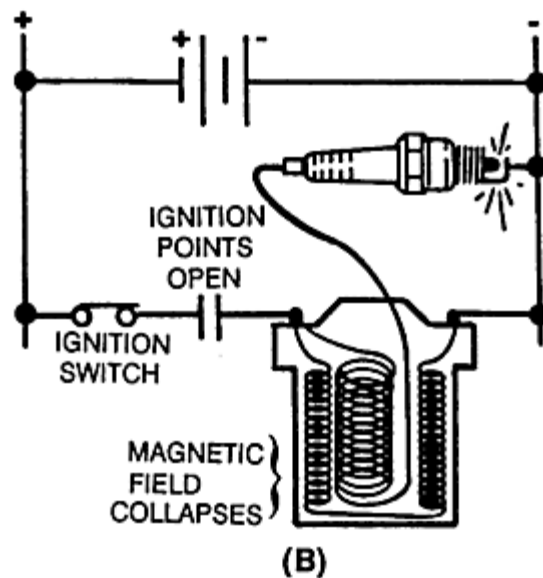
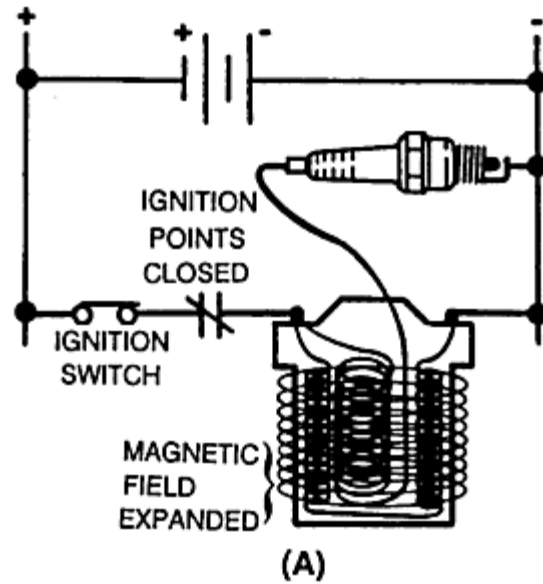


## TRANSFORMERS

### INTRODUCTION

A transformer is a device that transfers electrical energy from one circuit to another by electromagnetic induction (also called transformer action). It is most often used to step up or step down voltage. Occasionally, it is used as an isolating device to eliminate a direct mechanical electrical connection between the power source and the loads. The electrical energy is always transferred without a change in frequency but may involve changes in the effective value of voltage and current. Because a transformer works on the principle of electromagnetic induction, it must be used with an input source that varies in amplitude.

Examining a very unusual transformer will show power is transferred through the use of electromagnetic induction. This direct current transformer will demonstrate the actions of a step-up transformer and provide stop-action analysis of the moving magnetic field. [Figure 8-1](#) shows a one-line diagram of the primary and secondary automobile ignition system. The primary circuit, or power source side, includes the battery positive terminal, the ignition switch, the primary winding to the ignition points, and the battery negative terminal. The secondary circuit starts with the secondary winding wire and connects the distributor rotor and the spark plug.



**FIGURE 8-1. Automobile Step-Up Transformer.**

When both the ignition switch and the points are closed, there is a complete circuit through the 12-volt battery terminals and the primary windings. As a current initially moves through the conductor, an expanding magnetic field is created. As the magnetic field from the primary winding expands across the secondary windings, a type of generator is created which produces an EMF in the secondary windings. Through electromagnetic induction, the secondary winding has all the necessities for generating an EMF a conductor (the secondary winding), the magnetic field (from the current flow

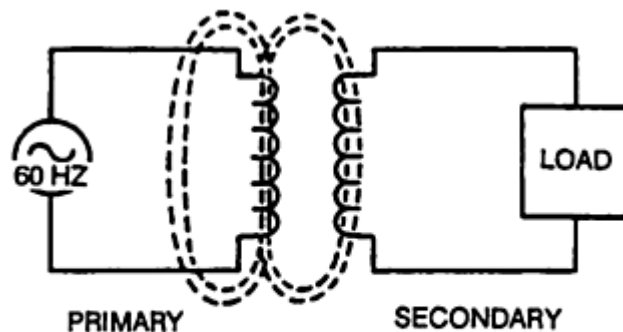
through the primary winding), and the relative motion between the expanding magnetic field and the secondary winding.

As the contact points open, the primary field collapses. With this collapse, there is again relative motion between the magnetic field and the secondary windings. This motion and the increased number of conductors in the secondary windings allow the coil to step up voltage from the original 12 volts to the 20,000 volts necessary to fire this type of ignition system.

The distributor, ignition points, and condenser that comprise this DC switching device are very costly. It is not very practical to use DC to step up voltage. AC has certain advantages over DC because it changes direction readily and has a constantly moving magnetic field. One important advantage is that when AC is used, the voltage and current levels can be increased or decreased by means of a transformer.

## BASIC OPERATION OF A TRANSFORMER

The transformer circuit in [Figure 8-2](#) shows basic transformer action. The primary winding is connected to a 60 hertz AC source. The magnetic field (flux) expands and collapses about the primary winding. The expanding and contracting magnetic field around the primary winding cuts the secondary winding and induces an EMF into the winding. When a circuit is completed between the secondary winding and a load, this voltage causes current to flow. The voltage may be stepped up or down depending on the number of turns of conductor in the primary and secondary windings.



**FIGURE 8-2. Basic Transformer Action.**

The ability of a transformer to transfer power from one circuit to another is excellent. For marine engineering applications, the power loss is negligible. Power into the transformer is considered equal to power out. It is possible to increase, or step up, the voltage to loads with a subsequent reduction in current. The power formula ( $P = I \times E$ ) demonstrates this phenomenon. The transformer is rated by power or VA for volts times amps. Transformers are rated more often in kVA for thousands of volt amps. The terms "step up" or "step down" refer to the actions of the voltage. A step-down transformer means that the voltage of the source has been reduced to a lesser value for the loads.

Examples of step-down transformers can be found on most Army watercraft. The ship service generator provides 450 VAC to the distribution system. The lighting panels and smaller motors require 115 VAC for a power supply. The ship's transformers step down the 450 volts to 115 volts. Although there is a lesser voltage in the load side than in the power supply side, the current in the load side will be greater than the current provided from the source side.

For example, if the ship service generator provides 450 VAC at 20 amperes to the primary winding of the transformer, the secondary winding of the transformer will provide 115 VAC at 78 amperes to the loads.

Primary (generator) side:

$$P = I \times E$$

$$P = 20 \text{ amps} \times 450 \text{ volts}$$

$$P = 9,000 \text{ VA (or 9kVA)}$$

Secondary (load) side:

$$P = I \times E \text{ or } I = \frac{P}{E}$$

$$I = \frac{9,000 \text{ VA}}{115 \text{ volts}}$$

$$I = 78 \text{ amps}$$

The conventional constant-potential transformer is designed to operate with the primary connected across a constant-potential source, such as the AC generator. It provides a secondary voltage that is substantially constant from no load to full load.

Transformers require little care and maintenance because of their simple, rugged, and durable construction.

## APPLICATIONS

Various types of small single-phase transformers are used in electrical equipment. In many installations, transformers are used in switchboards to step down the voltage for indicating lights. Low-voltage transformers are included in some motor control panels to supply control circuits or to operate contractors and relays.

Instrument transformers include potential, or voltage, transformers and current transformers. Instrument transformers are commonly used with AC instruments when high voltages or large currents are to be measured.

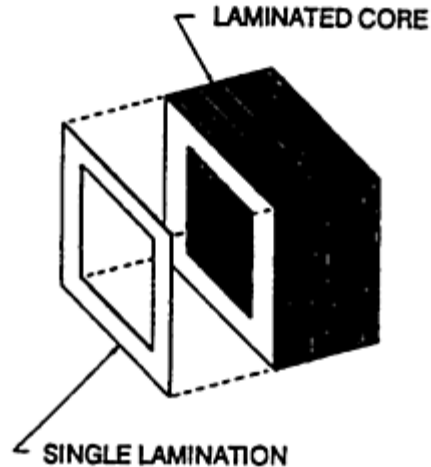
## **TRANSFORMER COMPONENTS**

The principle parts of a transformer and their functions are --

- The core, which provides a path for the magnetic lines of flux.
- The primary winding, which receives power from the AC power source.
- The secondary winding, which receives power from the primary winding and delivers it to the load.
- The enclosure, which protects the above components from dirt, moisture, and mechanical damage.

## **CORE CHARACTERISTICS**

The composition of a transformer core depends on such factors as voltage, current, and frequency. Size limitations and construction costs are also factors to be considered. Commonly used core materials are air, soft iron, and steel. Each of these materials is suitable for particular applications and unsuitable for others. Generally, air-core transformers are used when the voltage source has a high frequency (above 20 kHz). Iron-core transformers are usually used when the source frequency is low (below 20 kHz). A soft-iron-core transformer is useful when the transformer must be physically small, yet efficient. The iron-core transformer provides better power transfer than does the air-core transformer. A transformer whose core is constructed of laminated sheets of steel dissipates heat readily, providing efficient transfer of power. Most transformers in the Army marine field contain laminated steel cores. These steel laminations ([Figure 8-3](#)) are insulated with a nonconducting material, such as varnish, and then formed into a core. It takes about 50 such laminations to make a core an inch thick.

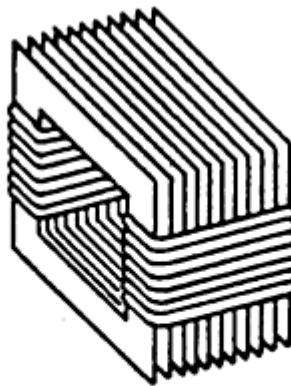


**FIGURE 8-3. Hollow-Core Construction.**

The laminations reduce certain losses which will be discussed later. The most effective transformer core is one that offers the best path for the most lines of flux with the least magnetic and electrical energy loss.

Two main shapes of cores are used in laminated steel-core transformers: the hollow core and the shell core.

The hollow core is shaped with a square through the center ([Figure 8-3](#)). The core is made up of many laminations of steel. [Figure 8-4](#) shows how the transformer windings are wrapped around both sides of the core.



**FIGURE 8-4. Windings Wrapped Around Laminations.**

The shell core is the most popular and efficient transformer ([Figures 8-5 through 8-7](#)).

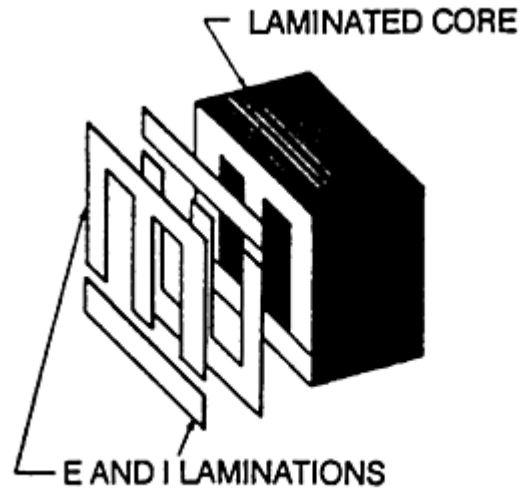


FIGURE 8-5. Shell-Type Core Construction.

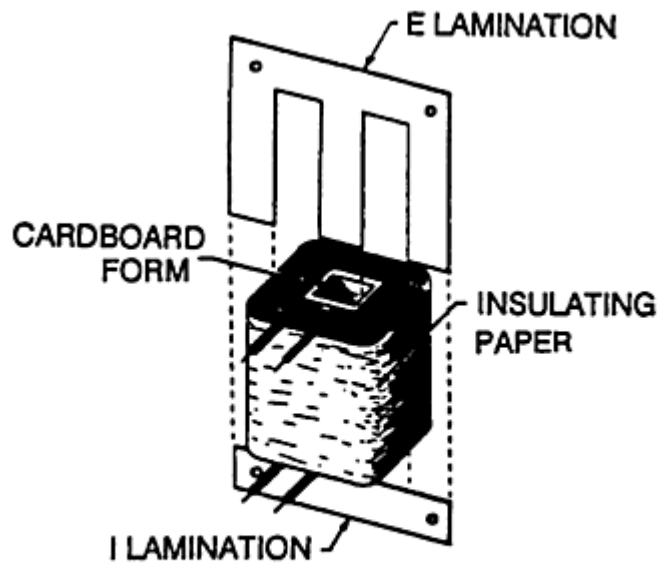
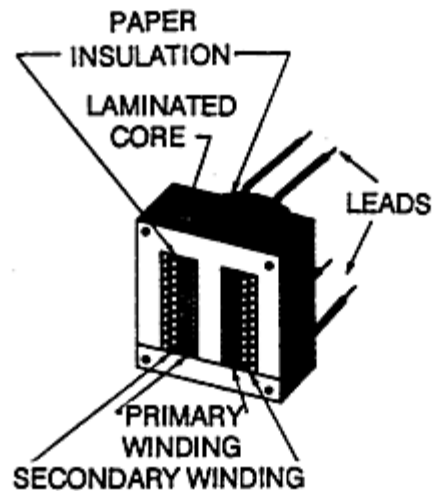


FIGURE 8-6. Exploded View of Shell-Type Transformer Construction.



**FIGURE 8-7. Cutaway View of Shell-Type Core With Windings.**

As [shown](#), each layer of the core consists of E- and I-shaped sections of metal. These sections are butted together to form laminations. The laminations are insulated from each other and then pressed together to form a core.

## **TRANSFORMER WINDINGS**

Two wires called windings are wound around the core. Each winding is electrically insulated from the other. The terminals are marked according to the voltage: H indicates the higher voltage, and X indicates the lesser voltage. [Figure 8-8](#) shows examples of this.



































