December 2013

Electric Arc Furnaces

EAF Pour

An Electric Arc Furnace (EAF) is a furnace that heats a mass of metal (referred to as a "charge") to its' melting point by means of an electric arc.

Arc furnaces are very popular for the melting of alloy steels and range in size from a few pounds, for laboratory units, to in excess of 100 tons per batch. Typical foundry factory furnace capacities range from 1 to 20 tons. The most common furnace construction consists of a steel refractory lined shell. The cover which raises and swings away to allow charging, includes three graphite electrodes powered via a three-phase power supply.

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The electrodes protrude vertically through the cover and an electric current passes directly through them and into the metal charge. The distance between the electrodes and the charge is automatically controlled and determines the furnace power level.

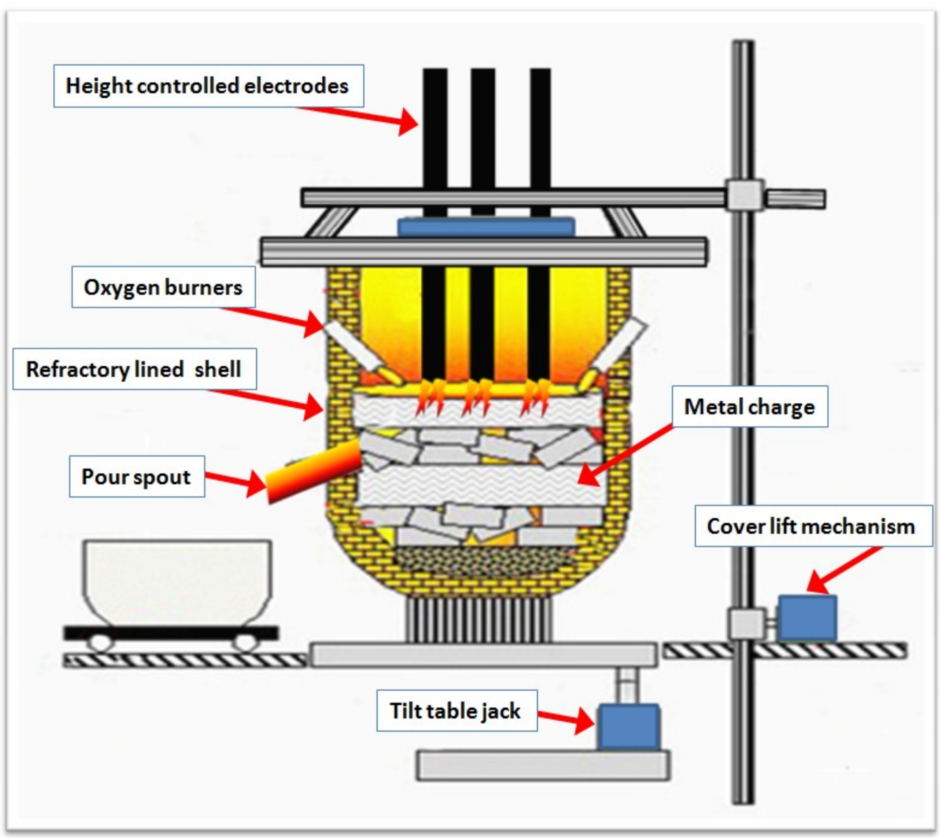
The electrodes are initially lowered to a point above the metal charge, the current is initiated, and the electrodes bore through the charge to form a pool of liquid metal. The charge protects the furnace lining from the high intensity arc.

Cover mounted graphite electrodes

The arc is gradually lengthened by increasing the voltage to maximum power. In the final stage, when there is a nearly complete metal pool, the arc is shortened to reduce radiation heat losses and to avoid hot spots and refractory damage.

After the charge melt, oxygen is injected to oxidize any resultant carbon. The carbon monoxide that evolves helps minimize the absorption of nitrogen and flushes hydrogen out of the metal thereby purifying the melt.

The entire unit is capable of being tilted for discharge of the melt through the pour spout.

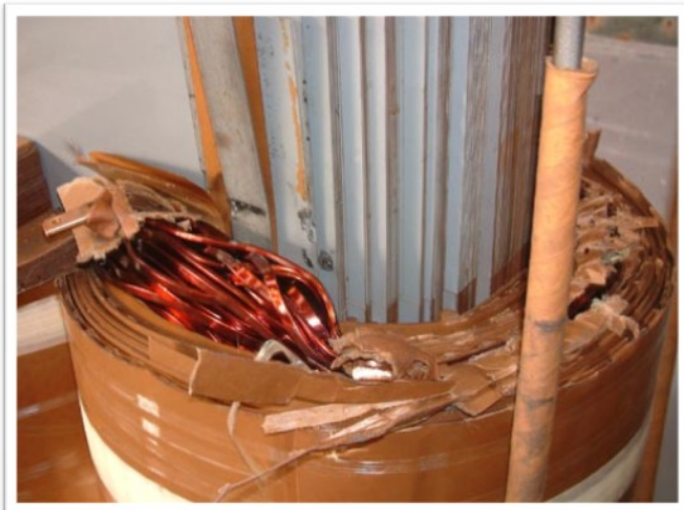


Due to the random movement of the melting material, no two cycles of the arc voltage and current waveforms are identical. When the electrodes are in direct contact with the charge they are effectively short-circuited thereby short circuiting the secondary of the power supply transformer. When the electrodes are not in contact with the charge the load varies wildly and the arc may extinguish. These large, varying loads have a direct impact on the power quality of the interconnected power supply. The abrupt initiation and interruption of current flow provides a source of harmonic currents and causes considerable disturbance in high-impedance circuits. Voltage and current waves fluctuate considerably from symmetrical sinusoidal patterns. These disturbances are worst during the initial meltdown period, occurring at varying frequencies. Harmonics generation results in further flicker problems which can result in damage to connected power system equipment. Although static capacitors may be used to improve the power factor, an analysis must then be used to ensure that resonance does not exist at any of the harmonic frequencies. Harmonics contribute to wave distortion and to the increase in effective inductive reactance. Furnace input current may therefore be quite different than what would be expected from calculations based on sinusoidal wave shapes, resulting in increased losses in the power supply transformer.

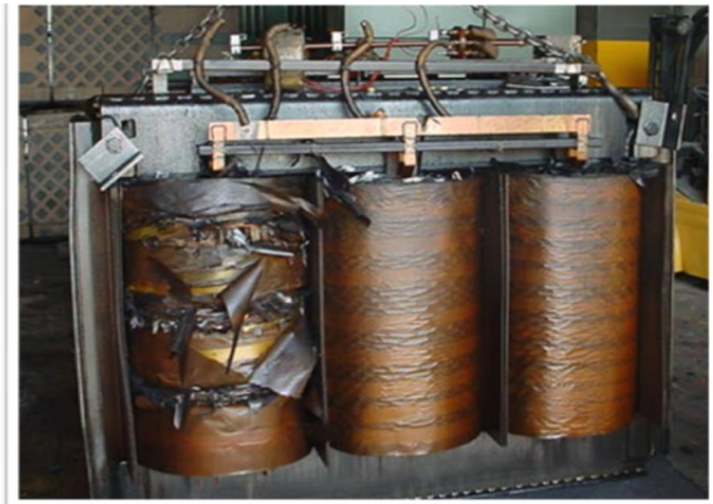
This extreme load profile MUST be taken into consideration in the design of the electric arc furnace transformer. The coils need to be designed to withstand repeated short-circuiting and the cores need to be designed and constructed to manage the anticipated increase in losses attributed to waveform distortion and generated harmonic currents.

The high frequency nature of the short circuits attributed to the furnace electrodes results in high magnitude transformer inrush currents which translate to high magnitude winding forces. These forces are axial and radial in nature.

Axial forces are those exerted on the ends of the transformer windings (top and bottom). These forces can lead to movement in the winding turns which can result in telescoping and turn to turn shorts.



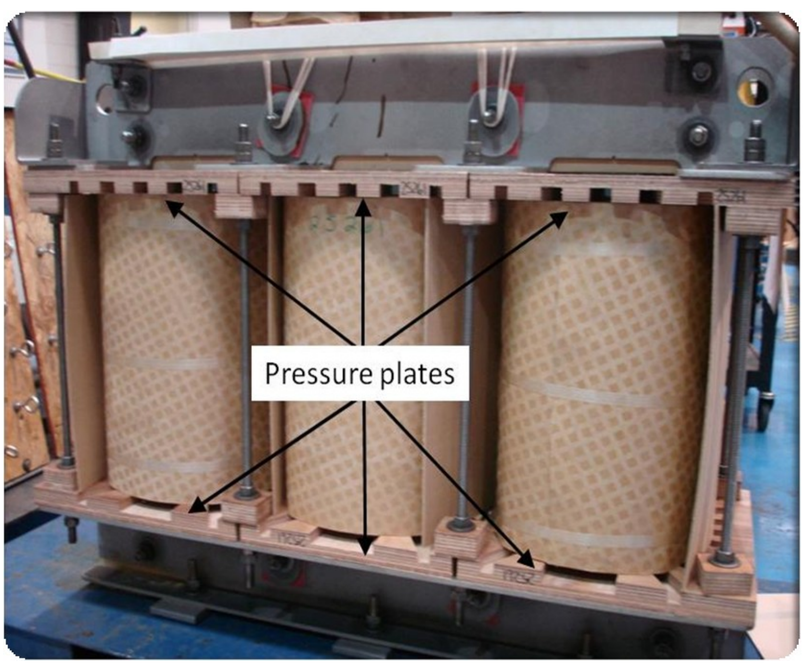
Axial force winding failure



Radial force winding failure

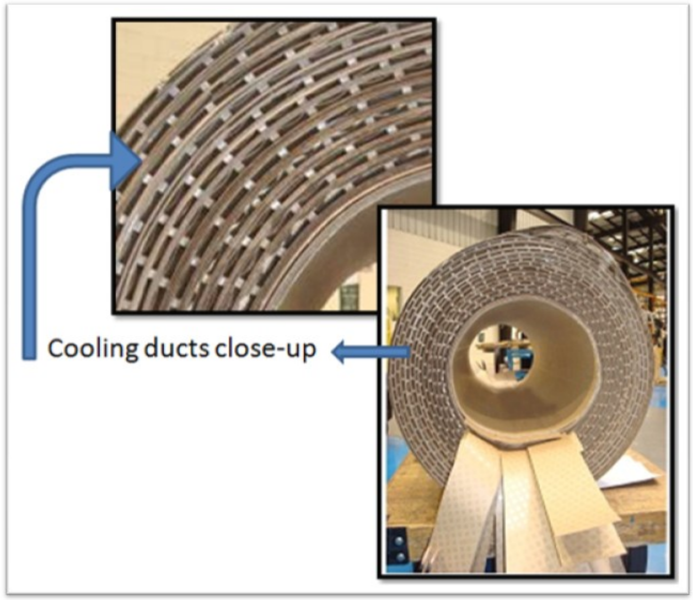
Radial forces are exerted on the circumference of the windings. These forces cause the windings to expand or contract which stresses the conductor insulation. If movement due to these forces is not constrained, the turn to turn or layer insulation may fail resulting in short circuit failure.

Pacific Crest Transformers manages axial forces exerted as a result of arc furnace operations by utilizing round coils with upper and lower pressure plates.



The plates are secured via steel all-thread rods at 4 points around each coil. Sufficient pressure is applied to contain the calculated axial forces. Routered paths around each plate allows for the free flow of the insulating and cooling fluid.

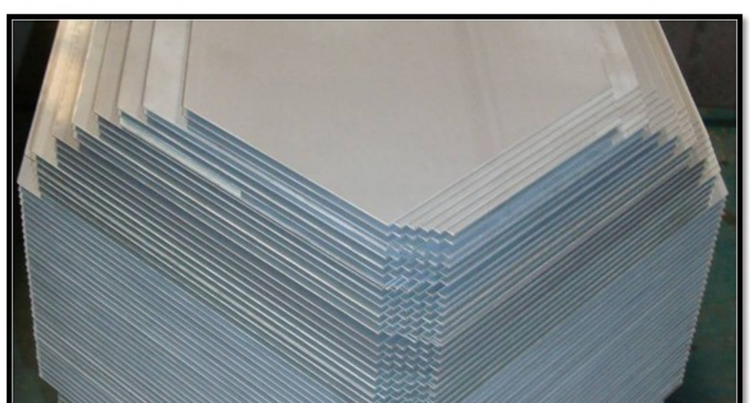
Management of radial forces is best obtained by the utilization of round coils in lieu of rectangular. PCT's round coil design equalizes radial forces in all directions. Equalizing forces has the effect of cancelling same.



PCT's round coil construction also provides the capability to incorporate 360 degree cooling ducts. This is of particular importance with arc furnace loads since the high frequency short circuiting and overloading of the windings can cause rapid development of elevated conductor temperatures in areas not provided with direct interfaces to free flowing cooling fluid. Failure to adequately restrain conductor heating leads to rapid deterioration of the insulation system and subsequent winding failure.

Although management of axial and radial forces is critical, the electric arc furnace transformer must also be designed to accommodate the electrical losses generated by the furnace, including harmonic content. Total winding losses are largely determined by the cross sectional area of the high and low voltage conductors.

The transformer core provides the path for magnetic flux. The core used with PCT round coils is made up of step lap sheets of carlite insulated grain oriented electrical steel. The progres-sive increase in lamination width results in the creation of

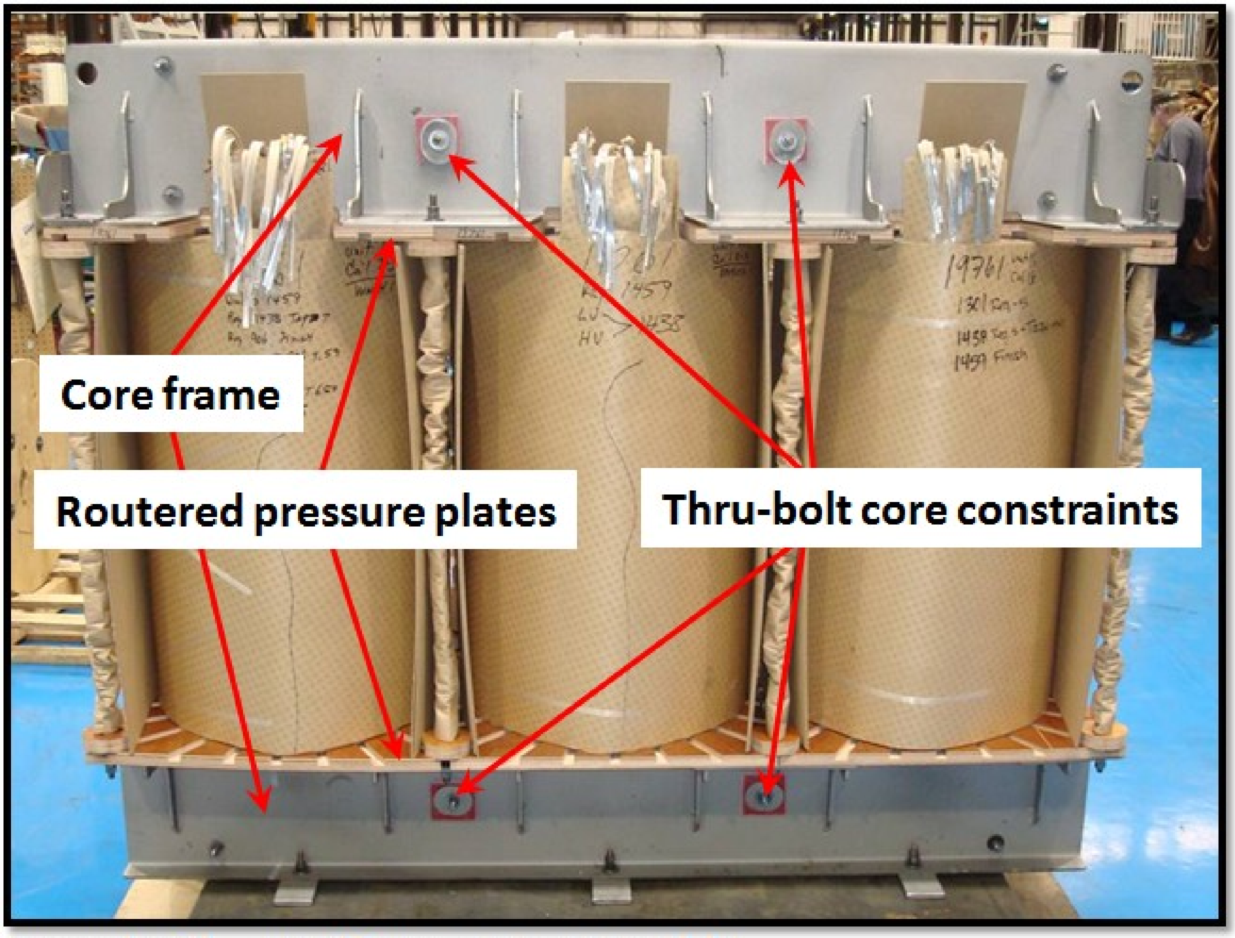


Close-up of step lap core leg

round core legs on which the coils are designed to fit snugly.

The core's flux density is designed to accommodate the harmonics produced by the furnace. The core laminations are secured by insulated bolts inserted through the core frame and laminations, to minimize vibrations due to the currents and forces produced by the windings.

Assembled cruciform core legs



Round coil – cruciform core assembly

Electric arc furnace power requirements place extreme demands on the power supply transformer. In order to provide reliable power, these demands dictate that the transformer be specifically designed to accommodate the furnace load. A "standard" distribution or power transformer simply is not adequate for such an application. PCT's experience and expertise in the market provides the confidence that the transformer is properly matched to the load, thereby insuring long term, reliable performance.

Pacific Crest Transformers: Providing innovative solutions for today's complex challenges