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VERA ADAMSON

in collaboration with

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9 The Heat Engine

One of the major factors which has contributed to the development of our society is that we have learned to harness some of the sources of energy found in Nature. The ability to do this has provided us with machines capable of converting energy taken from natural sources into useful mechanical work, and the possession of such machines is now essential to the maintenance of our civilization. It is seldom, if at all, that we turn our attention to considering this fact. We have become accustomed to our mode of life and take for granted the necessities and commodities which industry makes available to us without giving much thought to their origin and production.

The manufacture of goods and the preparation of foodstuffs etc. depend upon the availability of a vast source of mechanical power which, is, in turn, dependent upon the function of the machines mentioned above.

These machines are called 'prime movers', the most important of which is the heat engine. This type of prime mover, examples of which are the petrol and oil engines, steam turbines, gas turbines and so on, convert into useful mechanical work some of the energy which is supplied to them from a natural source of heat, such as the combustion process of some form of fuel. All prime movers are able to drive other machines which perform all sorts of useful tasks many of which would be impossible for man to carry out unaided. The essential nature of the prime mover will, therefore, be at once appreciated.

The heat engine is not the only kind of prime mover; a greater part of the machinery used in industry nowadays is driven by electric motors which receive electrical energy from the electrical supply system. The generators which produce the electrical energy, however, are driven by some form of basic prime mover such as a heat engine or a hydraulic turbine.

Prime movers, then, might be classified into two groups, as

follows:

(*a*) Those of the first order, which receive energy directly from a natural source of energy, and

(*b*) Those of the second order, which receive energy indirectly from a natural source through the agency of a prime mover of the first order.

Heat engines, hydraulic turbines, windmills, etc., are of the first order, whilst the electric motor is a prime mover of the second order, since the energy it receives derives from a generator driven by a prime mover of the first order.

Of the various sources of energy at out disposal most use is at present made of the chemical energy in fuels, which through a combustion process is converted into heat, and thence transformed into mechanical energy in a heat engine. Several attempts have been made to harness the energy received upon the earth in the form of direct radiation from the sun, but these attempts have met with limited success. Similar remarks apply to tidal energy and the heat energy deep within the earth. In the past wind and water power were widely used, and even now hydro-electric power stations provide a fraction of the world's electrical power.

In recent years the development of methods of conversion of the energy bound up within the atom itself have taken place, but no direct conversion from nuclear to mechanical energy is yet known, and the method employed is through the medium of the heat engine. Already electrical energy is being produced in this way, and it seems fairly certain that great progress will be made in this field in the future.

The employment of animals was probably man's first attempt at reducing his own labours, and he used them in conjunction with the primitive agricultural efforts of the time, and later for drawing carts. Thus in harnessing an ox he harnessed a source of energy! The use of animals resulted in increased productivity and hence an improved standard of living. The early hand grinding of corn was inadequate to deal with the increased crop yield, and the development of mills propelled by wind and water power followed. For centuries these two energy sources remained the only sources to be successfully tapped, and it was not until the eighteenth century that the first steam engines were made. This fact is rather surprising, since a crude form of steam turbine had been invented about two thousand years

before the idea of using steam to drive an engine was put into practice. This turbine was designed by a Greek from Alexandria, and was known as Hero's Eolipile. Several people revived the idea of using steam from time to time, but no efficient practical machines were built until Newcomen, in 1712, patented the atmospheric engine. (In the early nineteenth century several of these machines were in use in mines to drive pumps.) Shortly afterwards (1765) James Watt improved upon Newcomen's engine, and produced what was really the forerunner of the reciprocating steam engine as we know it today.

It was during the nineteenth century that the rapid development of the heat engine took place, and with ever increasing power at the disposal of man, the mechanical age began. The demand for more and more power as new industries evolved created a great incentive for invention. At first, attention was solely devoted to practical improvement, but later the trend was more toward philosophical reasoning, with a result that engineers found it necessary to review their fundamental ideas. It was seen that the consideration of practical detail alone was insufficient in the attempt to produce more efficient machines. Theoretical reasoning was also necessary, and it was through the work of men such as Carnot, Clausius, Joule, Kelvin, Gibbs, Rankine and others, that the theoretical study developed. The combination of their philosophy and the skill of the craftsmen, together with the ingenuity of the practical engineers, resulted in progressively more efficient engines.

Compared with the prime movers of the nineteenth century, our present-day engines and power plants are very efficient. Nevertheless, design and development engineers are continually striving to produce even more efficient machines. In this task they must engage in conflict with the restrictions which Nature imposes upon energy conversion processes, and they must be armed with the knowledge which is gained from the study of the subject of Thermodynamics.

D. H. MARTER
Extract from *Engines*

NOTES

1 *factors:* circumstances
2 *harness:* put to use
6 *maintenance:* support

7 *seldom:* rarely
if at all: if ever
8 *accustomed to:* familiar with
9 *mode:* way
10 *commodities:* things that can be used or traded in
11 *giving much thought to:* thinking much about
15 *mentioned above:* mentioned in the previous paragraph
16 *'prime movers':* machines which convert natural energy into mechanical power
19 *turbines:* rotating prime movers driven by water, steam or gas turning a wheel
and so on: etcetera (etc.)
22 *some form of:* is used when a thing is not named
25 *The essential nature of the prime mover will therefore at once be appreciated:* Therefore the reader will realize at once the essential nature of the prime mover (i.e. that it converts natural energy into mechanical power)
27 *nowadays:* during the present period of time. 'Now' usually refers to the immediate present, but compare its use in Passage 18, line 75.
37 *agency:* action
40 *whilst:* but on the other hand (expressing contrast cf. Passage 6 line 36)
41 *derives:* comes from
43 *at our disposal:* available for our use
45 *thence:* from there; from that stage
48 *radiation:* transmission of heat through space and through the earth's atmosphere
49 *Similar remarks:* remarks indicating that attempts at harnessing (tidal energy) have met with limited success i.e. have not been very successful
50 *tidal energy:* energy created by movements of great masses of water as the sea level rises and falls periodically in tides produced by the attraction of the sun and moon. Attempts to harness tidal energy have usually been made at the mouths of sea inlets or estuaries where the rise and fall of the tide causes huge quantities of water to rush through a restricted opening.
the energy bound up within the atom itself: atomic energy
57 *medium:* agency
62 *in conjunction:* together
63 *of the time:* of that period of history
64 *drawing:* pulling
66 *hence:* thus (as a logical consequence)
67 *inadequate:* not sufficient
68 *propelled:* driven
70 *tapped:* used; drawn off

72 *crude:* rough
74 *put into practice:* actually used
76 *Eolipile* was the first steam engine invented in the second century B.C., and consisted of a closed globe-like cylinder from which steam came out through bent tubes
78 *Newcomen:* See Passage 8, note on Newcomen, line 6.
79 *atmospheric engine:* See Passage 8, note on Newcomen, line 6.
81 *improved upon:* made more efficient
82 *was really the forerunner:* really led the way for or pioneered
83 *reciprocating steam engine:* See Passage 8 note, line 55.
84 *It was during the . . . that:* This is a more emphatic way of saying *During the 19th Century.*
87 *as:* when
88 *incentive:* stimulus
89 *attention was solely devoted to:* engines concentrated on making (practical improvements)
solely: exclusively
95 *Carnot:* Sadi Carnot (1796–1832), French physicist and engineer who was a pioneer of thermodynamics, and stated 'Carnot's Principle', that the efficiency of a reversible engine depends on the temperatures between which it works.
Clausius: Rudolf Clausius (1822–1888), German physicist and mathematician who applied his work on the theory of thermodynamics to the development of the steam engine. He stated the Second Law of Thermodynamics in 1850.
Joule: James Prescott Joule (1818–1889), English experimental physicist who established the First Law of Thermodynamics. He calculated the amount of work needed to produce a unit of heat (the mechanical equivalent of heat) and his name is given to the energy unit, the 'joule'.
Kelvin: William Thomson, Lord Kelvin (1824–1907), British physicist and mathematician. Although he was one of the founders of thermodynamics, his best known work was in electricity (he discovered the 'Thomson Effect') and in the design of instruments for navigation.
Gibbs: Josiah Willard Gibbs (1839–1903), American mathematical physicist who did important work on the application of thermodynamics to chemistry. He also made major contributions to the theory of surface forces and the electromagnetic theory of light.
96 *Rankine:* William Rankine (1820–1872), Scottish scientist and engineer who applied thermodynamics to the development of steam engines and other prime movers.
97 *philosophy:* wisdom
98 *ingenuity:* inventive skill
99 *resulted in progressively more efficient engines:* produced engines which became more efficient one after another
101 *plants:* machinery
103 *striving:* trying hard
104 *engage in conflict with:* attempt to overcome; grapple with (compare *grappling with*, Passage 8, line 58)
107 *Thermodynamics:* the relationship between heat and work

EXERCISES

1 Answer these questions, basing your answers on information in the text.
a In line 3 to what does *this* refer in *the ability to do this*?
b What is essential to our civilization?
c What is the difference between the function of the heat engine and the function of the electric motor?
d What two classes of prime movers are there, and into which would you put the electric motor?
e What sources of energy were used in the past, what sources are being experimented with now, and what may become the chief source in the future?
f What part did Hero, Newcomen and James Watt play in the transition from animal and elemental energy to mechanical energy?
g What was the contribution of men like Carnot and Rankine to the mechanical age?
h Why must design and development engineers be experts in thermodynamics?

2A Give nouns related in form and meaning to these adjectives in the text.
a major; *b* dependent; *c* essential; *d* basic; *e* chemical; *f* tidal; *g* nuclear; *h* crude; *i* atmospheric; *j* reciprocating.

2B Give adjectives related in form and meaning to the nouns in the text.
a machines; *b* mode; *c* examples; *d* combustion; *e* motors; *f* order; *g* disposal; *h* stations; *i* labours; *j* grinding; *k* work; *l* study; *m* combination; *n* ingenuity.

3 Substitute for the words printed in italics the ones used in the text.
a We have learned to *make use of* natural sources of energy.
b We accept the necessities and commodities which industry *supplies us with.*
c *Much* of the machinery used in industry nowadays is driven by electric motors.
d These attempts *have not been very successful.*

e *Methods of converting the energy in atoms have recently been developed.*
State in each case whether you find this version or the original one in the text easier to understand.

4 Supply prepositions in the spaces.
a has contributed . . . the development
b has provided us . . . machines
c the maintenance . . . our civilization
d depend . . . the availability.
e convert . . . useful mechanical work
f classified . . . two groups
g bound . . . the atom
h in conjunction . . . primitive agricultural efforts
i James Watt improved . . . Newcomen's engine
j armed . . . the knowledge
k derives . . . a generator

5 Write out the sentences substituting an infinitive or noun *-ing* form of the verb for the verb in parenthesis, and supplying, where necessary, the correct preposition.
a We have learned (harness) some of the sources of energy found in Nature.
b The ability (do) this has provided us with machines capable (convert) energy taken from natural sources into useful mechanical work.
c It is seldom that we turn our attention (consider) this fact.
d All prime movers are able (drive) other machines which perform useful tasks which would be impossible for man (carry out) unaided.
e The employment of animals was probably man's first attempt at (reduce) his own labours.
f Thus in (harness) an ox, he harnessed a source of energy.
g A crude form of steam turbine was invented about 2,000 years before the idea of (use) steam (drive) an engine was put into practice.

6 Punctuate with commas.
a Heat engines hydraulic turbines and windmills are of the first order whilst the electric motor is a prime mover of the second order.
b This type of prime mover examples of which are the petrol and oil engines steam turbines gas turbines and so on convert into useful mechanical work some of the energy of which is supplied to them from a natural source of heat.
c It is seldom if at all that we consider this fact.

7 Combine these pairs of sentences using the words in parenthesis as connectives, and making any necessary omissions or changes in word order.

a These machines are called prime movers.
The most important is the heat engine (of which).
b The generators are driven by some form of basic prime mover.
These generators produce electrical energy (which).
c Energy in the atom itself has been converted.
No direct conversion from nuclear to mechanical energy is yet known (although).
d Later the trend was more towards philosophical reasoning.
Engineers reviewed their fundamental ideas (with the result that).

8 To what do these words refer?
a such as (line 21); *b* thus (line 64); *c* thence (line 45); *d* nevertheless (line 102).

9 Write out paragraph one and paragraph 7 again in simple concise English, using not more than 70 words for each.