Cold Rolled Motor Lamination Sheet is a special type of cold-rolled steel sheet product that is produced to maximize the performance of the products for use as electro-magnetic core materials for electrical equipment components. These include electric motors, generators, and transformers. The steels used for these applications are designed to maximize the useful energy, i.e., minimize energy losses, obtained from the electrical energy input into motors, etc.

The manufacture of Cold Rolled Motor Lamination Sheet is similar to the practices used to make Cold Rolled Steel Sheet in that the product is processed through slab-casting, hot rolling, cold rolling, annealing, and temper rolling steps. The differences between conventional cold-rolled sheet and lamination sheet products relate to the composition of the steel and certain processing modifications such as hot band annealing which is used in the manufacture of the more energy efficient lamination steel grades.

<table>
<thead>
<tr>
<th>Type of Equipment</th>
<th>Principal End Users</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small Motors</td>
<td>Automobiles, major appliances, small appliances, room air-conditioners, heating and ventilating equipment, power tools</td>
</tr>
<tr>
<td>Large Motors</td>
<td>Mill drives, machine-tool drives, central air-conditioning systems</td>
</tr>
<tr>
<td>Generators</td>
<td>Motor generator sets, gasoline and diesel-powered generators</td>
</tr>
</tbody>
</table>
## Basic Principles of CR Motor Lamination Sheet Products

In order to understand the performance of CR Motor Lamination Sheet products, one needs to understand the workings of electromagnets and how these workings take place in electrical motors and transformers.

The simplest electromagnet consists of loops of wire (an electrical conductor) connected to a direct-current source. When the power is on, the flow of electrical current in the wire makes a magnet similar to the common familiar permanent magnet. In technical terms, the flow of electrical current creates lines of force. These lines of force are present as long as current flows through the wire; when the current stops flowing, the lines of force and their magnetic effects disappear. The strength of the lines of force are directly associated with the total current flow. If the current strength is increased, the number of lines of force increases.
A steel bar placed within the coil field behaves just like a permanent magnet. It has a North and South pole. Which end of the bar is the North pole depends on the direction of current flow. If the power comes from a direct-current source (a battery, for example), the polarity of the electromagnet will not change. But, if the power comes from an alternating-current source like in most of today's homes and offices in the United States, the poles will switch places 60 times a second.

As is the case with a permanent magnet, the strength of an electromagnet is directly related to the number of force lines created. The number of lines of force, in turn, is a direct function of the number of loops of wire ("turns") and the magnitude of the current in the wire. That is, the greater the number of wire loops and the greater the current flow, the greater the number of lines of force (strength of the electromagnet).

The strength or lines of force also depends on the type of material in the core. If the core is composed of air, the strength is very low because air is not a good magnetic material. But, when the core consists of materials like iron, nickel or cobalt (ferromagnetic materials), the lines of force or strength of the electromagnet is increased many times. These
ferromagnetic materials have special fundamental physical properties that make them very desirable materials for use in electromagnets. Since iron or steel possesses very good ferromagnetic properties and is relatively inexpensive versus the other two highly ferromagnetic materials, it is a very desirable product for use in electromagnets.

Remember that one of the important characteristics of a material used to make electromagnets is the efficiency of use of the inputted current. The objective is to maximize the efficiency of the input current by minimizing the losses associated with heat buildup in the lamination steel core and within the electrical device as a whole.

**Efficiency**

Electrical equipment such as motors, generators, and transformers are devices that operating using the principles of electromagnetism. Motors convert electrical energy into mechanical energy; generators convert mechanical energy into electrical energy; and transformers transfer electrical energy through a ferromagnetic core from one electrical circuit to another.

Because electricity is costly, it is very important to obtain the maximum efficiency from the core material in an electromagnet device. Maximizing the core material (CRML steel) efficiency maximizes the amount of output energy or work of the device. The design of the electromagnetic core as well as the properties of the steel comprising the core are important
factors that must be considered when designing for maximum efficiency. Thus, CR Lamination Electrical Sheet products are specially developed cold rolled steels to answer the needs of the electrical industry.

Critical to achieving high efficiency is selecting a core material that has low core loss and high permeability. The term "core loss" relates to the total energy lost through the generation of heat. Heat, a form of energy loss, is produced by eddy currents in the core material and by a behavior called magnetic hysteresis.

Hysteresis refers to the fact that, as iron is magnetized and then demagnetized during the passage of alternating current, the behavior with respect to the rate of buildup of magnetic flux during the magnetizing portion of each cycle does not follow identically with the rate of decrease in magnetizing flux during the demagnetizing portion of the cycle.

Eddy currents are small stray electrical currents that are generated within the core material by the magnetic field. These can be minimized, but not avoided in total. Since there is a current flowing in the core material (steel), heat is generated. Remember, it is an inherent characteristic of metals that current flow generates heat because of the resistance to
current flow that is part of all steels. This source of electrical energy loss is called "eddy current loss".
Eddy current losses are lowered by increasing the resistance of the path through which the eddy current flows.

The resistance of the core is increased in two ways:

1. constructing the core from a number of thin sections (light-gauge sheets) or laminations*, and
2. alloying the steel with elements such as manganese, silicon, and aluminum; elements that increase the electrical resistance of steel.

*Thin sections of steel sheet restricts the current to very small paths assuming that the laminations are insulated from each other.

To minimize hysteresis losses, the core steel must:

1. be relatively free of internal particles such as oxides, nitrides, and sulfides,
2. have a very low carbon content, and
3. have a large grain size.

Peak permeability is another characteristic of the steel affected by the efficiency of magnetization. It refers to the amount of magnetizing force that is required to achieve a given magnetic flux density. That is, the permeability is defined as the ratio of flux density to the magnetic field strength. The higher this ratio, the higher the permeability. A high permeability is desired because in effect it takes less current flow (electrical energy) to achieve a given flux density if a material exhibits a high permeability. In effect, a high permeability material requires less current to achieve a given magnetic force; less current flow means less heat loss, higher efficiency, and less electrical costs for the end user.

U. S. Steel Motor Lamination Sheet Grades
The following steel grades are available from U. S. Steel. These grades have been engineered for use as electromagnetic-core material for electrical equipment components.

- USS Type 1
- USS Type 2-S
- USS Q-Core II
- USS Q-Core P21
- USS Q-Core P19
- USS Q-Core XL

The primary distinguishing features of these grades is a specified Core Loss requirement. These grades are furnished in the semi-processed condition, that is, the customer performs the lamination anneal that is needed to develop the required magnetic properties.

**Core Loss**
Core loss is the energy lost as heat generated by alternately magnetizing and demagnetizing during use of electrical equipment. Core loss is measured by the Epstein Test method. It is expressed in units of watts per pound.

Maximum Core Loss* Table
Watts per Pound, 60 Hz at 1.5T
(Equivalent ASTM type shown in parentheses)

<table>
<thead>
<tr>
<th>STEEL GRADE**</th>
<th>EQUIVALENT THICKNESS, INCHES**</th>
<th>GRADE</th>
</tr>
</thead>
<tbody>
<tr>
<td>USS TYPE 2-S</td>
<td>USS Q-CORE</td>
<td>USS Q-CORE II</td>
</tr>
<tr>
<td>-------------</td>
<td>-----------</td>
<td>--------------</td>
</tr>
<tr>
<td>21</td>
<td>0.0340</td>
<td>6.10</td>
</tr>
<tr>
<td>22</td>
<td>0.0310</td>
<td>5.60 (79D610)</td>
</tr>
<tr>
<td>23</td>
<td>0.0280</td>
<td>5.05 (71D550)</td>
</tr>
<tr>
<td>24</td>
<td>0.0250</td>
<td>4.50 (64D490)</td>
</tr>
<tr>
<td>25</td>
<td>0.0220</td>
<td>3.95 (56D440)</td>
</tr>
<tr>
<td>26</td>
<td>0.0185</td>
<td>3.35 (47D380)</td>
</tr>
</tbody>
</table>

*Epstein test samples annealed at 1450°F in a decarburizing atmosphere.
**Test procedure per ASTM A343.
Note: USS Type 1 is not sold to a maximum core loss requirement.

**Some Points to Note Carefully**

It is important to note that all U. S. Steel published maximum core loss values are based on testing of samples that have been annealed at 1450°F in a decarburizing atmosphere. This procedure attempts to simulate the typical customer’s lamination anneal. Customers who anneal using other conditions may not experience core losses below the values published by U. S. Steel.

It is also important to recognize the relationship between core loss and lamination thickness. The thinner the laminations, the lower the core loss. This relationship combined with the relationship between core loss and steel grade is the common way in which customers select the material that they wish to purchase. For example, a customer could consider
substituting 0.025-inch thick Q-Core II material for 0.022-inch thick Q-Core. The decision has to be made on economics combined with the customer's processing capability.

**ASTM Specifications**

ASTM Specification A726 covers Cold Rolled Magnetic Lamination Quality Steel, Semi-processed types. Core losses of higher quality core-loss type steels are guaranteed.

The ASTM designator system used to define core-loss types are outlined below:

- First two digits represent nominal thickness in millimeters, e.g., $64 = 0.64$ mm
- Code letter D is the magnetic material category
- The last three digits represent maximum core loss in watts per pound, e.g., $3.60$ w/lb.