CLIFFS

TRAN-COR® X

GRAIN-ORIENTED ELECTRICAL STEELS

X-0 CARLITE® DR® | X-1 CARLITE® DR®

Distribution Transformers

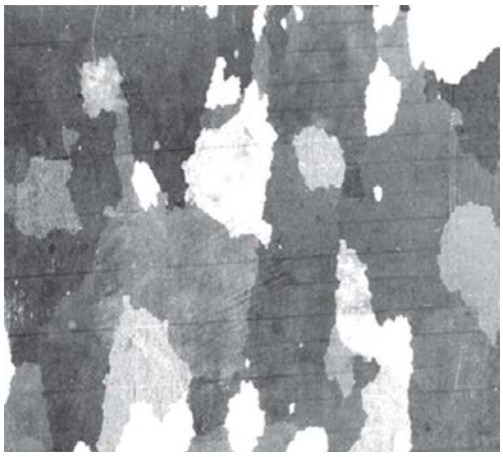
Medium Power Transformers

Large Power Transformers

Grain-oriented electrical steels are iron-silicon alloys that were developed to provide the low core loss and high permeability required for efficient and economical electrical transformers. Cleveland-Cliffs' product, **TRAN-COR X®**, is suitable for distribution, medium power and large power transformers which employ stacked core technology. The high permeability of TRAN-COR X offers the potential for lower core loss and lower noise transformer core structures when compared to conventional grain-oriented electrical steels. The core loss characteristics are further enhanced with laser scribing. The patented alloy design of TRAN-COR X is only available from Cleveland-Cliffs.

Product Description

TRAN-COR X CARLITE® DR® (Domain Refined) high permeability electrical steels offer an outstanding degree of grain orientation. The combination of high permeability, low residual stress and domain refining via laser scribing offers very low core losses. During the laser scribing process, a precisely focused laser beam is rapidly scanned across the steel surface. The micro-strain imparted in the material forces the pre-existing magnetic domains to subdivide. The finer domain structure reduces the distance that the domain walls must move during AC magnetization, thereby reducing eddy current losses. The result is far lower core loss than grain-oriented electrical steels without laser scribing.



Sample chemically etched to reveal laser scribe trace

DOING OUR PART

Cleveland-Cliffs' electrical steel products contain approximately 75 – 85% of post-consumer and post-industrial recycled materials. This content comes largely from the re-melting of scrap steel products. Not only does the electrical steel contain a high percentage of post-consumer and post- industrial recycled materials, at the end of its useful life, it is likely to be 100% recyclable.

Specifications

In terms of maximum core loss, TRAN-COR X specifications are determined at 1.5T and 1.7T at either 50 Hz or 60 Hz. Core loss and induction grading are conducted using as-sheared single sheet test samples which are tested in accordance with American Society for Testing and Materials (ASTM) test method A804. Flux density is specified at 800 A/m. Samples are secured from each end of the coil and the higher core loss value is used for certification of conformance to product grade guarantees.

TABLE 1 – SPECIFICATIONS

Grade	Approximate Equivalent International Grade	Thickness, mm	Assumed Density, gm/cm³	Maximum Core Loss W/kg		Minimum Flux Density
						B_8**
				$W_{15/50}$*	$W_{17/50}$*	T
X-0 CARLITE DR	M075-23P5	0.23	7.65	0.75	0.99	1.87
X-1 CARLITE DR	M085-27P5	0.27		0.85	1.13	1.87

$W_{17/50}$ and $W_{17/60}$ refer to core loss tests at 1.7T & 50 Hz and 1.7T & 60 Hz.
**B_8 refers to the magnetic flux density achieved at an applied field of 800 A/m.*

TABLE 2 – TYPICAL ELECTRICAL AND MAGNETIC PROPERTIES

Grade	Thickness, mm	Assumed Density, gm/cm³	Resistivity, Ω m, x10⁻⁸	Core Loss W/kg				Flux Density	Lamination Factor, %
								B_8	
				$W_{15/50}$	$W_{17/50}$	$W_{15/60}$	$W_{17/60}$	T	
X-0 CARLITE DR	0.23	7.65	52	0.54	0.73	0.71	0.96	1.91	96.9
X-1 CARLITE DR	0.27			0.62	0.83	0.83	1.10	1.91	97.5

Typical single sheet core loss values versus test induction for TRAN-COR X CARLITE DR are provided upon request. Typical SRA Epstein core loss values versus test induction for TRAN-COR X CARLITE are provided upon request. SRA Epstein testing is not applicable to TRAN-COR X CARLITE DR products since the domain refinement treatment is eradicated upon annealing at temperatures greater than 600 °C. The core loss and exciting power of Cleveland-Cliffs' TRAN-COR X grades are determined by magnetic tests performed in accordance with generally approved ASTM procedures. The following conditions apply:

1. Results for as-sheared single sheet specimens from fully processed material cut parallel to the rolling direction of the coil and tested per ASTM A804.

2. Density of all grades (7.65 gm/cm3) per ASTM A34.

ASTM A664 is a grade identification system for electrical steels. While this system has not been widely adopted by manufacturers and consumers of electrical steels, it is used in ASTM A876 to designate various grades of grain oriented electrical steel. The following is a listing of Cleveland-Cliffs and equivalent ASTM grades:

Cleveland-Cliffs grades TRAN-COR X-0 CARLITE DR and TRAN-COR X-1 CARLITE DR are approximately equivalent to ASTM Core Loss Types 23Q054 and 27Q057, respectively.

TABLE 3 – MANUFACTURING LIMITS AND TOLERANCES

Coils can be supplied with width tolerances in accordance with either ASTM A876 or IEC 60404

Product	Thickness[1], mm	Tolerance		Master Coil Width Max.[2], mm	Slit Width Range, mm	Inside Coil Diameter, mm
		Thickness, mm	Chamber Over a Length of 2 m, mm			
X-0 CARLITE DR	0.23	± 0.02	2.54	927.1	19 to 920	Slit - 406 or 508 Master - 508
X-1 CARLITE DR	0.27	± 0.02	2.54	932.2		

*$W_{17/50}$ and $W_{17/60}$ refer to core loss tests at 1.7T & 50 Hz and 1.7T & 60 Hz.
**B_8 refers to the magnetic flux density achieved at an applied field of 800 A/m.

Design Tables

TABLE 4 – TYPICAL VALUES OF CORE LOSS

At 50 Hz And 60 Hz For Typical Sheet Specimens

Flux Density T	Core Loss, (W/kg) – ASTM A804			
	0.23 mm X 0 CARLITE DR		0.27 mm X 1 CARLITE DR	
	50 Hz	60 Hz	50 Hz	60 Hz
0.1	0.00269	0.00358	0.00314	0.00423
0.2	0.01022	0.01359	0.01202	0.01620
0.3	0.0223	0.0300	0.0264	0.0356
0.4	0.0394	0.0527	0.0462	0.0624
0.5	0.0609	0.0813	0.0712	0.0958
0.6	0.0864	0.1152	0.1010	0.1358
0.7	0.1160	0.1546	0.1359	0.1825
0.8	0.1500	0.1997	0.1761	0.236
0.9	0.1883	0.251	0.222	0.297
1.0	0.232	0.309	0.273	0.365
1.1	0.280	0.373	0.330	0.441
1.2	0.334	0.445	0.393	0.525
1.3	0.394	0.525	0.462	0.616
1.4	0.460	0.613	0.537	0.715
1.5	0.536	0.711	0.619	0.825
1.6	0.619	0.819	0.711	0.945
1.7	0.730	0.961	0.830	1.099
1.8	0.893	1.165	1.007	1.323
1.9	1.242	1.594	1.362	1.773

TABLE 5 – TYPICAL VALUES OF RMS EXCITING POWER

At 50 Hz And 60 Hz For Typical Sheet Specimens

Flux Density T	Exciting Power, (rms VA/kg) – ASTM A804			
	0.23 mm X 0 CARLITE DR		0.27 mm X 1 CARLITE DR	
	50 Hz	60 Hz	50 Hz	60 Hz
0.1	0.00543	0.00658	0.00486	0.00592
0.2	0.01801	0.0220	0.01576	0.01929
0.3	0.0362	0.0440	0.0311	0.0381
0.4	0.0580	0.0707	0.0494	0.0607
0.5	0.0824	0.1005	0.0699	0.0859
0.6	0.1089	0.1330	0.0922	0.1131
0.7	0.1378	0.1680	0.1159	0.1421
0.8	0.1694	0.206	0.1418	0.1738
0.9	0.205	0.250	0.1711	0.210
1.0	0.248	0.302	.0.207	0.255
1.1	0.300	0.365	0.253	0.311
1.2	0.365	0.444	0.315	0.385
1.3	0.450	0.546	0.398	0.487
1.4	0.553	0.670	0.504	0.614
1.5	0.698	0.846	0.656	0.799
1.6	0.882	1.067	0.852	1.030
1.7	1.294	1.568	1.280	1.548
1.8	2.37	2.889	2.42	2.93
1.9	9.65	12.050	11.01	13.54

Surface Insulation Curves

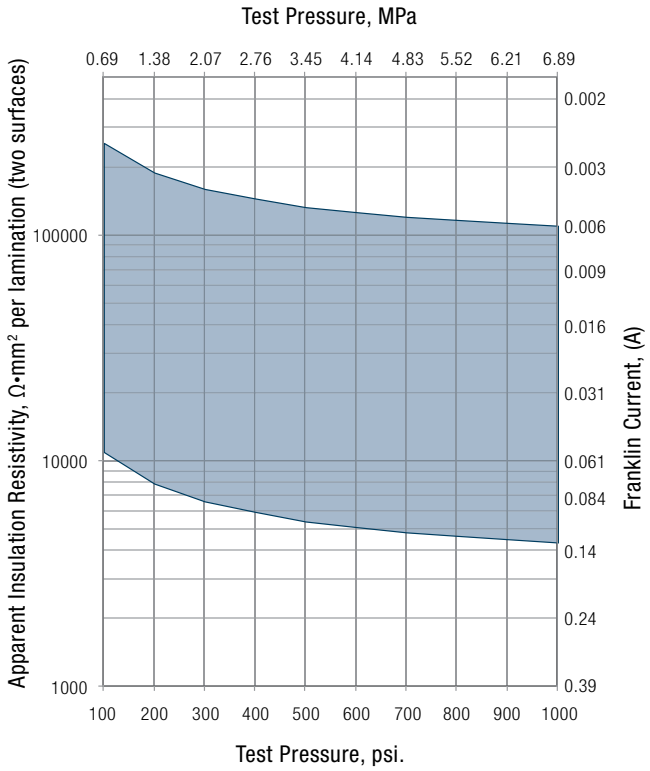
CARLITE 3 SURFACE INSULATION

Cleveland-Cliffs' TRAN-COR X products are supplied with CARLITE® 3 insulative coating, an inorganic coating equivalent to ASTM A976 C-5. CARLITE 3 insulation is ideal for materials that will be used in the form of sheared laminations for power transformers and other apparatus with high volts per turn. In addition to supplying all the benefits of C-5 insulation, CARLITE 3 provides other important advantages which include:

- Potential for reduced transformer building factor from added resistance to elastic strain damage.
- Potential for reduction of magnetostriction related transformer noise.
- High stacking factor.
- Easy assembly due to smoothness of coating (low coefficient of friction).

Figure 1 shows the variation of surface insulation resistivity versus pressure. The range of surface insulation resistivity values between the upper and lower lines are typical of those for CARLITE 3 insulated surfaces as determined by the Franklin Test method (ASTM A717). However, the user should recognize that the normally small variations in mill oxide and coating thickness within a lot necessitate allowing for test values lower as well as higher than those shown in the curves.

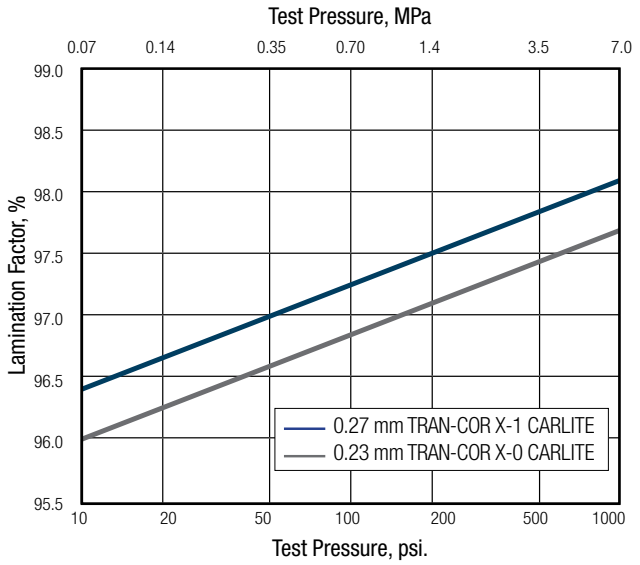
FIGURE 1 – TYPICAL SURFACE INSULATION



Typical surface insulation characteristics of Cleveland-Cliffs oriented electrical steels at various pressures as determined by the Franklin Test.

Lamination Factors

FIGURE 2 – REPRESENTATIVE LAMINATION FACTORS



Representative lamination factors for Cleveland-Cliffs Oriented Electrical Steels at various pressures.

TEST METHOD

The lamination factor of electrical steels is determined from measurements of a stack of Epstein strips under known pressure, 345 kPa (50 psi.), in accordance with ASTM A719. Figure 2 illustrates how the lamination factor varies as a function of pressure for TRAN-COR X electrical steels. The values shown are representative of the lamination factor determined by this test. Lamination factors determined in accordance with IEC 60404-13 will be approximately 0.5% higher than these values due to the higher pressure specified in that test method 1 MPa (145 psi.).

About Cleveland-Cliffs Inc.

Cleveland-Cliffs is the largest flat-rolled steel producer in North America. Founded in 1847 as a mine operator, Cliffs also is the largest manufacturer of iron ore pellets in North America. The Company is vertically integrated from mined raw materials and direct reduced iron to primary steelmaking and downstream finishing, stamping, tooling, and tubing. The Company serves a diverse range of markets due to its comprehensive offering of flat-rolled steel products and is the largest steel supplier to the automotive industry in North America. Headquartered in Cleveland, Ohio, Cleveland-Cliffs employs approximately 25,000 people across its mining, steel and downstream manufacturing operations in the United States and Canada.

CLIFFS

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