, and a film of oxide is formed on the heated surfaces. For this reason, a flux is applied to the heated metal. As welding heat, the flux melts, and the oxide particles are dissolved in it together with any other impurities which may be present. The metal surfaces are pressed together, and the flux is squeezed out from the centre of the weld. A number of different types of weld may be used, but for fairly thick bars of metal, a vee-shaped weld should normally be employed. It is rather stronger than the ordinary butt weld.

Electric arc welding

The heat for fusion welding is generated in several ways, depending on the sort of metal which is being welded and on its shape. An extremely hot flame can be produced from an oxy-acetylene torch. For certain welds an electric arc is used. In this method, an electric current is passed across two electrodes, and the metal surfaces are placed between them. The electrodes are sometimes made of carbon, but more frequently they are metallic. The work itself constitutes one of them and the other is an insulated filler rod. An arc is struck between the two, and the heat which is generated melts the metal at the weld. A different method is usually employed for welding sheets or plates of metal together. This is known as spot welding. Two sheets or plates are placed together with a slight overlap, and a current is passed between the electrodes. At welding temperature, a strong pressure is applied to the metal sheets. The baffle film, and any impurities which are trapped between the sheets, are squeezed out, and the weld is made.

WORD STUDY

**Adopt** ( = take over, accept, put into use)

1. Various methods can be adapted to keep the temperature down.
2. We have applied the conclusions reached in the report to the machine.
3. Parallax is now a more compact form of construction for the machine.
4. Great Britain recently adopted the Centigrade scale for temperature.
5. The designer applied the principle recently.

**Apply** ( = put an)

1. A pressure of x lb./in.² is applied to the piston.
2. When pressure is applied to the ice, some of it will melt.
3. Insulation should be applied to the wire in the form of a paste.
4. Grease may be applied to the bearings with a grease gun.
5. This principle was successfully applied to the design of high-speed aircraft.

**Utilise, Employ, Employ**

1. The government intends to make use of the natural resources of the country, its five-year lead over other countries in jet-planes.
2. Electrical power from the generator is used in nuclear reactors.
3. Steam at boiler pressure is utilised to produce draughts in the boiler.
4. Different types of electric arc are used for various purposes.

**Slightly, Rather, Slightly**

1. The temperature in the boiler is normal (50° C), slightly high (50° C).
2. This is an advantage.
3. Rather high ( = this is a disadvantage).
stop-valve at high pressure. A fresh supply of water is fed by pumps into the boiler to replace it. The feed-water should be pure, and free from dissolved salts which will cause deposits on the tubes and lead to overheating.

**WORD STUDY**

*Attain, Achieve (= reach)*

- The aircraft is capable of reaching a speed of 4000 miles per hour.
- Achieving

1. Pressures of up to 300 lb/in² were reached in the boiler.
2. An efficiency of only 4% or 5% was attained by the engine.
3. A high degree of accuracy can be achieved by cold-working the metal.

A greater efficiency should be attainable with certain modifications.

*Absorb (= take in)*

1. A sponge will absorb water.
2. The spring must absorb most of the shock.
3. The water will absorb a large proportion of the heat from the furnace.
4. Dark surfaces absorb heat more than bright surfaces.

Sponges are absorbent. They have a great absorptive power.

*Conserve - Dissipate*

- The law of the conservation of energy states that energy cannot be lost or created. It can only be changed into different forms. Energy is always conserved, or kept.
- The refractory linings of the furnace conserve the heat (= keep it in).
- The government tries to conserve the natural resources of the country (= to use sparingly).
- But in many countries, the natural resources are being dissipated (= used wastefully). 60% of the heat which the engine produces is dissipated through the cylinder walls (= escapes).
- Firebricks are used in a furnace to prevent undue dissipation of useful heat to the atmosphere.

*Efficiency*

1. The efficiency of a machine is the ratio of the work which is done to the energy which is supplied.
2. The efficiency of a jet engine at great speeds and altitudes is greater than that of a piston-engine.

3. An ideally efficient machine is one which has an efficiency of 100%.
4. An efficient water circulation in the boiler is necessary for rapid production of steam.
Section 6

Reading: Steam Boilers

Large quantities of steam are used by modern industry in the generation of power. It is therefore necessary to design boilers which will produce high-pressure steam as efficiently as possible. Modern boilers are frequently very large, and are sometimes capable of generating 300,000 lb of steam per hour. To achieve this rate of steam production, the boilers should operate at very high temperatures. In some boilers, temperatures of over 1650°C may be attained. The fuels which are burned in the furnace are selected for their high caloric value, and give the maximum amount of heat. They are often pulverized by crushers outside the furnace and forced in under pressure.

Modern boilers which employ solid fuels are usually too large to be hand-stoked, and stoking is then carried out by mechanical stokers, which ensure that an adequate quantity of fuel is conveyed into the furnace at the proper speed. The air which is needed by the fuel for combustion is blown across the fire grate by steam jets or fans. The amount of air which is allowed to enter is just more than sufficient for complete combustion of the fuel. An insufficient supply of air will prevent complete combustion, but any air in excess of the minimum merely reduces the temperature of combustion. The hot gases which are produced by the combustion of the fuel are circulated round banks of water-tubes. These are inclined at an angle over the furnace, and connect the upper and lower steam drums. A large proportion of the heat is absorbed by the water in the boiler. The remainder may be used to heat up the incoming air-supply through an air-heater. The water and steam in the boiler should circulate freely. The water and steam circuits are designed to allow the greatest possible fluid velocity to be attained, and rapid movement of the fluid is achieved by forced circulation. This assists rapid heating and also prevents the formation of steam pockets in the tubes.

Loss of efficiency in the boiler will be caused by the dissipation of heat through the walls of the combustion chamber. This heat loss can be considerably reduced by the use of firebricks round the walls of the chamber. This helps to insulate the chamber and to conserve the heat which is generated. However, at the temperatures which are attainable in modern boilers, the solid walls of the furnace are liable to be damaged by excessive heat. To avoid this, they are often lined with water-tubes, and some of the heat of combustion is absorbed by the water.

The steam from the boiler is passed through a superheater and out past a
**EXERCISE**

Complete these statements, as shown above.

1. The boiler should be strong ...... to withstand the pressure inside it.
2. The sand should be ...... porous to permit the air to escape.
3. The heat which is generated is ...... to raise the steam to a high temperature.
4. Heavy water was ...... expensive to be used as a coolant in the reactor.
5. The quantity of oil which is delivered ...... the quantity which is needed for lubrication.
6. An ...... overflow pipe should be fitted to carry away the ...... water.
7. The diet of many undernourished people is ...... protein.
8. The fall in speed is ...... rapid ...... this method of testing to be adopted.
9. The fall in speed is ...... rapid ...... adopt this method of testing.
10. ...... little grease may cause bearing failure because of ...... lubrication.
11. Vehicles are not permitted to ...... a speed of 30 m.p.h. in built-up areas.
12. When supply ...... demand for any product, the prices are liable to fall.
13. The motor should not be run at an ...... speed.
14. Efficient heat removal at an ...... high temperature is necessary for the economic working of the reactor.
15. ...... surveys must be carried out before the construction of the dam can begin.
16. The world supply of petroleum is ...... for all foreseeable demands.
17. This load is ...... heavy ...... be carried by the motor.
18. This load is ...... heavy ...... the motor to carry.
19. The load is ...... for the motor.
20. To avoid ...... frictional losses, the bearings must be efficiently lubricated.

**EXERCISE**

*(should and imperative)*

1. Give instructions on how to mend a puncture in a bicycle tyre.
2. Give advice on how to prevent burglars from entering houses.
3. Tell a new employee of the safety precautions he should observe in the machine shop.
4. Instruct an apprentice on how to cut screws on a lathe.
5. Rewrite this passage, using *should* with passive forms instead of the imperative form.

   Fill a test-tube half full of water and heat it nearly to boiling point. Support the tube on a stand and allow it to cool. Take the temperature every minute. Stir carefully with a glass rod. Record the readings you obtain, and plot them on a graph of temperature against time. Repeat this with a tube half-full of crystals. Allow the solid to melt. Heat the liquid to 100° C, fix the tube on the stand and allow it to cool. Record the results as before and plot them.
6. Rewrite this passage, using the imperative instead of should.

   The ends of the metal articles should be thoroughly cleaned. No dirt should be left on them. The ends should then be heated to a white heat. An oxy-acetylene torch should be used for this. A flux should then be applied to the weld. The surfaces should be pressed together. Care should be taken to squeeze out the whole of the flux. The joint should then be smoothed off.

**Instructions (Imperative)**

In Section 5, we noted that *should* is often used to give impersonal instructions to operators, etc. on the correct method of doing something, or on what is wanted. A more direct form of instruction is given by the imperative form of the verb. It is often used for experimental or handling instructions, and in hypotheses or calculations.

1. Allow the water to cool for ten minutes and then take the temperature.
   *Hold the convex lens in front of the white paper.*
2. Calculate the amount of expansion which will take place.
Deposit (not put down)

1. a. The money was
   b. The copper ions are
   c. Condensed steam is
   d. The side which is —— deposited in the bank.
   on the cahade as metallic copper.
   on the cold surfaces of the cylinder.
   in the water-tubes must be removed.

2. a. A fairly small deposit of spent on boiler tubes may be beneficial.
   b. There are large coal deposits in the north of the country.

Patterns

1. Passive Verb + by + Noun (agent)
   'The postman delivered the letters' could be written in the passive as 'The letters were delivered by the postman.' By the postman is simply the grammatical agent in the passive sentence.
   In technical writing, it is not usual to add the name of the agent to a sentence of this kind, if the agent is a person. But very often the agent is not a person, and it may be necessary to add it. For example:

   Large quantities of steam are required by modern industry.

Note: This agent only occurs in passive sentences.

Exercise

Complete these sentences in the same way, using the Present tense, and where possible the Past and Future tenses.

1. The bridge (...... build ......) the Know-all Construction Company.
3. Many engineering scholarships (...... give ......) the government.
4. The machine (...... power ......) a small electric motor.
5. Loss of efficiency (...... cause ......) dissipation of heat through the furnace walls.
6. Unequal contractions (...... produce ......) rapid cooling of the metal.
7. Blow holes in castings (...... cause ......) bubbles of trapped air.
8. The bronze plates can (...... replace ......) soft rubber discs.
9. The steam (...... carry along ......) a jet of water.
10. A large proportion of the heat (...... absorb ......) the water.
11. The heat (...... provide ......) an oxy-acetylene torch.
12. Three machines can (...... control ......) a single operator.
13. The light (...... refract ......) the surface of the glass.
14. Coal (...... form ......) the decay of vegetable matter.
15. All responsibility for the accident must (...... accept ......) the designers.

16. A very strong joint (...... produce ......) a vee-shaped weld.
17. Some of the heat (...... absorb ......) the water-tubes round the boiler.
18. The work (...... grip firmly ......) the jaws of the chuck.
19. The heat (...... provide ......) the combustion of pulverised fuel.
20. The damage to the machine last week (...... cause ......) carelessness.

2. Too Much or Too Little

| The boiler consumes an excessive amount of fuel. |
|---|---|---|---|
| Too much air | enters the furnace. |
| An excessive amount of air reduces the temperature of combustion. |
| The temperature was excessive, excessively high. too high. |
| The metal was too hard to machine. to be machined. |
| The temperature in the combustion chamber exceeded was greater than 2000 C. degrees. |
| Enough heat must be supplied to melt the metal. for the metal to melt. for the metal to be melted. |
| The heat was not enough inadequate insufficient to melt the metal, etc. |
| Nuclei which are deficient in have a deficiency of neutrons are unstable. |

34
WORD STUDY
Admit, Introduce

1. = allow to enter
   a. The steam is admitted to the cylinder through a port.
   b. A fuel/air mixture is introduced into the cylinder.
   c. The admission of steam into the cylinder is controlled by a slide-valve.

2. Introduce (= make for the first time)
   a. Engines with rotary movements were introduced about 1780.
   b. An engineer named Trevithick introduced the steam locomotive in 1804.
   c. Many modifications have been introduced to improve the performance of the engine.

Speed Rate
1. The aircraft is capable of travelling at a speed of 4000 miles per hour.
2. A falling body accelerates at a rate of 32 ft/s².
3. This generator can produce steam at a rate of 200,000 lb/hour.
4. The population of the world is growing at a dangerous rate.

Capacity
1. This oil tank is capable of holding ten gallons.
2. This oil tank has a capacity of ten gallons.
3. The evaporative capacity of the boiler is 200,000 lb/hour.
4. The thermal capacity of a substance is the amount of heat needed to raise its temperature by 1° C.

Evaporate (= give off - gas, vapour, heat)
1. When water boils, steam is evaporated.
2. When a fuel is burnt, hot gases are evolved.
3. The evaporation of hot gases follows the burning of a fuel.

Generate (= make, produce - power, steam, heat, etc.)
1. This type of boiler can generate steam pressures of 300 lb/in².
2. The heat which is generated in an air-compressor must be kept to a minimum.
3. An electric generator is a machine for generating electric current.

Develop
1. = make, produce - power or heat
   a. Electric power is developed in the generator.
   b. The amount of heat which a fuel will develop depends on its calorific value.
   c. This engine develops 120 brake horse power (b.h.p.).

PATTERNS
1. Purpose
   These are the commonest ways of expressing the purpose for which we do something.

<table>
<thead>
<tr>
<th>Purpose</th>
<th>object</th>
</tr>
</thead>
<tbody>
<tr>
<td>The aim of the safety valve is to allow excess pressure to escape.</td>
<td></td>
</tr>
</tbody>
</table>

Exercise One
For practice, read these sentences using purpose, aim and object in front.

1. The purpose of fitting water-tubes in a boiler is to absorb some of the heat.
2. etc.
3. annealing the metal is to relieve some of the stresses.
4. Lubricating bearings is to reduce the friction.
5. Superheating the steam is to ensure that it is fairly dry.
6. Working a metal cold is to obtain a more accurate finish.
7. Using firebricks is to minimise heat losses in the boiler.
8. Incorporating a gauge is to measure the pressure in the boiler.
9. Using pure feed-water is to prevent the formation of deposits.
10. The test is to calculate the total temperature rise.
11. Forced circulation is to prevent the formation of steam pockets.
12. A large heating surface is to increase the amount of steam which is produced.
Section 7

Reading: Steam Locomotives

From the date of the introduction of the steam locomotive about 130 years ago, there was a continuing increase in the size and weight of trains. This necessitated engines of greater and greater power. In order to achieve this increase in power, much higher steam pressures were required. The modern steam locomotive is capable of generating steam pressures often in excess of 300 lb/in², against the 50 lb/in² pressure of Stevenson's 'Rocket'. Normally the demand for increased steam capacity is met by increasing the size of the boiler. However the boiler of a steam locomotive is strictly limited in size by the dimensions and load capacity of the railway track which it works on. It is therefore necessary to have a very large heating surface within the boiler.

There are two fire-boxes inside the boiler, an inner one and an outer one, which extend a long way forward. The inner fire-box is linked by tubes to the fire-plate at the front of the boiler. Practically the whole of the heating surface, which includes these fire-tubes, is surrounded by water. A high rate of evaporation in the boiler is essential, in order to generate the large quantities of steam which are required. For this purpose a powerful draught of air is blown over the fire. The steam which is evolved is passed through a superheater, which raises its temperature and makes it as dry as possible. Rapid evaporation at the heating surface tends to make the steam wet. The use of wet steam necessitates excessively high pressures in the cylinder. Superheating the steam enables the requisite power to be obtained with considerably lower pressures.

The superheated steam is passed to the steam-chest which is attached to the cylinder. From the steam-chest it is introduced into the cylinder at the appropriate moments through ports. These ports are opened and closed by slide valves, which are actuated by the rotation of the locomotive crankshaft. The steam is admitted under pressure to one side of the cylinder, and drives the piston forwards. The inlet port is then closed, and a second charge of steam is admitted at the other side of the cylinder to drive the piston in the reverse direction. The exhaust steam from the first charge is driven out into the atmosphere through a blast pipe. This is done in order to increase the draught over the fire. The reciprocating action of the piston is changed into a rotational movement of the wheels by a connecting rod and crank.
amount of steam may be (generated, evolved, given off). For (this, that) reason, the furnace must be built of (substance, material) which is (able, capable) to (restrict, restrain, withstand) extreme temperatures. In order to (prevent, avoid) heat losses through the furnace walls, they are lined (by, with) bricks. By this (mean, means, way) the heat is (preserved, conserved) inside the furnace.

3. The crew of the aircraft (it, are) (comprised, composed, constituted) of two pilots, a navigator and a radio operator. They have all been flying (since, for) (a number, numbers) of years, and are all (largely, greatly, highly) qualified men.

4. Coal production has been (fairly, rather) higher this year (as, than) last year. (That, This) is because of the (employment, exploitation) of new automatic (machinery, mechanism, engines) capable (to cut, of cutting) far more coal (as, than, that) can be cut (with, by) hand.

5. Mercury (provides, produces, offers) (a number, quantity) of advantages (on, over) alcohol in measuring (heat, temperature). It has a (rather, fairly) constant rate of expansion (in, respect, irrespective) of temperature, and remains liquid over a (big, large, wide) range of temperatures. It can be employed up to about 350° C. (under, in) normal atmospheric pressure, and even higher when the pressure is (bigger, larger, greater) than atmospheric.

6. In (the most, most) countries, the Centigrade scale has been (adopted, adapted, applied) for all temperature measurements. (On, in, by) this scale 0° is the temperature (with, on, at) which pure ice melts, and 100° is the boiling (point, level) of pure water under (usual, normal, normally) atmospheric pressure.

7. Ferrous metals are very (apt, liable, possible) to corrosion by oxidation or by some other (chemic, chemical) (act, action), and they have therefore to be (prevented, avoided, protected) in some (method, way). One (mean, means) which is often employed to (achieve, obtain, acquire) this is to give the metal a (coat, jacket, clothing) of zinc by a process which is (known, called, termed) as galvanising.

8. The lathe is a (machine, tool, mechanism) which enables (works, work, jobs) to be (worked, machined) to a (great, high, exact) degree of accuracy. The (food, feed) is controlled automatically by (means, way) of a shaft which is (revolved, impelled, driven) by a system of gears which are (incorporated, accommodated) in the headstock.

9. An (enough, adequate) supply of air is necessary (to, for) the combustion of the fuel in the furnace. If (too, excessive) much air is present, the temperature of the furnace will (reduce, fall, lower). There should be just enough air to (ensure, enable, let) (complete, thorough) combustion to take place.

10. An (intensely, intensively) hot flame is produced in an (electric, electrical) arc by passing a current (through, across, between) two electrodes and placing the metal plates which are (to weld, to be welded) (between, among, through) them.

11. A (rise, raise) in temperature will (make, cause) the steam pipe to (extend, expand, increase) in length, and in order to (prevent, resist, eliminate) stresses from being set up in the metal, expansion joints are fitted which (relieve, reduce, release) the stresses by (allowing, permitting, letting) the pipe to expand or contract freely.

12. A country which possesses (few, a few, little) natural (resources, reserves, deposits) is dependent (on, of) the import of (natural, crude, raw) materials, and must pay (them, for them) by exporting the manufactured goods.

13. These (experiences, experiments) began a few months (ago, since), and some progress (has, have) already been (done, performed, made). It is unfortunate that, owing to (lack, absence, short) of money, they must now be (culminated, terminated) before the real (object, subject) has been (accomplished, achieved, resulted).

14. The dam which is now being (erected, constructed) will (bring, cause, make) many benefits to the country. It will (at first, first of all) (dispense, prevent, obstruct) the danger of flooding, and also (enable, ensure) that there is plenty of water for irrigation. It will also (enable, ensure) the water to be used to provide hydro-electric (power, force, energy).

15. Dr Smith has (devoted, concentrated) many years to (carrying, carry) out (research, researches) (on, in, into) the (characters, properties) of this (matter, material). The results of his work have appeared as (articles, essays, papers) in a number of learned (journals, magazines, papers), and have (roused, aroused, raised) much interest.
EXERCISE TWO

Change each of the sentences in Exercise One into the patterns shown in (2) above.

N.B. For the last three sentences, you will have to add a verb. e.g.: The purpose of the text is to calculate the total temperature rise = The text is made for the purpose of ... etc.

2. Requirements and Necessity

<table>
<thead>
<tr>
<th></th>
<th>lubricating, to be lubricated, some lubrication.</th>
</tr>
</thead>
<tbody>
<tr>
<td>The bearings</td>
<td></td>
</tr>
<tr>
<td>need</td>
<td></td>
</tr>
<tr>
<td>require</td>
<td></td>
</tr>
<tr>
<td>The machine</td>
<td>repairing, to be repaired, a new clutch.</td>
</tr>
<tr>
<td>needs</td>
<td></td>
</tr>
<tr>
<td>requires</td>
<td></td>
</tr>
<tr>
<td>The tool</td>
<td>re-grinding, to be re-ground, a re-grind.</td>
</tr>
<tr>
<td>needs</td>
<td></td>
</tr>
<tr>
<td>requires</td>
<td></td>
</tr>
<tr>
<td>The scale in the tube</td>
<td>removing, to be removed, removal.</td>
</tr>
<tr>
<td>needs</td>
<td></td>
</tr>
<tr>
<td>requires</td>
<td></td>
</tr>
</tbody>
</table>

The bearings must be lubricated.

It is necessary for the bearings to be lubricated.

<table>
<thead>
<tr>
<th>Friction</th>
<th>a good lubrication system.</th>
</tr>
</thead>
<tbody>
<tr>
<td>makes necessary</td>
<td></td>
</tr>
<tr>
<td>necessitates</td>
<td></td>
</tr>
<tr>
<td>Increased wages</td>
<td>an increase in prices.</td>
</tr>
<tr>
<td>makes unnecessary</td>
<td></td>
</tr>
<tr>
<td>necessitates</td>
<td></td>
</tr>
<tr>
<td>The use of plastic pipes</td>
<td>protection against corrosion.</td>
</tr>
<tr>
<td>makes unnecessary</td>
<td></td>
</tr>
<tr>
<td>dispenses the need for</td>
<td></td>
</tr>
<tr>
<td>does away with the need for</td>
<td></td>
</tr>
<tr>
<td>Superheating the steam</td>
<td>very high pressures in the boiler.</td>
</tr>
<tr>
<td>makes unnecessary</td>
<td></td>
</tr>
<tr>
<td>dispenses the need for</td>
<td></td>
</tr>
<tr>
<td>does away with the need for</td>
<td></td>
</tr>
</tbody>
</table>

The furnace rapidly reaches the required temperature.

EXERCISE

Complete these statements, as shown above.

1. Increased speeds ...... improved cooling systems in the engines.
2. This type of engine has the advantage that it ...... very little maintenance.
3. It is ...... for the feed-water to the boiler ...... pure.
4. The crude ore ...... purifying before it can be of any industrial use.
5. Clear diagrams ...... the need for lengthy explanations.
6. The production of this new model will ...... complete re-tooling of the factory.
7. By placing the engines in the tail of the aircraft, we ...... with the need for very thick wings.
8. To ensure freedom from distortion, it is necessary ...... the metal bar ...... cooled slowly.
10. A large area of heating surface ...... to produce the ...... weight of steam.
11. A nuclear reactor ...... large quantities of water for cooling, and this ...... siting it near a river or on the coast.
12. The metal is heated up to the ...... welding temperature.
13. The demand for low-cost power ...... engines of greater efficiency and with a low fuel consumption.
14. With vehicles which will run on a cushion of air, the need for wheels can be ......
15. 10% of the total power developed will be ...... to drive the super-charger.
16. Radiation is the most efficient form of transmission for heat which ...... to be transmitted in all directions.
17. Steel with the ...... properties is ...... for this special purpose.

REVISION (SECTIONS 1–7)

Read these statements, choosing the correct word from the alternatives in brackets.

1. The clinical thermometer is used (for, to) measuring (body's, body) temperature. It (contains, includes, consists of) a tube made (of, from, with) glass, which (contains, consists of, comprises) a certain (amount, number) of mercury. When the mercury is (hot, heated), it (expands, extends, increases) and (raises, rises) up the tube, which is graduated in degrees Fahrenheit or Centigrade (according, depending) on the country of manufacture.

2. The temperature in the furnace is (great, high, hot), so that the maximum
WORD STUDY

Product, Produce, Production

1. a. The company produces 1000 cars a day. (= makes)
b. The boiler produces high-pressure steam. (= generates)
c. Combustion produces very hot gases.

2. a. Most of our industrial products are sold abroad.
b. These hot gases are the products of combustion.
c. Petrol and kerosene are products of crude petroleum.

3. a. Motor-car production is increasing rapidly.
b. Recent figures show an improvement on last year.
c. A new line will be set up in the factory.

Consume, Consumption

1. a. The boiler consumes 3 tons of fuel per hour.
b. The reactor consumes less material than it produces.

2. a. Engine efficiency may be measured by steam consumption.
b. Family cars are designed for low fuel consumption.

Achieve, Obtain, Effect, Accomplish (= bring about)

1. A reduction in condensation is achieved by the use of steam-jackets.
2. Control of the power output is effected by varying the fuel supply.
3. Rapid closing of the valve is accomplished by fitting a heavy spring.
4. Removal of excess heat is accomplished by means of a radiator.

Withdraw, Extract, Abstract (= take out or draw out)

1. The condensate is withdrawn from the condenser by a pump.
2. The molten metal is extracted from the furnace, ready for casting.
3. Some of the steam is abstracted for heating and other purposes.
4. The exhaust gases are abstracted from the cylinder.
5. The fuel-rods are abstracted from the reactor core mechanically.

Inject (= squirt through jet or nozzle)

1. The fuel is injected into the cylinder by compressed air.
2. The oil is injected directly into the combustion chamber.
3. Pulverised fuel is injected into the furnace.

Eliminate, Get Rid Of

1. The use of oil in hydraulic systems largely eliminates corrosion.
2. In the interview, all except one applicant was eliminated for one reason or another, and this one man got the job.

PATTERNS

1. Means (by + noun or -ing)
In Section 6 we noted that by + an agent sometimes follows the verb in a passive statement

Large quantities of steam are required by modern industry

A second and more important use of by is to indicate the means or method of doing something or achieving some result.
It can occur in both active and passive statements.
It often occurs with the phrase by means of.
Sometimes it is possible to use with instead of by before a noun.
With really means with the help of, and there is a slight difference in meaning; it is not advisable to use with unless the meaning is truly instrumental.

The road was cleared by (means of) a bulldozer.
The road was cleared with (the help of) a bulldozer.

<table>
<thead>
<tr>
<th>Heat losses can be reduced</th>
<th>by firebricks</th>
</tr>
</thead>
<tbody>
<tr>
<td>We can reduce heat losses</td>
<td>the use of firebricks, lining the furnace with firebricks.</td>
</tr>
<tr>
<td>This can be done accomplished</td>
<td>by means of firebricks.</td>
</tr>
<tr>
<td>By</td>
<td>lining the furnace with firebricks.</td>
</tr>
<tr>
<td>heat losses can be reduced</td>
<td></td>
</tr>
</tbody>
</table>

N.B. You will notice in the last example that a clause or participial phrase may come before the main part of the statement. The word thereby means by means of this. By means of cannot be used before a participle; only by is possible in such a case.

EXERCISE ONE

Complete these statements in the same way, using the verb in brackets.

1. We reduce the ore to pig-iron ...... it in a blast furnace. (smelt)
2. Production will be greatly increased ...... the new machinery. (introduce)
3. A hot steel bar can be hardened ...... it in water. (quench)
4. Bars of steel can be made ...... them through rollers. (pass)
5. The heat-resistant properties of steel are improved ...... more chromium and nickel. (add)
6. ...... roller bearings, the friction is reduced still further. (use)
7. ...... the bearing in an oil-bath, adequate lubrication is ensured. (dip)
8. ...... a flux to the metal, we can prevent oxidation. (apply)
Steam which is admitted to a cold engine cylinder is liable to be partially condensed by contact with the cylinder walls. That part of the steam nearest to the walls is cooled and condenses as a film of water. The volume of steam in the cylinder is thereby considerably reduced, and more steam must be admitted in order that the pressure is sufficiently high to drive the piston along the cylinder. Condensation in a cylinder therefore reduces the steam consumption of the engine and thereby lowers its efficiency. It is therefore necessary to devise means of getting rid of this condensation as far as possible, and in modern reciprocating steam engines, condensation problems have been practically eliminated.

This is effected by superheating the steam in the boiler and also by fitting steam jackets round the cylinder. These are fitted into the annular space between the cylinder and the cylinder liner, and are connected to the steam supply. By raising the temperature of the cylinder walls in this way, the outward flow of heat is greatly reduced.

Steam which is exhausted from the cylinder still has a considerable heat content, and in order that this heat energy should not be wasted, the steam is condensed and passed back to the boiler as hot feed water. Rapid condensation is accomplished by means of a condenser. In this condenser, a liquid coolant is circulated through banks of metal tubes. By flowing over these tubes, the steam is caused to transmit some of its heat to the liquid, and a rapid drop in temperature occurs. The steam condenses, and is collected at the bottom of the condenser as condensate. By ensuring that there is no contact between the condensate and the coolant, a pure distilled water can be produced which is ideal for boiler feed water. This type of condenser is commonly used where pure water is not plentiful. The condensate is usually re-heated, so that it may be circulated back to the boiler at an adequate temperature.

In other types of condensers, which are known as jet condensers, the steam is cooled by allowing it to mix intimately with jets of cold water which are injected into the condenser. By this means, rapid condensation takes place, and the mixture of condensate and coolant is withdrawn by means of an extraction pump. The water which is normally used as a coolant cannot usually be utilised in the boiler, and cannot therefore be re-circulated. It is either pumped up to a cooling tower or it gravitates into a cooling pond, and is stored for later use in the condenser.

Cross-sections of (a) horizontal-process condenser (b) steam surface condenser
The relationship between the two nouns may vary quite a lot, as you can see from these examples:

Steam consumption = the consumption of steam.
Metal tubes = tubes made of metal.
Heat treatment = treatment with or by heat.
Steam jackets = jackets containing steam.
Cooling towers = towers for the purpose of cooling.
Butt weld = weld of the type called 'butt'.
Friction losses = losses caused by friction.

N.B. The possessive form ('s) is very seldom used in technical writing.

Exercise

Expand these Noun + Noun phrases to show the full meaning:
1. air supply 16. workshop machinery
2. water tube 17. gear mechanism
3. heat transfer 18. grease gun
4. mercury thermometer 19. lock nut
5. concrete structure 20. temperature drop
6. cylinder walls 21. petrol engine
7. steel bar 22. heat content
8. stop valve 23. turret lathe
9. boiler feed water 24. machine testing conditions
10. steam chest 25. power transmission problems
11. nickel alloy 26. condenser extractor pump
12. roller mill 27. generator power output
13. power cable 28. cylinder condensation losses
14. cylinder head design 29. gravity feed lubrication system
15. blast furnace 30. fire tube boiler inspection door

Section 9

Reading: Centrifugal Governors

Most engines in industrial use are rated to run at a constant speed, irrespective of the load they carry. In order to keep the engine speed within the limits which it was designed for, a device which is known as a governor is incorporated in the engine. Its function is to control the running speed under all conditions of load.

The simplest form of governor consists of a pair of balls which are attached to a vertical shaft by means of arms. These balls act as weights. While they are stationary, they are acted on only by gravity. Now the vertical shaft is geared to the engine, and rotates with it. When the engine starts, it causes the shaft to rotate, and this forces the rotating balls outwards under the influence of centrifugal force. This movement of the balls at the end of their arms is transmitted to a sleeve which is free to slide up and down the shaft. As the engine increases speed, it rotates the shaft more quickly, and the weights rise further against the force of gravity. The sleeve also rises up the shaft, and when it rises beyond a certain point, it operates a throttle valve lever, and so reduces the flow of steam. The engine speed will then decrease, and as the sleeve slides down, it opens the throttle valve again. When the engine is running at constant speed, it produces a state of equilibrium in the governor, with the centrifugal force equal and opposite to the controlling force—that is, the weight of the governor and its gear. Governors which are required to work at very high engine speeds are normally weight-loaded. A weight is attached to the sleeve, and serves to prevent the sleeve from rising too far.

Both the simple and weight-loaded governors depend on gravity and must therefore be kept in a vertical position. This is often a disadvantage, and may be obviated by the use of a spring instead of a weight. The spring performs the same function as the weight, and keeps the sleeve depressed. It can be mounted in any position. By making simple adjustments to the loading on the spring, the governor speed can easily be altered. The governor is mounted in a dome-shaped housing which contains the spring and the belt-crank levers, on which the rotating balls are pivoted. Ball bearings at the pivots and at the top of the spindle serve to reduce wear and friction. As the spindle rotates, it causes the weights to fly outwards, and this movement about the pivot raises the sleeve against the pressure of the spring. Equilibrium is attained at a constant engine speed by the balancing of the centrifugal force and the compressive load on the spring.
9. Forced circulation in the boiler, better results are obtained. (employ)
10. A gas rapidly in a cylinder, we raise its temperature. (compress)
11. Steam over the hot coke, producer gas is formed. (blow)
12. A casting is produced into molten metal into a mould. (pour)
13. Improved heat-transfer rates were achieved fins to the outside of the cylinder. (fit)

EXERCISE TWO
Complete these statements with by, by means of or with, whichever you think most suitable.

1. Production can be greatly increased the introduction of new machinery.
2. We can prevent oxidation of the metal a flux.
3. Rapid heating in the boiler is achieved forced circulation.
4. The work is firmly held in the lathe the centres.
5. Better combustion is obtained a hemispherical combustion chamber.
6. The heat-resistant properties of the steel can be improved addition of chromium and nickel.
7. Frequent measurements of the bar were made a micrometer.
8. Lubricant is forced into the bearing pressure of the grease gun against the nipple.
9. A soldered joint may be made a soldering iron made of copper.
10. The temperature of the liquid is raised the application of heat.
11. Greater speeds can now be attained by modern aircraft the new metals which are now being developed.
12. More rapid burning is made possible the use of pulverised fuels.

2. Purpose (Clauses)
See also Section 7.
Here is a further structure which is used to indicate purpose.

The steam is superheated so that is may be fairly dry.

EXERCISE
Complete these statements in the same way.

1. Phosphorus is added to the metal better castings produced.
2. The iron demagnetised, it is necessary to apply a negative magnetising force.
3. The metal properly soldered, the metal and the solder should both be made clean.
4. The steam velocity across the tubes is kept high any stationary air swept away.
5. The storage tank is elevated its contents withdrawn by gravity.
6. The condenser water is cooled it re-used in the condenser.
7. The coal gas is sometimes compressed condensation in the gas mains avoided.
8. A by-pass road is being constructed the traffic (not) need to go through the city centre.
9. Deposits not form on the tubes, only pure feed water should be used.
10. Water is sprayed into the cylinder immediate condensation of the steam occur.
11. The amount of expansion calculated, the coefficient of expansion of the metal must be known.
12. The diameter of the bar should be measured frequently too much metal (not) taken off.

3. Noun + Noun
The normal way of describing an object in greater detail is by putting an adjective in front of it:

<table>
<thead>
<tr>
<th>Mild steel</th>
<th>Hat water</th>
<th>Coal steam</th>
</tr>
</thead>
</table>

But English allows us very often to put another noun in front of the noun, and sometimes two or three:

<table>
<thead>
<tr>
<th>Steam jacket</th>
<th>Heat content</th>
<th>Steel bar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon dioxide</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
This type of machine can be **assembled** in a few hours.

1. The components are shipped abroad, and **assembled** in local factories.

2. The **assembly-line** of the factory is where all the components are put together.

3. The delegates to the conference **assembled** in the Assembly Hall.

## PATTERNS

### 1. Time Statements (1)

**Look at these double statements:**

1. John finished his work. John went home.
2. The steam leaves the boiler. The steam enters the turbine.

**In both, the subject of the two parts is the same (John and the steam).**

They both describe two events in a time-sequence.

So we can write them together in this way:

1. After John finished his work, he went home.
2. After the steam leaves the boiler, it enters the turbine.

The other common 'time-links' we can use are these:

1. Before the steam leaves the boiler, it is passed through a superheater.
2. While the metal is still molten, it is poured into moulds.
3. As soon as the steam passes over the metal tubes, it is condensed.
4. When the clutch is engaged, the car is in gear.
5. Until the machines are properly tested, they must not be used.
6. Once the machines are tested, they may be put into service.

### EXERCISE

Join these double statements, using the most suitable 'time-link'.

1. The steam reaches a certain pressure. Immediately the steam lifts the valve.
2. The rivet cools. The rivet contracts and draws the plates together.
3. The air enters the furnace. The air is pre-heated by the turbine exhaust.
4. The first stage of the reactor burns out. Immediately the first stage is ejected.
5. The piston descends. The descending piston creates a partial vacuum above it.
6. Metal plates are prepared for a weld. But first the metal plates are clamped together.
7. The fuel travels along the conveyor chain. The fuel burns.
8. The ore cannot be used industrially. The ore is smelted and reduced to iron.

### EXERCISE ONE

Use each of these structures to complete the following statements:

1. A fan **...** (induce) a forced draught over the fire grate.
2. A thermometer **...** (measure) the temperature of a body.
3. A distributor **...** (provide) a spark in each of the cylinders.
4. A chuck **...** (hold) the work firmly on the lathe.
5. The safety valve **...** (prevent) excessive pressure in the boiler.
6. The vice **...** (clamp) the work on to the drilling machine.
7. The intermediate gears **...** (connect) the stud and lead-screw gears on the lathe.

9. Gases pass through the turbine. They are still very hot afterwards.

10. The throttle valve closes. It reduces the supply of steam.

11. A bearing is properly lubricated. The bearing will last much longer.

12. The fuel enters the boiler. It is first pulverised.

13. New water pipes are installed. They should first be given cathodic protection against corrosion.

14. The velocity of the air is increased. Finally it reaches the speed of sound.

15. The pulverisers rotate. The pulverisers repeatedly strike the coal.

16. The piston moves along its stroke. The piston ejects the exhaust steam.
WORD STUDY

Device, Device, Instrument, Apparatus

1. We must devise some way of overcoming the difficulty. (= think out)

   A separation process was devised for the extraction of plutonium.

2. A device is (usually) a clever mechanism which is devised or invented to solve some particular mechanical problem.

   A thermostat is a device for regulating temperatures.
   A clutch is a device for engaging and disengaging gears.
   A burglar alarm is a device for giving warning that thieves are trying to enter a building.

3. An instrument is (usually) a small manufactured object which enables us to perform some precise action or measurement.

   A pyrometer is an instrument for measuring high temperatures.
   A seismograph is an instrument for recording earth tremors.
   A spectroscope is an instrument for measuring the spectra of rays.

4. An apparatus is (usually) a complicated mechanism or assembly of many different pieces used for some scientific experiment or test.

   An Orsat apparatus is used to analyse the products of combustion.
   A bomb calorimeter is an apparatus for finding out the calorific value of a solid or liquid fuel.

State, Condition, Conditions

1. a. The pig-iron comes out of the blast-furnace in a molten state.
    b. Metal which is hardened by cold-working may be brought back to its original condition by annealing.

2. a. The inspector found that working in the factory were very bad.
    b. Flying was impossible, for weather became much worse.
    c. The engine should be under normal working conditions during the test.
    d. The initial steam for this turbine are 500 lb/in² and 800° F.

Elevate, Depress (= lift up, push down)

1. The cooling tower is elevated above the level of the condenser.
2. The railway was elevated above street level.
3. The high-pressure air compresses a piston against a spring.
4. Evaporation of the fuel depresses the temperature to freezing point.
5. The engineers plunger to set off the explosive charge.

Assemble, Dismantle

1. The machine was dismantled, or taken to pieces, in order to transport it more easily.
2. When the machine arrived at its destination, it was quickly re-assembled.
Section 10

Reading: Impulse Turbines

In an impulse turbine steam is admitted through a nozzle and directed against one or more rows of blades. Prior to passing through this nozzle, the steam is at high pressure but low velocity. The nozzle normally consists of a convergent and divergent section. In the former, the steam suffers a drop in pressure, but its velocity is increased. The function of the divergent section is to reduce to a minimum the tendency of the fluid to turbulence, and thus to ensure that the fluid flow is as smooth as possible.

On emerging from the nozzle at its maximum velocity, the steam impinges on the row of moving blades which project radially from the turbine shaft. In this axial-flow type of turbine, the steam flow is along the axis of rotation of the shaft, and therefore the blades radiate outwards from the shaft. On entering the blades, which are set at a definite angle to the steam flow, the steam is deflected from its original path. In being deflected, it exerts an impulsive force on the blades, which causes them to rotate. While passing over the blades, the steam suffers a slight reduction in velocity through friction. In a simple turbine, it is then passed out into the atmosphere, or to a condenser, where it is condensed and led back to the boiler.

However, after leaving the blades of the turbine, the steam still possesses a considerable velocity, and this may be utilised in another type of turbine by passing it through a series of two or more turbine wheels. This is known as velocity-compounding. On passing through the first row of moving blades, the steam encounters a row of stationary blades which deflect the steam on to a second row of moving blades, and so on. Each time part of the kinetic energy of the steam is lost through friction, and therefore the velocity of the steam is progressively reduced. In order to compensate for this, the blades in each successive row are made progressively larger in cross-section, and their pitch is increased. In this way, a larger proportion of the kinetic energy of the steam can be utilised than in the simple turbine.

Another type of turbine in common use is known as the pressure-compounded turbine. It incorporates several rows of blades, but each one is enclosed between diaphragms to form a separate pressure stage. After passing through the first set of blades, the steam is directed through nozzles set in the succeeding diaphragm, and impinges on the following row of blades.

WORD STUDY

Tend, Apt, Inclined

1. A person tends to put on weight when he eats too much.
2. Wet steam is apt to erode the blades of a turbine.
3. Cast-iron is apt to fracture under excessive tension.
4. Turbulence dissipates the kinetic energy of the steam.
5. Leaks tend to develop around the tips of the turbine blades.
6. Steam pockets are apt to form in the water tubes.
7. There is a tendency for leaks to develop around the tips of the blades.
8. The present tendency is to use pulverised fuels in large boilers.

Impinge on, Encounter

1. The flames from the furnace should not impinge on the joints. (= strike)
2. On entering the turbine, the steam impinges on the rotating blades.
3. The beam of accelerated protons impinges on a beryllium target.
4. On entering the turbine, the steam encounters a row of fixed blades. (= meet)
8. Baffles \( \textit{direct} \) the flue gases round the boiler tubes.
9. Piston rings \( \textit{prevent} \) steam leakage past the piston.
10. The limestone \( \textit{remove} \) the non-metallic impurities in the iron ore.
11. A re-heater \( \textit{re-heat} \) the steam between one cylinder and the next.
12. The examination \( \textit{test} \) the students' knowledge.

**EXERCISE TWO**

State the function of:
1. The water-tubes in the boiler.
2. An anvil.
3. A liquid pump.
4. The lubricant in a bearing.
5. Steam jackets round a cylinder.
6. A die.
7. The tuyeres at the bottom of a blast furnace.

3. Forces (Impel, Exert, Act, Balance, etc.)

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>1. a. The impeller blades</td>
<td>\textit{force} the water forwards. \textit{drive} the piston down the cylinder.</td>
</tr>
<tr>
<td>1. b. The expanding gases</td>
<td>\textit{impel}</td>
</tr>
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<tbody>
<tr>
<td>2. a. The weight</td>
<td>\textit{a turning force on the lever}.</td>
</tr>
<tr>
<td>2. b. The fluid</td>
<td>\textit{exerts a pressure on the walls of the container}.</td>
</tr>
<tr>
<td>2. c. The load which a spring</td>
<td>\textit{may be varied by adjusting nuts}.</td>
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<tr>
<td>2. d. The gases</td>
<td>\textit{a force on the piston}.</td>
</tr>
<tr>
<td>2. e. We have to</td>
<td>\textit{great force to prevent the expansion of the heated metal}.</td>
</tr>
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<tbody>
<tr>
<td>3. a. The force \textit{acts} perpendicular to the axis of the spindle.</td>
<td></td>
</tr>
<tr>
<td>3. b. These two forces</td>
<td>\textit{in line with each other}.</td>
</tr>
<tr>
<td>3. c. The force of gravity</td>
<td>\textit{acts on all objects vertically downwards}.</td>
</tr>
<tr>
<td>3. d. Friction</td>
<td>\textit{acts on moving bodies and brings them to a stop}.</td>
</tr>
<tr>
<td>3. e. A lift force</td>
<td>\textit{acts on the underside of the aircraft wing}.</td>
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<tbody>
<tr>
<td>4. a. One substance \textit{reacts} with another in a chemical reaction.</td>
<td></td>
</tr>
<tr>
<td>4. b. A force which \textit{acts} on an object is opposed by an equal and opposite \textit{reaction}.</td>
<td></td>
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<tbody>
<tr>
<td>5. a. Bodies with similar charges \textit{repel} each other. They exert a \textit{repulsive} force.</td>
<td></td>
</tr>
<tr>
<td>5. b. Bodies with opposite charges \textit{attract} each other. They exert a \textit{attractive} force.</td>
<td></td>
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<tbody>
<tr>
<td>6. a. The weights at opposite ends of the lever \textit{balance} each other.</td>
<td></td>
</tr>
<tr>
<td>6. b. The two opposing forces \textit{counterbalance} each other.</td>
<td></td>
</tr>
<tr>
<td>6. c. When opposing forces balance each other, a state of \textit{equilibrium} or \textit{balance} is reached.</td>
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<tbody>
<tr>
<td>7. a. The power of the engine must be sufficient to \textit{overcome} the resistance of friction.</td>
<td></td>
</tr>
<tr>
<td>7. b. The aircraft must develop enough power to \textit{overcome} the force of gravity.</td>
<td></td>
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</tbody>
</table>
7. In the construction of locomotives, the provision of a large heating surface is very important.
8. After the roughing cut is taken, the cutting tool should be sharpened.
9. Before the final cut is taken, the exact size of the bar should be measured.
10. Before the dam can be built, the course of the river will have to be diverted.
11. After you have read the book, a summary should be made of the important chapters.
12. Before starting production, extensive tests must be made.
13. In the course of construction of the motorway, vast quantities of earth have to be moved.
14. While the engine was being examined, a number of defects were found.
15. After £1,000,000 were spent on research and development, the whole project was suddenly abandoned.

3. Sequence

When steam enters the turbine, it has a very high initial velocity. When it leaves the turbine, it has a much lower final velocity. As it passes through the turbine, its velocity is progressively reduced.

The rows of blades in the turbine are made progressively larger. Each row is a little larger than the previous or preceding row. From January to August, the weather gets progressively warmer. Each month is slightly warmer than the previous or preceding one.

The first steam engine was built during the nineteenth century. During the following or succeeding hundred years, it became the main source of power. The initial attempts to solve the problem ended in failure. So did the three succeeding attempts. The final attempt succeeded.

Subsequent or later attempts to repeat the experiment failed. The condensate is stored in a cooling tower, for subsequent use in the condenser.

In a turbine, the steam passes through a series or succession of wheels holding blades. It passes through them one after the other. Each successive row reduces the kinetic energy of the steam. The energy of the steam is progressively reduced as it passes through the successive rows.

Not every row of blades rotates. There is a rotating ring, followed by a stationary ring, and this is succeeded by another rotating ring. Every second ring is a rotating ring. Every other ring is a rotating ring. Each alternate ring rotates.
The rotating rings alternate with the stationary rings. Each alternate stroke on a two-stroke engine is a working stroke. Only one stroke in four of a four-stroke engine is a working stroke. The strokes occur in a sequence.

EXERCISE

Complete these statements:

1. During the past century, there has been a …… increase in the size of boilers.
2. The metal which was …… heated is now quenched in a cold liquid.
3. A complicated …… of operations is necessary to produce steel.
4. As the metal cools, its surface grows …… harder and tougher.
5. The pneumatic riveter closes the rivet by a quick …… of blows.
6. The …… cost of the machines is high, but maintenance and operating costs are low.
7. Modern boilers are designed for higher pressures than those of the …… century.
8. The exhaust steam is condensed, and can …… be used again in the boiler.
9. The original design was not very satisfactory, and a …… of modifications were made over several years.
10. The …… pressure of the steam before expansion is 60 lb/in².
11. The neutrons lose their energy gradually by …… collisions with other particles.
12. As work went on, the dam grew …… higher.
13. The manager retired and was …… by his assistant.
14. After a …… of tests, the model was put into production.
15. He works …… shifts: this week he is on the day-shift, and next week he will be on the night-shift.
Deflect, Refract (bend); Reflect (bend back)

1. A ray of light entering water at an angle is **refracted** at the surface.
2. A ray of light passing through the glass of a mirror is **reflected** by the silver.
3. A billiard ball which strikes another ball is **reflected** from its path.
4. Steam which impinges on the turbine blades is **deflected** from its course.
5. A nearby piece of iron causes a compass needle to be **deflected** from north.

Diverge, Converge

1. Railway lines seem to **converge** as they go away from the observer.
2. All roads tend to **converge** as they approach a large city.
3. The sides of the nozzle **towards the throat**.
4. Railway lines seem to **diverge** as they go away from the observer.
5. All roads tend to **diverge** as they go away from the city.
6. The sides of the nozzle **diverge** as they go away from the throat.

PATTERNS

1. **Contracted Time Statements (1)**

   In the previous section, we practised time statements in which the subjects of both parts of the statement were the same.

   *e.g.* Before the steam enters the nozzle, it is at very high pressure.

   Before it enters the nozzle, the steam is at very high pressure.

   These time statements are very often shortened or contracted to:

   Before entering the nozzle, the steam is at very high pressure.

   Here are the different possibilities of this structure:

   **Before** entering the nozzle, the steam is at high pressure. = before it enters.

   **When** passing through the blades, the steam is deflected. = while it is passing through.

   **After** leaving the blades, the steam passes out to at the atmosphere. = after it leaves.

2. **Contracted Time Statements (2)**

   These contracted forms on, before, while, etc. + -ing are normally used when the subject of both statements is the same, as you have just seen.

   They are not normally used when the subjects are different. But one other type of statement can be expressed in the same way.

   **On removing the impurities**, the water can be passed back to the boiler.

   **When installing a boiler**, the floor space which is available is very important.

   You will notice that this really means:

   When we remove the impurities, *and* When we are installing a boiler.

**EXERCISE**

Use the contracted structure to re-write the following statements:

1. Before we apply heat for a weld, the plates should be clamped together.
2. When we use superheated steam, compounding becomes less effective.
3. When we are drilling deep holes, the feed movement should be released from time to time.
4. While we are making an efficiency test on an engine, certain precautions should be observed.
5. When screws are being cut, the lead-screw on the lathe is engaged.
6. When railway tracks are being laid, allowance must be made for expansion.
ORD STUDY

IRE, Ignite

A rifle is fired by pressing the trigger, which releases the firing-pin.

A boiler is fired mechanically or by hand, by the fireman.

The explosive is ignited by some detonating mechanism.

The mixture is ignited by a spark from the ignition system.

Some liquids are more easily than others.

INHALE, Aspirate (suck in, draw in)

1. A fresh charge of petrol and air is drawn into the cylinder.
2. A current of air is sucked into the cylinder.
3. An electro-magnetic force is induced in the circuit.
4. Intense stresses on the blades are produced by centrifugal force.

EXHALE, Eject, Discharge (= push out)

The burnt gases in the cylinder are expelled from the cylinder.

1. a. Sixty of the workmen were by the company.
   b. The steam is through the divergent nozzle.
   c. The air is into the inter-cooler.
   d. A large mass of air is seawards by the propeller.
   e. The contents of the tank were by the pump.

2. a. The exhaust gases from the cylinder pass into the atmosphere.
   b. When the world's oil resources are exhausted, other sources of power must be found.

IMPACT (= give)

1. A high velocity is imparted to the air in the compressor.
2. Thermal energy must be imparted to the particles by the ionised gas.
3. An electric charge is imparted to the gas through conduction.

CONVERT (= turn)

1. Any form of energy can be into any other form.
2. Water is into steam in a boiler.
3. Fahrenheit temperature is converted into Centigrade by a simple formula.
4. Thorium 232 can be into fissile material by neutron bombardment.

5. The conversion of Fahrenheit into Centigrade temperatures is achieved by a simple formula.

PROPAGATE, Distribute

1. The initial flame is propagated rapidly through the mixture. (= spread)
2. The heat is propagated through the gas near the speed of sound.
3. A pressure wave is by lectures and articles.
4. The new theory was by conduction through an iron bar.
5. The heat is evenly throughout the material. (= shared)
6. The weight should be evenly over the foundations.
7. The current is to each of the plugs by the distributor.
8. The mixture is to each of the cylinders in turn.

PATTERNS

1. Time Statements (2)

   In the previous two sections, we have seen examples of Time Statements which had the same subject in both parts of the sentence.

   Here are examples of Time Statements which have different subjects in the two parts of the sentence. Notice that they are not usually contracted.

   Before the piston reaches the top of its stroke, the mixture is ignited. It continues to burn until combustion is complete. By the time the piston reaches top dead centre, combustion is well under way. While any unburnt gas remains in the cylinder, combustion will continue. As combustion proceeds, the gases expand and drive the piston down. As soon as the piston reaches bottom dead centre, the exhaust valve is opened. When the piston nears the top of its stroke again, the inlets valve is opened. Once all the exhaust gases are driven out, the exhaust valve is closed. After one cycle is completed, another cycle begins.

EXERCISE

Use the appropriate 'time-link' to join these statements.

1. Steam in the boiler reaches a certain pressure. The safety valve is lifted.
2. The fuel travels along the conveyor chain. The flame ignites it.
3. Combustion proceeds. The temperature of the mixture rises.
4. The steam engine was invented. Water could not be pumped out of coal mines.
5. The critical temperature is exceeded. The steel undergoes structural changes.
6. Steam passes through the turbine nozzle. Its velocity increases.
7. The second world war was over. Jet engines were in common use.
8. The gas leaves the turbine blades. Expansion takes place in the jet-pipe.
9. The condensate is led back to the boiler. Oil and dirt from the engine are removed.
Section II

Reading: The Petrol Engine

In the internal combustion engine, heat is generated by the combustion of an inflammable charge inside a cylinder, and the heat energy is immediately converted into mechanical energy. Some heavy internal combustion engines use a gas fuel or else Diesel oil, and the fuel/air mixture may be ignited either by a spark or by compression of the mixture. However, for small i.e. engines, such as those which are used in motor-cars, the charge is a mixture of petrol and air, and is ignited by a spark from the distributor.

When the mixture is ignited, the products of combustion expand down the cylinder, which is fitted with a reciprocating piston. The downward movement of the piston is converted into a rotational movement of the crankshaft by means of a connecting rod. As the crankshaft rotates, the piston is driven upwards again, and the exhaust gases are expelled through the exhaust valve in the cylinder head. When the piston nears the top of this stroke, the inlet valve is opened and the exhaust valve closed. The piston then descends on the induction stroke, and draws a fresh charge into the cylinder. As the piston rises again on the compression stroke, the charge is compressed and ignited, and the cycle begins again. This is the four-stroke cycle which is in common use. An alternative cycle is the two-stroke cycle, which combines the exhaust and compression strokes into one.

The combustion of the mixture does not take place instantaneously. The spark is therefore timed to occur before the piston reaches top dead centre, otherwise maximum pressure would not be reached in time. By the time the piston is at top dead centre, combustion is well under way and the expansion of the gases is beginning. Once combustion starts, it should be carried through the mixture very rapidly, and this is assisted by making the clearance space above the piston as small as possible, and by careful design of the cylinder head. Rapid propagation of the flame through the compressed gas is also assisted by creating turbulence in the gas.

Most small i.e. engines in common use have four cylinders, which fire in a definite and regular sequence. This is necessary, otherwise the torque which the pistons impart to the crankshaft will be irregular and uneven. The torque is liable to be uneven in any case when the engine is running slowly, and a flywheel is fitted to the crankshaft to damp out these variations.

It is essential for the inlet and exhaust valves to open and close at exactly the appropriate moment in relation to the position of the piston. Therefore they are actuated by a cam-shaft running in phase with the crankshaft.
Section 12

Reading: The Carburation System

Since it is essential to secure rapid and complete combustion in the cylinder of an internal combustion engine, the fuel and air mixture must be thoroughly mixed and further, it must be in the correct proportions for all running conditions of the engine. This is accomplished by means of a device called a carburetor. In this carburetor, a stream of air blown over a jet mixes intimately with a spray of petrol drawn out of it. The jet is immersed in a tube or venturi in the intake manifold, and is supplied with petrol at atmospheric pressure.

During the suction stroke of the piston, the pressure in the intake manifold is below atmospheric, and air is induced through the intake and over the jet. As there is a further drop in pressure at the venturi, the pressure difference produced is large enough to draw petrol up out of the jet and atomize it. The level of the petrol in the jet is kept constant by the float and needle valve in the float chamber, which acts as a reservoir for the fuel. Above the venturi there is a thermostatic valve operated by the accelerator pedal, which controls the amount of mixture admitted to the cylinder.

However, this simple form of single-jet carburetor will not give correct mixture strengths for all engine speeds. The chief difficulty encountered is that, at high running speeds, the amount of petrol taken up by the jet will increase faster than the increase in air flow. Therefore, a carburetor not to give correct mixtures at low speed will give a progressively richer mixture as the speed increases. To compensate for this, a second jet is provided, fed from a well open to the atmosphere and supplied with petrol from the float chamber. Owing to the fact that this compensating jet is larger than the main jet, it can supply petrol at a quicker rate than the main jet until the well is emptied. As the speed is increased, more and more of the petrol required is drawn from the main jet. The compensating jet can now supply only as much petrol as can pass through the smaller compensating orifice in the float chamber.

Another problem to be solved is that of starting. In order to obtain the rich mixture required for starting, the throttle must be almost closed. At the air velocity is then very low in the venturi, insufficient petrol is drawn out of the jet. This difficulty is overcome by the provision of an idler jet in the wall of the intake manifold near the throttle valve. This jet will only function when the throttle is nearly closed. When it is opened for faster running, the petrol "cuts out" the edge of the throttle, decreases, and the idler automatically increases. 
10. The steam is cooled below its condensation temperature. It turns to water.
11. The crank was invented. The steam engine could not be used to produce rotary motion.
12. Light falls on certain substances. Electrons are emitted.
13. The fluid passes through the blades. Frictional losses occur.
14. Heat transfer will continue. The system attains a uniform temperature throughout its mass.
15. The speed of sound is reached. Shock waves are formed.
16. The development programme is completed. It will have cost £10,000,000.
17. The fire engines reached the scene of the fire. The factory was already half-destroyed.
18. The material is available. Tests will start immediately.

2. Alternatives

Ignition can be produced either by a spark or by compression of the mixture. Bearings are lubricated either by gravity feed or by forced feed. They can be lubricated in other ways. Bearings can be lubricated either by gravity feed or alternatively by forced feed.
- The drive can be transmitted either by a belt or alternatively by a chain.
- The drive can be transmitted either by a belt or else by a chain.

An alternative method of transmitting the drive is by an inelastic chain. There are several alternative methods of lubricating bearings.

The temperature must not exceed 650°C or else the metal will melt.
otherwise

- The toughness of the steel depends on whether it contains a smaller or a greater proportion of carbon.
- The type of condenser we use will largely depend on whether (or not) there is a plentiful supply of pure water.

EXERCISE ONE

Complete these statements with otherwise and or else.

1. The governor should not be over-sensitive; it will cause the engine speed to oscillate continuously.
2. The furnace should not be overcharged with fuel; heavy smoke will be produced through poor combustion.
3. Some means of cooling the compressed air is necessary; the losses in the compressor will be large.
4. A high octane fuel has to be used; detonation is liable to occur.
5. Turbulent conditions are required in the combustion chamber; the flame will not propagate itself rapidly enough.

6. A compensator jet is necessary; the carburettor will not work properly at low speeds.
7. A flywheel is always fitted to the crankshaft; the vibration would be excessive at low engine speeds.
8. Piston rings must be replaced when they are worn; gas will leak past the pistons into the crankcase.
9. The project must be carefully prepared before work is actually started; a great deal of time will be wasted.
10. The aircraft will have to jettison some of its fuel; it will not be able to land safely.

EXERCISE TWO

Complete these sentences.

1. An method of reducing the risks of detonation is by adding dopes to the fuel.
2. The use of aluminium magnesium alloys is now quite common.
3. The heat which is required for welding is produced by an oxy-acetylene torch or by an electric arc.
4. a centre a chuck is fitted into the spindle depending on turning; boring work is being done.
5. The fuel may be intimately mixed with the moderator or spaced at intervals through it.

3. Transmission

a) Mechanical

1. The power from the engine is transmitted to the machine through a belt.
2. The piston movement is communicated to the wheels through a crankshaft.
3. The movement of the spindle is communicated to the lead-screw through gears.

b) Radio

The broadcasting station transmits television and radio programmes.

- transmits broadcasts


c) Transfer

1. The molten metal is transferred from the ladle to the mould.
2. The heat from the reactor is transferred to the heat exchanger by a liquid coolant.
3. Heat is not easily transferred from a dry vapour to a metal surface.
Allow for, Compensate for

1. The candidate left home ten minutes early to allow for delays on the journey.
2. The turbine is built in sections to allow for expansion and contraction of the casing as it cools.
3. The pattern maker has to compensate for the shrinkage of the metal.
4. Allowances must be made for expansion or contraction of the metal.
5. It is always made for frictional losses and leakage losses in the turbine.
6. The employer paid him £4000 for his injury.
7. The idler jet is provided to compensate for low air velocity in the ventilator.
8. The loss of pressure through condensation is compensated for by the admission of more steam.
9. The disadvantages of the jet engine are offset by many virtues.

PATTERNS

1. Explanations of Cause (1)

S


Since the compensating jet is larger, it can supply more petrol. The compensating jet can supply more petrol, since it is larger.

In these statements, the part which begins with since is a clause explaining why the main event took place.

The common 'cause-words' which are used in this structure are:

1. Because
2. Since
3. As
4. In view of the fact that
5. On account of the fact that
6. Owing to the fact that
7. Seeing that

Notice three more useful structures:

1. The reason why he went to bed early was that he was tired.
2. He was tired. This explains why he went to bed early.
3. He was tired. This accounts for the fact that he went to bed early.

EXERCISE

Use each of the structures given above to link these statements:

1. The steam from the boiler is wet. It has to be passed through a superheater.
2. The temperatures reached are very high. Some method of cooling must be adopted.
3. This type of turbine is very widely used. It has a much greater efficiency.
4. Metal expands when it is heated. Expansion joints are fitted to steam pipes.
5. Exhaust gases still possess a great deal of heat. They can be used to heat the incoming air to the boiler.
6. Atomic power is not available in sufficient quantity. Coal is still a very valuable source of power.
7. The carburettor may become choked with dirt. An air filter is fitted.
8. Vertical boilers were installed in the factory. Only a limited floor-space was available.
9. The earliest steam engines could be used only for pumping. The crank had not been invented.
10. Gas turbines are not self-starting. A starting motor must be fitted to drive the compressor.
11. The neutron is an uncharged particle. No repulsive forces are exerted on it by the nucleus.
12. The apprentices had very little training. Their work was very poor.

2. Contraction Relative: Passive

Look at these three sentences. Each one contains a relative clause with a passive verb.

The petrol mixes with a stream of air which is blown over it.

There is a throttle valve which is operated by the accelerator.

The locomotive which was invented by Trevithick revolutionized transport.

This type of statement is very common indeed in technical writing and speech, and it is usually shortened by leaving out the words 'which is' and 'which were':

The petrol mixes with a stream of air blown over it.

There is a throttle valve operated by the accelerator.

The locomotive invented by Trevithick revolutionized transport.

EXERCISE

Change these statements in the same way:

1. The exhaust steam is passed over tubes which are filled with cold water.
2. The tube area which is exposed to the incoming steam is relatively large.
3. The efficiency of an engine is the ratio of the work which is done to the heat which is received.
4. The power which is demanded from modern turbines is continually increasing.
5. The research which is being carried out on this subject is extensive.
WORD STUDY

Supply, Provide, Fit

1. A generating station supplies electricity to the city.
2. The compressor supplies compressed air to the engine.
3. A generating station supplies the city with electricity.
4. The compressor supplies the engine with compressed air.
5. Electricity is supplied to the city by the generating station.
6. Compressed air is supplied to the engine by the compressor.
7. Cold water is supplied to the condenser.
8. Air for combustion is supplied to the furnace.
9. The city is supplied with electricity by the generating station.
10. The engine is supplied with compressed air by the compressor.
11. The condenser is supplied with cold water.
12. The furnace is supplied with air.
13. Expansion joints of various kinds are fitted on steam pipes.
14. Drains are provided on the underside of the casing.
15. Steam pipes are fitted with expansion joints of various kinds.
16. Boilers are provided with safety valves.
17. The provision of a drain on the underside of the casing is necessary.
18. Provision must be made for draining the casing.
19. One way of providing for expansion is by a bend in the pipes.

Equip, Install

1. The new factory was equipped with the latest machinery.
2. The hospital is equipped with X-ray facilities.
3. Divers have to be equipped with oxygen apparatus.
4. The latest machinery was installed in the factory.
5. Several turbo-generators have been installed in the house last year.
6. A central-heating system was installed at the dorm.
7. The installation of atomic engines in ships and aircraft is not likely for a year or two.

Insert (= put into)

1. A film of oil is inserted between the sliding surfaces of a bearing.
2. The workpiece is inserted between the lathe centres.
3. Diaphragms are inserted between the stages of the turbine.
4. The advertisement was inserted in the newspaper yesterday.
atmosphere. Owing to the high proportion of unburnt oxygen in this efflux, after-burners are often provided in the jet-pipe, whereby the hot gases are again ignited. This increases their velocity, and provides extra thrust for take-off.

**Word Study**

**Work, Function, Operate, Run**

1. This compressor is designed to run at relatively low speeds.
2. This type of engine will work for long periods without repair.
3. Jet engines are able to operate over a wide range of mixture strengths.

4. The machines should be tested under normal working conditions. Operating

5. When the engine speed increases, the governor is brought into operation. Comes into operation.

**Control, Regulate**

1. The steam supply to the engine is regulated by the governor.
2. The movement of the valve is controlled by a servo-motor.
3. Working conditions nowadays are governed by government acts, to within strict limits.

**Govern, Determine, Fix**

1. The type of engine adopted is determined by the use to which it is put.
2. The amount of excess air provided is governed by the combustion temperatures required.
3. The angle at which the deflection plates are set is fixed by the need to achieve maximum turbulence.

**Residue, Remainder**

1. What remains of the heat from the exhaust gases is used to heat the incoming air.
2. The remainder of the energy of the steam is not recoverable.

4. The residual heat of the gases is used to heat up the incoming air.

5. The remaining energy of the gases is ejected from the jet-pipe.

**Dilute, Diffuse, Disperse**

1. Liquid is added to the acid in order to dilute it. (= weaken)
2. Zinc and capper electrodes are put into dilute sulphuric acid.
3. The hot gases have to be diluted by the addition of cool air.
6. The steam which is extracted from the turbine is passed through a condenser.
7. The torque which is exerted on the crankshaft should be even.
8. The manufacturing process which was adopted was a revolutionary one.
9. Generators which are not required for service are stopped.
10. The steel which is obtained in this way is suitable for machine tools.

3. Problems, Difficulties and Solutions

| Various problems encountered were met with in the development of a satisfactory carburettor. |
|---|---|
| approached tackled | by a study of the airflow in the choke. |
| solved dealt with | by the provision of a compensating jet. |
| The difficulty was overcome avoided got round | by providing a compensating jet. |

Note: Solution has two meanings:

1. Knowing certain values enables us to solve the equation.

The problem is quite incapable of solution, unsolvable.

2. a. Joints should be dipped in a solution of ammonium chloride to neutralise the acid.
   b. The gases are passed through solutions of various chemicals in water.
   c. Various chemicals are dissolved in water, and gases are passed through them.
   d. A solvable substance is one which can be dissolved in a liquid.
   e. A solute (e.g. sugar) can be dissolved in a solvent (e.g. water).

Section 13

Reading: The Jet Engine

Jet engines with which most modern high-speed aircraft are equipped develop thrust on the same principle as the propellers of conventional aero-engines. In both, the propulsive force is derived from the reaction produced by a stream of air driven rearwards at high velocity. However, in jet-propulsion the air is directed rearwards in a jet from the engine itself. The earliest forms of jet-propulsion, such as the pulse jet utilised in the Flying Bomb, were incapable of functioning at rest, in view of the absence of any means of air-compression. But the introduction of the turbo-jet overcame this problem, since the turbine developed sufficient power to drive a compressor.

Air enters the engine through a divergent inlet duct, in which its pressure is raised to some extent. It then passes to a compressor, where it is compressed, and from which it is delivered to the combustion chambers. These are arranged radially round the axis of the turbine, into which the products of combustion pass on leaving the combustion chambers. A proportion of the power developed by these gases is utilised by the turbine to drive the air-compressor, and the residual energy provides the thrust whereby the aircraft is propelled. Due to the expansion of the exhaust gases in the jet-pipe behind the turbine, their exit velocity is very high.

In each of the combustion chambers, there is a perforated flame-tube, into which kerosene is sprayed and ignited. Owing to the need to limit temperatures in the combustion chambers, a large volume of excess air is required. The air/fuel ratio necessary to reduce combustion temperatures to an acceptable level is about 60 : 1. However with this ratio of fuel to air, the mixture would be difficult to ignite. Therefore only a small proportion of the compressed air is fed into the flame-tube, where it is ignited in a ratio of about 15 : 1. The remainder enters the flame-tube further down, or mixes with the products of combustion as they leave the tube. By virtue of this dilution of the hot gases with cooler air, the temperature at which they reach the turbine is reduced to about 850° C.

On entering the turbine, the gases pass through nozzles, by means of which they are directed through a ring of blades. These blades, the shape of which is determined by the need to reduce the torque to a minimum, rotate at high speed. Because of the tendency of fast-running blades to creep and change their shape, a special high-nickel alloy is used for them. After passing through the turbine, the gas expands down the jet-tube and is ejected into the atmosphere.
11. The shape of the electrodes, the breakdown strength depends can be altered.
12. This fuel is a mixture of gases, the chemical combination is known.
13. There is a combustion chamber, in the top is fitted an inlet valve.
14. Other materials are used in the workshop also, some details should be given.
15. The expansion will be greatest at these parts, the metal is hottest.
16. The heat is absorbed by a fixed weight of water, the temperature rise can be measured.
17. The micrometer is an instrument by means very accurate measurements can be made.
18. The hot water is taken to a heat exchanger, steam is generated.
19. The dew point is the temperature a gas is saturated with vapour.
20. Resistors are devices, a resistance is interposed in a circuit.

**Exercise Two**

Join these sentences using a preposition - relative.

1. The earliest turbine consisted of a sphere. Steam was passed into the sphere.
2. The air is passed to a compressor. Here it is compressed.
3. The brush is depressed by a spring. The tension of the spring is adjustable.
4. The lathe can also cut screws. For this, the lead-screw is engaged.
5. There is a perforated flame-tube. Kerosene is sprayed into it.
6. Iron is converted into steel by various processes. All of these processes involve heating it to very high temperatures.
7. The soil was sandy. The mad surface was laid over the soil.
8. The light passes through a prism. The prism disperses the light.
9. The fuel is contained in a metal can. The purpose of this can is to prevent reactions between the fuel and the coolant.
10. The power station is in the north of the country. Plutonium is produced in this power station.

3. **Ratio and Proportion**

1. a. There is one professor to every ten students. They are in a ratio of 1 to 10.
   b. There are 13 parts of air to every part of fuel. They are in a ratio of 13 to 1.
   c. The professor, student ratio is 1:10.
   d. The air to fuel ratio is 1:1.
   e. The ratio of the clearance volume to the swept volume in a cylinder differs in different types of engine.
   f. A compression ratio of about 4:1 can be obtained with a turbo-compressor.
   g. The efficiency of a cycle process is the ratio of the work done to the heat received.
4. The acid diffuses into the rest of the solution in the cell. (spread out)
5. The dust particles in the air diffuse the light.
6. The air in the pump is diffused in a divergent cone.
7. The light passing through a prism is dispersed into a band of colours. (scatter)
8. The factory buildings are dispersed over a wide area.

PATTERNS

1. Explanations of Cause (3)
In the previous section, we saw some examples of 'cause-words' which are used when a verb follows: that is, they introduce a clause.
Now we shall look at 'cause-words' which are used when a noun only follows. That is, they introduce a phrase.

- The steam pressure falls because of condensation in the cylinder.
- The high temperatures, special alloys are used.
- The two following expressions are used less commonly, as their meaning is rather restricted:
  - In view of the importance of this problem...
  - Owing to its simplicity of construction...

EXERCISE

Practise this pattern with the following statements:

- Because of the high cost of labour, a mechanical stoker was installed.
- On account of the velocity of the steam, the blades are caused to rotate.
- Due to expansion of the shaft, misalignment occurs at the bearings.
- Owing to the provision of heat exchangers, the efficiency was increased.
- Etc. The increase in temperature, there is an increase in pressure.
- Each enormous lifting capacity, electro-magnets are used.
- The high air/fuel ratio, a lot of oxygen present in the products of combustion.
- The wetness of the steam, it must be superheated.
- The intense stresses involved, a high-carbon steel must be used.

- Dust particles in the atmosphere, accurate observation is very difficult.
- The need to dispose of waste products, the installations must be sited near the sea.
- The size and complexity of the plants required, only a few countries possess them.
- Expansion or contraction of the shaft, axial movement of the bearing takes place.
- Their greater viscosity, liquids are less likely to leak than gases.
- The expense of the project, government assistance is necessary.

2. Prepositions with 'which'
In technical writing, the preposition is usually placed before which (or whom) and not at the end of the sentence, as it normally is in speaking.

Jet engines, with which most modern aircraft are equipped...

Notice:

1. The air passes to a compressor where it is compressed. (= in which)
2. After-burners are provided whereby the hot gases are again ignited. (= by means of which)

EXERCISE ONE

Insert the correct word or words in these sentences.

1. The exhaust steam is passed to a condenser ..... it is condensed.
2. 10 degrees is the limit ..... the nozzle can control the steam flow.
3. There are a number of tubes ..... the water circulates.
4. Radial flow turbines differ in the manner ..... the steam flow is arranged.
5. This depends on the purpose ..... the exhaust steam is used.
6. Cold water ..... the condenser is supplied circulates in these tubes.
7. The rate of wear of the bearing depends on the efficiency ..... it is lubricated.
8. There is an expansion period ..... after-burning of the fuel may take place.
9. Openings in the crankcase ..... the crankshaft passes are well sealed.
10. The material ..... the apparatus is made is a good non-conductor of heat.
4. The jet thrust needs to be augmented during take-off and landing.
5. Pressure in the induction passages is boosted by the use of a supercharger.
6. The aircraft's speed can be augmented by the use of rockets.
7. The efflux from the jet-pipe is amplified by the ducted air. (— made bigger)
8. The sound in the radio is amplified by a valve called an amplifier.
9. The arrangement of levers amplifies the movement of the bar.
10. During winter, stocks of coal diminish owing to heavier consumption. (— lesson)
11. The steam enters each successive row of blades at a diminishing velocity.

### Couple
1. The turbine wheel is coupled to the driving shaft through helical gearing.
2. The metal strip are coupled together to form a thermo-couple.
3. The wagons are coupled together by couplings to form a train.
4. The low initial cost of the engine, coupled with its ease of maintenance, make it very suitable for this purpose.

### Perform
1. Work is performed by the steam during expansion. (— carry out)
2. Compression can be performed in two or more stages.
3. Tests must be performed on the material to establish that it can be safely used.
4. The performance of the aircraft is very satisfactory. (— what it can do)
5. Modifications to the engine improved its performance considerably.

### Limit, Restrict, Impair, Impose
1. The length of the runway restricts the landing speed of aircraft.
2. The low melting point of the metal limits its usefulness to industry.
3. The limited floor-space available restricts the size of the engine.
4. The metal is limited in its usefulness by its low melting point.
5. The aircraft is restricted in speed to about 100 m.p.h.
6. The usefulness of this machine is impaired by its low efficiency. (— spoiled)
7. The insulating properties of rubber are impaired by long exposure to sunlight.
8. The length of the runway imposes limitations on the landing speed of the aircraft.
9. The low melting point of this metal imposes limitations on its usefulness.
10. The available floor-space imposes restrictions on the size of the engine which can be installed.

### Patterns

#### a)
1. The temperature of the gas rises. Consequently it expands in the cylinder.
2. After-burners have to be used. Therefore fuel consumption is heavier.
3. The aircraft speed is limited. Hence it will soon become obsolete.
4. The temperature of the gas rises so that it expands in the cylinder.
5. After-burners have to be used, but the more fuel is consumed.
6. The aircraft is limited in speed. As a result it will soon become obsolete.

#### b)
1. As a result of its rise in temperature the gas expands.
2. In consequence of having to use after-burners more fuel is consumed.
3. Consequently upon its limited speed the aircraft is now obsolete.
4. A rise in the temperature of the gas results in its expansion.
5. The use of after-burners results in increased fuel consumption.
6. Superheating the steam results in greatly increased efficiency.
7. Standardizing the size of the blades leads to production costs being lowered.

### Exercise One

Use the patterns given in a) to link these statements:
1. Heat flows in from the surrounding air. The ammonia evaporates.
2. The circulation in the unit is effected by gravity. No working parts are involved.
3. The friction losses are greatly reduced. They may be neglected.
4. The crystal boundaries of the metals are broken down. The metals disintegrate.
5. Water was sprayed into the steam causing condensation. A partial vacuum was produced.
6. There is a pressure and heat drop through the blades. The velocity of the steam increases.
7. The valve closes some of the low-pressure nozzles. The speed drops.
8. 30% of the working steam is used for feed heating. There is an improvement in thermal efficiency.
9. A corrosive acid is liable to be produced. Special precautions have to be taken.
10. Superheating dries the steam. Blade erosion is considerably reduced.
11. The cooling water and condensate are kept separate. The condensate is not contaminated.
Section 14

Reading: The Turbo-prop Engine

The efficiency of a turbo-jet engine varies with the speed and altitude at which it operates. Whilst it is very efficient at supersonic speeds and high altitudes, it is not suited to the low speeds involved in take-off and landing. Under these conditions, thrust augmentors or after-burners are often required to boost the power, and this entails heavy fuel consumption and restricts the range of the aircraft. On the other hand, propeller-driven aircraft cannot attain speeds much in excess of 300 m.p.h., whereas at low speeds they have a much better performance. Since subsonic speeds are still acceptable for most civilian airliners, a type of engine known as the turbo-prop was developed, which combined some of the advantages of both jet and piston-driven engines.

In the turbo-jet, the turbine is required to develop enough power to drive the compressor only, whereas in the turbo-prop engine, it must supply power also for the propeller, to which it is coupled by means of reduction gearing. As the propeller rotates, it drives rearwards a much larger column of air than that which is expelled from the jet-tube of the turbo-jet, but at a much lower velocity. Consequently it is quieter than the turbo-jet, since the volume of noise produced by an aircraft engine increases with the velocity of the air column. Most airports are situated in or near large centres of population, with the result that any reduction in the noise level is a decided advantage. Furthermore, a large proportion of the energy of the products of combustion is needed to drive the compressor and the airscrew. As this proportion increases, so the amount of thrust developed in the jet-pipe diminishes. In consequence, the destructive blasts of hot gas which emanate from the jet-pipe of the turbo-jet while taxiing on runways or taking-off are greatly reduced.

The main disadvantage of the turbo-prop engine is of course the limitation imposed on speed by the airscrew, as a result of which it is likely to become obsolete on all except short-haul aircraft.

A more recent development in jet propulsion is the ducted-fan jet, in which the turbine drives a multi-bladed fan enclosed in a duct. A certain proportion of the air which enters the engine by-passes the compressor and combustion chambers, and is impelled by the fan down the outside of the duct, so that it is expelled at considerable velocity from the rear of the engine. It amplifies the mass of hot exhaust gases, and thus serves to augment the thrust derived from them. Consequent on the more moderate speed of this ducted air, the noise level is kept reasonably low. In addition, this type of engine performs well both below and above the speed of sound, whereas the other types of engine are efficient only at certain speeds.

**WORD STUDY**

**Involve, Entail (= implies, makes necessary)**

1. a. The fitting of a superheater
   b. Rapid compression of a gas
   c. The Diesel cycle
   d. A re-entry turbine
   e. The planning of road gradients

2. a. Less manual labour is
   b. All the engineers are
   c. A number of factors are

**Augment, Boost, Amplify, Diminish**

1. The velocity of the molecule is
2. The jet thrust may be
3. Cylinder condensation is
EXERCISE ONE

Use the patterns of (1) and (2) to link these statements.
1. The population of the world goes up. The demand for food goes up.
2. The cost of living rises. Wages must rise.
3. Industrial towns attract more people. Few people are available for farming.
4. The steel is hard. It is difficult to work.
5. The rivet gets cold. The plates are drawn tighter together.
6. The shaft rotates faster. More friction is developed.
7. Expansion proceeds. The intrinsic energy of the steam decreases.
8. The steam pressure falls in the nozzles. Its velocity increases.
9. The fuel/air mixture is richer. The temperature in the engine is higher.
10. The turbine blades rotate faster. The stresses imposed on them increase.
11. The rate of evaporation is high. More steam will be generated.
12. The mass flow of air decreases. The compressor delivery pressure falls.

EXERCISE TWO

Complete these statements as in (3) above, using vary, increase or decrease as appropriate.
1. The efficiency of the turbo-jet varies as the temperature.
2. The efficiency of the turbo-jet varies as the size of the cylinder.
3. The efficiency of the turbo-jet varies as the size of the nozzle.
4. The weight of the workmen varies as their skill and experience.
5. The strength of the steel varies as the amount of carbon it contains.
6. The air temperature varies as the height above the ground.
7. The speed of rotation of a pulley varies as its diameter.
8. The weight of the fuel varies as the fuel octave number.
9. The wind velocity varies as the height above the ground.
10. The molecular agitation in a liquid varies as its temperature.
11. The proportion of CO₂ in the flue gas varies as the amount of excess air supplied.
12. The noise level produced by a stream of gas varies as its speed.
13. The ratio of heating surface to grate area varies as the size of the grate.
14. The coefficient of expansion of water varies as its temperature.
15. The internal energy of a gas varies as the rise in temperature.

REVISION (SECTIONS 8-14)

Read these statements, choosing the correct word from the alternatives in brackets.
1. The factory is now furnished, equipped, installed with automatic lathes, and this has involved, implied, instilled a heavy capital [output, outlay].
On the other hand, a part of the labour force has been eliminated, dispensed, dispensed with as a result, since less, fewer men are required to [drive, function, operate] this type of [machine, machinery].
2. The rate, speed of heat transfer, transfer, transmission from the cylinder may be increased by [supplying, providing, cooling] fins on the outside of the cylinder. Hence, thereby the total weight, area, susceptible, instrumental, available for cooling is [largely, greatly, highly] increased, and the heat is [diffused, disseminated, dissipated] more rapidly.
3. There is, has been a progressive, successive, subsequent increase in production over the last, latest, recent ten years owing to the equipment, installation, installation of these new [machines, machinery] in the factory. A success, succession, progression of changes has been done, made in the management of the company, and a number of new techniques have been produced, introduced, achieved.
4. While, During, As) passing through the turbine blades, the steam is
12. The draught is thus increased. More air is available for combustion.
13. The fissile material is rapidly used up. The elements have to be frequently replaced.
14. The weather was very bad for some weeks. Progress with the building of the bridge was not so good as was expected.
15. Labour-management relations are very good. There are seldom any serious disputes.

EXERCISE TWO

Use the patterns given in b) to link these expressions in order to form a statement in each case:

1. heating the metal in air. it oxidises.
2. mass production. the goods become cheaper.
3. lubrication of the bearings. the friction is reduced.
4. working the metal cold. internal stresses are set up in it.
5. a drop in pressure. partial evaporation of the liquid.
6. increased demand for power. large capacity turbines were produced.
7. condensation. a partial vacuum was produced.
8. the development of the jet engine. much greater speeds can be attained.
9. the inefficiency of this type of engine. it was abandoned.
10. a pressure drop through the blades. an increase in the steam velocity.
11. increase in traffic density. underpasses and fly-overs were built.
12. overheating in the cylinder head. the mixture was detonated.
13. a rise in temperature. an increase in the pressure energy of the fluid.
14. the bad weather. progress on the bridge was held up.
15. the intensive research which was carried out. development of the engine proceeded very rapidly.

d) The contrast can be emphasised by adding on the one hand, on the other hand.

| A hot engine will run on a weak mixture, while on the other hand a cold engine requires a richer mixture. |
| Whereon the one hand a hot engine can run on a weak mixture, a cold engine requires a richer mixture. |

| On the other hand is often used alone, after a full-stop. |
| A hot engine will run on a weak mixture. On the other hand a cold engine requires a richer mixture. |

| d) Notice the expression in contrast to + Noun. |
| In contrast to the rich mixture needed to start a cold engine, a weak mixture is sufficient to keep a warm engine running. |

EXERCISE

Use these contrast words to link these statements:

1. The live centre on the lathe rotates with the spindle. The dead centre is stationary.
2. A belt drive provides a flexible link between shafts. A chain drive provides a positive link.
3. Un lubricated bearings develop a great deal of friction. Bearings which are properly lubricated develop much less.
4. Mercury has a very regular coefficient of expansion. Water has a variable coefficient of expansion.
5. Fuels rich in paraffin are liable to detonation. Aromatics are anti-detonators.
6. Insufficient air will prevent complete combustion. Too much air will reduce the temperature of combustion.
7. The traffic density on the road is very high during the peak hours. It is very low at midday and during the night.
8. A skilled craftsman can earn high wages. An unskilled worker earns very little.
9. Uranium 235 requires slow neutrons for its fission. The neutrons emitted during fission are fast neutrons.
10. The steam in contact with the steam chest is comparatively dry. The steam in contact with the piston is much wetter.
which are (liable, likely, possible) to be (affected, effected, performed) as a result of increased production and a more (efficient, effective) use of manpower.

14. The (purpose, function) of the flux which is (supplied, fitted, applied) to the (work, works) to be welded is the removal of any existing oxides, and the (protection, prevention, disposal) of further oxidation (during, while) heating.

15. The amount of steam which is (evolved, developed, generated) by a boiler increases (as, with) the (rate, ratio, speed) of combustion increases, and this can be (achieved, acquired) by providing a forced (straight, current) of air across the fire-grate.