C/G Electrodes LLC

partners...with pride

Proud... of our story

"You had a story I just couldn't refuse."

That's one of the first things we heard as we began introducing people to C/G Electrodes. And we understand why people feel that way. Our story is compelling, even if we do say so ourselves.

The name C/G Electrodes is new to some but we and our predecessor companies have a rich history and tradition – more than 100 years of operation on our site in St. Mary's, Pennsylvania. But what makes our story truly unique only begins with that century of tradition and pride. It's the C/G Electrodes of today that provides such a difference for our customers.

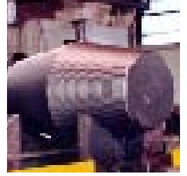
Today, C/G Electrodes is being guided by the visionary team that saw potential here and resolved to give the facility, our dedicated team and our customers new life. One way we've done that is by ensuring that all of the management team – and many of the employees – are C/G owners.

Working together after the commitment had been made, the new leaders and the long-time employees were able to bring C/G back to full capacity much more quickly than many thought possible. And we reached that capacity while also developing and maintaining a strong financial position as well as investing significant capital in modernization.

And what has been the result of our commitment, team, investment and expertise? Just months after beginning operation as C/G Electrodes, we were named Manufacturer of the Year by our area's regional planning commission.

We're naturally pleased by the honor. But more than that, it's satisfying to be recognized for proving this facility and our people were too valuable a resource to the steel industry – our customers -- to allow them to sit idle.

So, yes, we're proud of our story. And we're pleased to have the opportunity to tell you more of it.

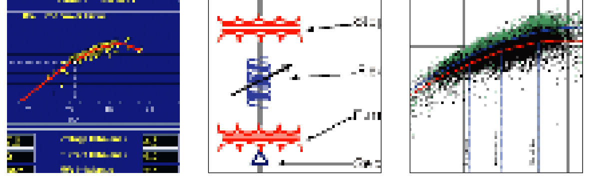


Proud... of our Quality

A lot of companies talk about quality. At C/G Electrodes, we began by assembling all of the elements it takes to make that quality commitment a reality.

- Our expert C/G workforce – We combine years of production expertise with fresh thinking to improve our processes and products.
- State-of-the-art facilities – We respect our tradition while incorporating the modernization needed to meet increasingly sophisticated and precise customer needs.
- Continuous quality monitoring – We assess quality in all areas on a regular basis so customers can have confidence in our products.
- Product formulation enhancements – We consider every aspect of the raw materials and formulas so that we are able to increase the performance and life of our electrodes.
- Process cycle modifications – We never stop looking for ways to do things better, smarter, and more efficiently.
- Process and production documentation – We do what we say and say what we do. At any point we can see how and why we're achieving the desired results.
- Machining tolerance and geometry – We understand that our customers need to know that they can rely on receiving what they expect from us – every time. And we have the equipment and qualified personnel to make that happen.
- Specialization in 18- through 28-inch diameter electrodes – We know that being jack of all trades really means being master of none. We're committed to being masters of the most demanding, ultra-high powered electrode applications.

Photograph provided by Core Furnace Systems



Proud... of our Service

The CG commitment to quality does not end when our products leave the plant. The fact is, our technical service specialists are continually working with customers to monitor electrode performance on the furnace, and to integrate their findings back into our production system for even better quality, consistency, performance and cost-effectiveness. We also provide a full range of technical support services that are designed to improve furnace performance and reduce conversion costs. Among these is our furnace optimization tool we call ArchiTech™. This one-of-a-kind software package accurately monitors all electrical parameters of electric arc furnaces and captures all necessary data for complete performance analysis, evaluation and – when necessary – remedial action. ArchiTech™ means furnace operations can be quickly adjusted for maximum electrical efficiency and production rates, and that means measurable savings in energy, graphite, and refractory consumption.

With the ArchiTech™ system, EAF operators can:

- Maximize energy input by determining effectiveness of power profile
- Maximize productivity by recharging at the optimal time
- Identify and solve regulation problems
- Determine electrical balance and solve arc flare problems
- Determine arc stability and effectiveness of foamy slag practice
- Trend more than 75 furnace parameters – including those affecting electrode consumption.

Our commitment to quality and service are unmatched in this industry. The ArchiTech™ System is another key differentiator for C/G Electrodes.

Proud... of our Team

Having a great organization begins with finding, training and retaining great people. But it takes more than that to generate the kind of commitment C/G Electrodes enjoys from our remarkable team. It takes exactly what we have: a culture of open and honest communication with all.

That culture has also put in place other strategic advantages where our team is concerned.

Our flat organization fosters unparalleled responsiveness and creativity. And making that team a self-directed workforce has the added benefit of allowing C/G Electrodes to operate more nimbly than other companies.

All managers and many of our shop personnel are investors, giving them a personal stake in meeting and exceeding the needs of our customers. That may help to explain why our productivity is three times that of our competitors. And it also helps to explain why everyone is involved in keeping our corporate overhead so low.

Our expertise extends from the production team to our technical service staff. In fact, the ArchiTech™ System was developed and is maintained by C/G Electrodes personnel. That means if customers have questions we don't give them the phone number of some software company. We resolve the issue right here.

Finally, our Steering Committee is empowered to make key decisions. And they do it based on the right mix of information because it includes representatives from production, maintenance, administrative and professional staff.

That's why – no matter which member of the C/G team you talk to – you're talking to someone committed to exceeding your expectations for quality and service.

Proud... of our Partnerships

C/G Electrodes took the time to assemble all of the assets we needed to make us truly proud of who we are and what we do. But there was one element we couldn't automatically put in place – our customer/partners. Their willingness to join with us is simply the result of all of our other commitments.

It's our customers who trusted us to do what we said we would – and could – do. Their willingness to join with us is the foundation of our commitment to go beyond the call of duty to serve their needs. After all, although our customers may think they're buying electrodes, we're confident that we're selling relationships and expertise.

For us, there's no such thing as a routine request. Every call, question or comment from a customer generates a unique response. If a customer has a technical question, we'll often send a member of our technical staff right to the customer site so they can generate the solution together.

That's our commitment to our customers because we believe it's what they deserve – and because it's what we believe is right.

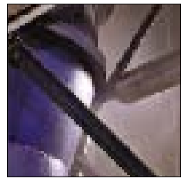
So while it may be true that we have "a story customers just can't refuse," we never forget that our customers are the real heroes of the story. And that's why we'll always do what it takes to help them succeed. Because at the end of the day, we know that we succeed together. That's our ongoing commitment to our customers, our partners.

Our Process

01

MIXING



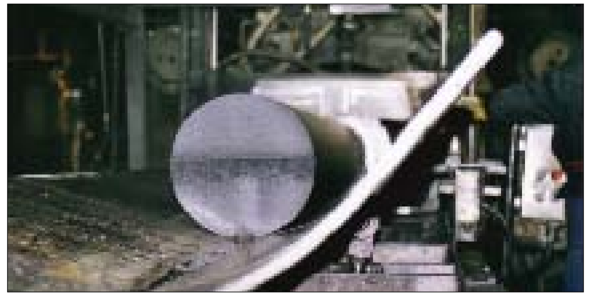
The process begins with the receipt of raw materials, the largest being needle coke.

The needle coke is then crushed, screened and milled to achieve proper sizing for the desired formulation.

The various needle coke sizes, stored in several holding bins, are then loaded into a mixer where coal tar binder pitch and other ingredients are introduced and thoroughly homogenized with the needle coke.

02

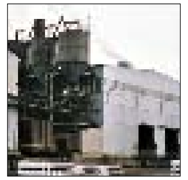
EXTRUSION




The mixed material is conveyed to an extrusion press where a green electrode is extruded, cut and cooled in a water bath.

03

BAKING

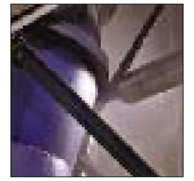



Green electrodes are
"sagger" cans, loade
furnaces where the e
excess of 1,500 deg
transforms the green

Our Process

01 MIXING



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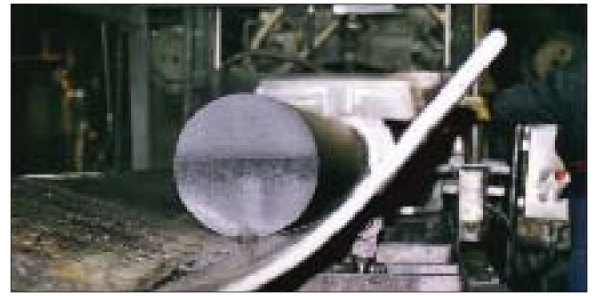


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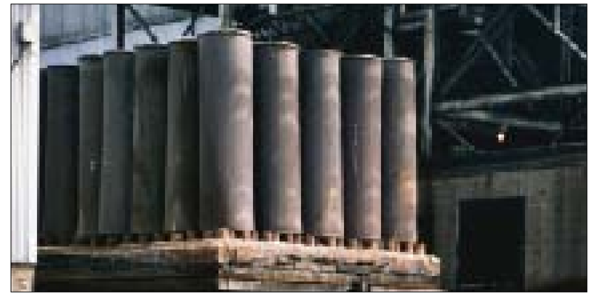
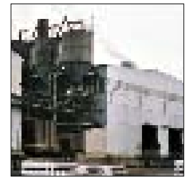
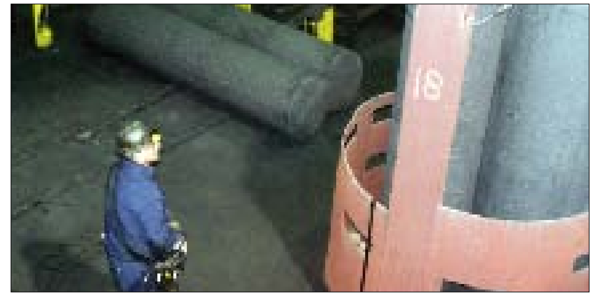
03 BAKING

Green electrodes are loaded individually into stainless steel "sagger" cans, loaded onto railcars, and are loaded into baking furnaces where the electrodes are raised to a temperature in excess of 1,500 degrees Fahrenheit, a process which transforms the green electrode into hard carbon.

04 PITCH IMPREGNATION




The baked rods are then removed from their cans, cleaned, and impregnated with in petroleum pitch to enhance the properties of the electrode

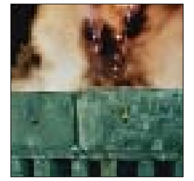
05 REBAKING




The electrodes are then re-baked, which converts the pitch impregnated into the electrode into carbon.

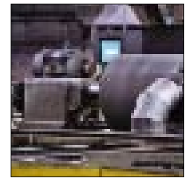
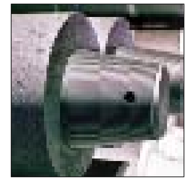
06 GRAPHITIZING



After re-baking, the electrodes are composed mainly of solid carbon, which must be converted to graphite so that they can perform their duties at the steel mills. C/G Electrodes uses longitudinal graphitizing furnaces for this process. In these furnaces, the electrodes are heated to over 5000 degrees Fahrenheit for several days, and their molecular structure is converted to graphite.

07 FINISHING


The graphitized electrodes are finished by turning down the outside diameter and machining connecting sockets on the ends utilizing large, multi-stage lathes.

Connecting pins, which join the electrodes together on the electric arc furnace, are also machined and finished.

The finished electrodes and pins are assembled, packaged and shipped from the St. Marys plant to customers throughout the world.

Specifications & Dimensions

Length of Graphite Electrodes

Nominal Length		Standard Length		Short Length	
Inches	*(mm)*	*Inches*	*(mm)*	*Inches**	*(mm)**
110	(2700)	114.0 to 100.4	(2895 to 2550)	100.4 to 94.5	(2550 to 2400)
96	(2400)	99.0 to 89.6	(2515 to 2275)	89.6 to 83.7	(2275 to 2125)
84	(2100)	87.0 to 77.8	(2210 to 1975)	77.8 to 71.9	(1975 to 1825)
72	(1800)	75.0 to 66.9	(1905 to 1700)	66.9 to 60.0	(1700 to 1525)
60	(1500)	63.0 to 55.1	(1600 to 1400)	55.1 to 48.2	(1400 to1225)

* Due to manufacturing variables, a small percentage of electrodes may have the minimum lengths given in this column.

Diameter of Graphite Electrodes

Nominal		Maximum		Minimum		Low Spot	
Inches	*(mm)*	*Inches*	*(mm)*	*Inches*	*(mm)*	*Inches*	*(mm)*
28	(700)	28.12	(714.3)	27.88	(708.2)	27.76	(705)
26	(650)	26.12	(663.6)	25.88	(657.2)	25.75	(654)
24	(600)	24.12	(612.7)	23.88	(606.6)	23.78	(604)
22	(550)	22.12	(561.9)	21.88	(555.8)	21.77	(553)
20	(500)	20.12	(511.1)	19.88	(505.0)	19.76	(502)
18	(450)	18.12	(460.3)	17.88	(454.2)	17.76	(451)

Remarks: The outside surface shall be machined finished. On the outside surface finishing, the part on which the tool edge does not touch is called a low spot. For a turned electrode having a low spot the minimum diameter shall be per above table

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Specifications & Dimensions

Electrode Joining System

Nom. Electrode Diameter		IEC	Nom. Connecting Pin *Major Dia x Length*		Threads	Electrode Socket *Minor Dia x Min. Depth*	
Inches	*(mm)*	*Designation*	*Inch*	*(mm)*	*# per Inch*	*Inch*	*(mm)*
28	(700)	374T4L	14.75 x 22.00	(374.65 x 558.8)	4	14.5010 x 11.1875	(368.33 x 284.16)
28	(700)	374T4N	14.75 x 18.00	(374.65 x 457.2)	4	14.5010 x 9.1875	(368.33 x 233.36)
26	(650)	374T4L	14.75 x 22.00	(374.65 x 558.6)	4	14.5010 x 11.1875	(368.33 x 284.16)
26	(650)	374T4N	14.75 x 18.0	(374.65 x 457.2)	4	14.5010 x 9.1875	(368.33 x 233.36)
24	(600)	317T4L	12.5 x 18.0	(317.5 x 457.2)	4	12.2510 x 9.1875	(311.18 x 233.36)
24	(600)	317T4N	12.5 x 14.0	(317.5 x 355.6)	4	12.2510 x 7.1875	(311.18 x 182.56)
22	(550)	298T4L	11.75 x 18.0	(298.45 x 457.2)	4	11.5010 x 9.1875	(292.13 x 233.36)
22	(550)	298T4N	11.75 x 14.0	(298.45 x 355.6)	4	11.5010 x 7.1875	(292.13 x 182.56)
20	(500)	298T4L	11.75 x 18.0	(298.45 x 457.2)	4	11.5010 x 9.1875	(292.13 x 233.36)
20	(500)	269T4L	10.625 x 18.0	(269.88 x 457.2)	4	10.3760 x 9.1875	(263.55 x 233.36)
20	(500)	269T4N	10.625 x 14.0	(269.88 x 355.6)	4	10.3760 x 7.1875	(263.55 x 182.56)
20	(500)	273T3L	10.75 x 18.0	(273.05 x 457.2)	3	10.4180 x 9.1875	(264.62 x 233.36)
20	(500)	273T3N	10.75 x 14.0	(273.05 x 355.6)	3	10.4180 x 7.1875	(264.62 x 182.56)
18	(450)	273T3L	10.75 x 18.0	(273.05 x 457.2)	3	10.4180 x 9.1875	(264.62 x 233.36)
18	(450)	269T4L	10.625 x 18.0	(269.88 x 457.2)	4	10.3760 x 9.1875	(263.55 x 233.36)
18	(450)	269T4N	10.625 x 14.0	(269.88 x 355.6)	4	10.3760 x 7.1875	(263.55 x 182.56)
18	(450)	241T4L	9.5 x 14.0	(241.30 x 355.6)	4	9.1680 x 7.1875	(232.87 x 182.56)
18	(450)	241T3L	9.5 x 14.0	(241.30 x 355.6)	3	9.1680 x 7.1875	(232.87 x 182.56)

Typical Properties

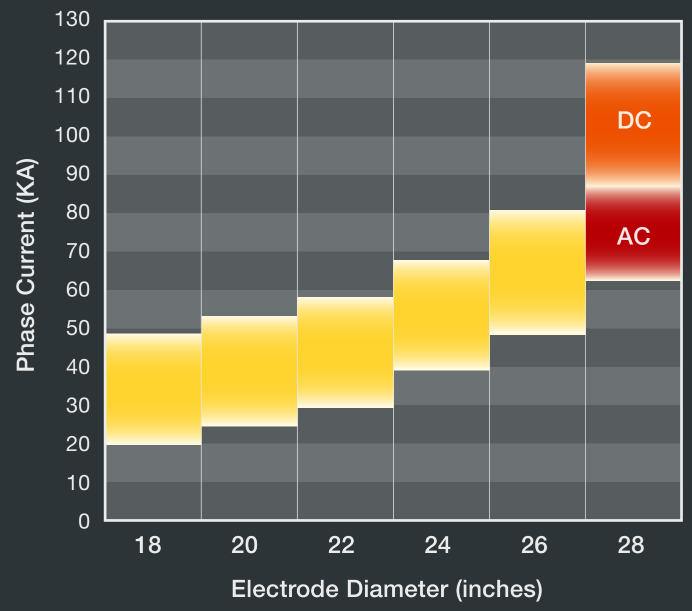
UHP Grade Electrodes

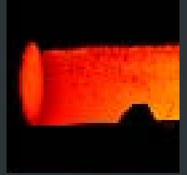
Diameter	Apparent Density	Specific Resistance		Flexural Strength Longitudinal	
(inches)	*(g/cm^3)*	*($10^{-5}\Omega$-in)*	*(μ-Ω-m)*	*(psi)*	*(MPa)*
18-28	1.68 – 1.74	17 - 21	4.3 – 5.3	1150 - 1750	8.0 – 12.0

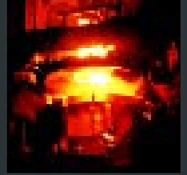
Connecting Pins

Diameter	Apparent Density	Specific Resistance		Flexural Strength Longitudinal	
(inches)	*(g/cm^3)*	*($10^{-5}\Omega$-in)*	*(μ-Ω-m)*	*(psi)*	*(MPa)*
9.5 – 14.75	1.78 – 1.82	13.3 - 16.8	3.4 - 4.3	3000 - 3800	20.0 – 26.0

Current Capacity Range







Managing Electrodes

Recommended Electrode Clamping Pressure

Electrode Diameter		Clamping Pressure	
inches	*(mm)*	*Psi*	*MPa*
28	700	109,760	757
26	650	94,640	653
24	600	80,640	556
22	550	67,760	467
20	500	56,000	386
18	450	45,360	313

Remarks: The recommended clamping pressures are provided to prevent an electrode column from slipping through the holder.

Electrode Tightening Specifications

Electrode Diameter		Torque	
inches	*(mm)*	*ft•lbs*	*N•m*
28	700	3580 - 3840	4854 – 5206
26	650	2650 - 3350	3593 – 4541
24	600	2140 - 2390	2901 – 3240
22	550	1560 - 1810	2115 – 2454
20	500	1230 - 1480	1667 – 2006
18	450	870 - 1120	1179 – 1518

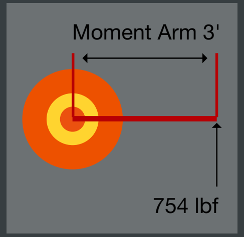
Remarks: The higher torque values are recommended for applications that use water spray rings, since the cooling effect of the water limits thermal expansion, which normally contributes to greater joint tightness.

To calculate Torque:
Force (lbf) = (Radius of Cylinder)^2 x π x cos (angle-90) x Pressure (psi)
Torque = moment arm (ft) x Force (lbf)

Example: A 24 inch electrode is tightened by applying 60 psi of pressure with a 4" diameter hydraulic cylinder at an angle of 90° with a 2 foot bar. What is the applied tightening torque?

Force = (2 in)^2 x 3.1416 x cos (90-90) x 60 psi = 754 lbf

Torque = moment arm x force
Torque = (2 +1) x 754 = 2262 ft-lbs



Improving Electrode Performance

1) **Inspect Lifting Plugs.** Remove metal burrs that could gouge or weaken threads in the electrode socket. When adding an electrode, check for excessive oxidation in the electrode socket and remove any foreign material that could prevent a perfectly tight joint.

2) **Maintain Clean, Tight Joint.** Poor addition practices can lead to a loose electrode joint. Loose electrode joints are typically the result of improper addition (i.e. cross-threading or poor thread engagement due to foreign material in the socket and end-face area), improper torque during the add, or the use of a damaged lift plug which will cause thread damage to the non-preset socket.

3) **Ensure Bore-in Amperage is not excessive.** As the electrodes seek a higher current level, the electrode tip is in constant contact with the scrap, causing frequent current surges and extended periods where the weight of the arm and mast rests on the electrodes (i.e. excessive mechanical stress on the top electrode joint).

4) **Minimize Electromagnetic Forces.** The forces acting on the electrodes are proportional to the square of the short circuit current. When scrap caves occur they create a short circuit which in turn subjects the electrode column to an electromagnetic force as well as a force caused by the weight of the fallen scrap. The higher the current spike and the longer it lasts, the greater the chance the electrode will break. Increasing the reactance in the circuit will reduce the short circuit current and thus reduce the force acting upon the electrodes.

5) **Ensure electrodes are not drifting downward.** Electrode drift is a result of an improper bias setting or zero offset compensation on the electrode drives. Generally, electrode control systems have a bias setting that controls the amount of hydraulic pressure required to support the weight of the arms without an error signal from the regulator. Too high of a bias setting causes the electrodes to drift up and too low of a bias setting causes the electrodes to drift down.

6) **Ensure scrap cave limits are set properly.** Determine at what amperage level the regulator will respond to a scrap cave and initiate a fast raise response. Once the short circuit is sensed, the up speed should be in the range of 50 ft/min.

7) **Verify Pre-arc Down Speed.** Pre-arc down speed should be set lower than the automatic up/down speeds to prevent electrode tip fracture and breakage during initial contact with the scrap. Auto up and down speeds vary from furnace to furnace but generally perform optimally when matched at 25 ft/min or less. Pre-arc down speed should be adjusted to approximately 10 ft/min.

8) **Non-Conductors.** Ensure the regulator will sense low hydraulic pressures to avoid electrode breakage due to non-conductors. Electrode stopping distance is proportional to the square of the speed. The slower the pre-arc down speed the lower the chance for electrode breaks due to non-conductors.

9) **Charging Methods.** Electrode breakage can be reduced by using clean, light scrap on top of the charge. This makes a good electrical contact and eliminates the possibility of breakage by thrust against large pieces of scrap that might be at an angle to the electrode.

10) **Roof Alignment.** Electrode roof ports and cooling rings should be centered so that the electrodes will have equal clearance on all sides. Electrode holders should be centered over the roof ports or binding will take place on either the cooling rings or the refractories and electrode breakage will result.

Electrode Consumption

Electrode Consumption Calculation

There are many different ways of making a seemingly simple electrode consumption calculation. The most accurate method is to weigh the columns at the start and end of some time period and then divide the weight of the graphite consumed by the tons of steel produced. The least accurate, but most commonly used method is to count electrode additions and heats produced over some time period and perform the same calculation. Daily and weekly numbers calculated using this method are almost never accurate and fluctuate wildly. The most practical yet very accurate method of calculating electrode consumption is by using the heats per add method.

Heats per add method of Calculating Electrode Consumption

Example: Calculate electrode consumption knowing the following information:

Average Electrode weight is 3040 lbs
Average heat size is 190 tons

Phase #1: 4 electrodes consumed over 45 heats
Phase #2: 4 electrodes consumed over 46 heats
Phase #3: 3 electrodes consumed over 39 heats

Total: 11 electrodes consumed over 130 heats

$$\text{Electrode Consumption (Lbs/Ton)} = \frac{\text{Average Electrode weight} \times 3}{\text{Avg heats per add} \times \text{Avg Heat Size}}$$

$$= \frac{3040 \times 3}{(130/11) \times 190} = 4.06 \text{ lbs/Ton}$$

Shipment Data

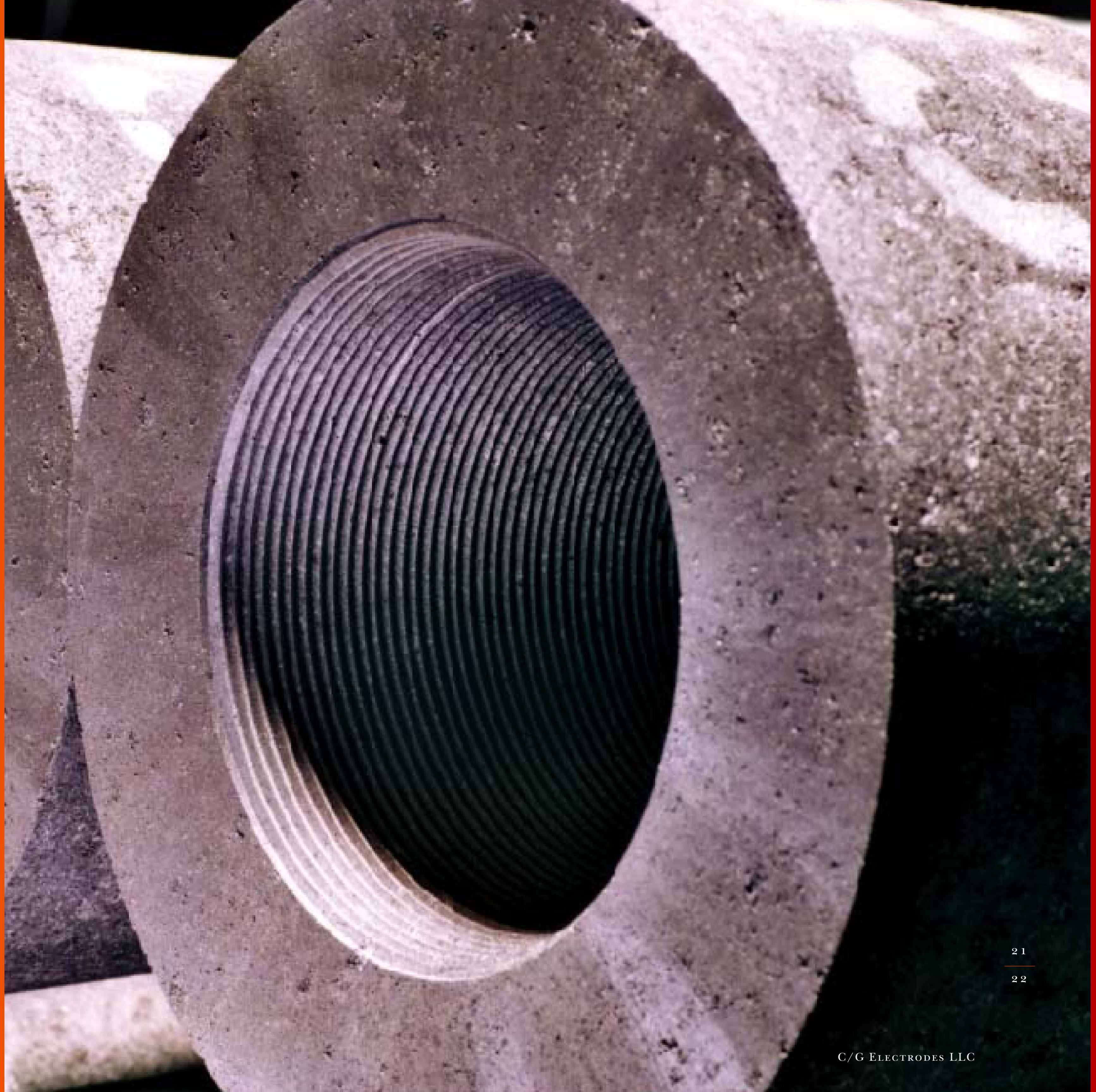
Stringerized Shipments (Truck)

Electrode Size *(inches)*	Approx. Weight per Piece	Pieces per Bundle	Approx. Net Lbs per Bundle	Pieces per TL	Approx Net *(lbs)*
28 x 110	4,264	2	8,528	10	42,640
26 x 110	3,459	2	6,918	12	41,508
26 x 96	3,170	2	6,340	14	44,380
24 x 110	3,116	2	6,232	14	43,624
24 x 96	2,721	2	5,442	16	43,536
24 x 84	2,407	2	4,814	18	43,326
24 x 60	1,715	2	3,430	24	41,160
22 x 110	2,580	2	5,160	16	41,280
22 x 96	2,288	2	4,576	20	45,760
22 x 84	2,088	2	4,176	22	45,936
20 x 96	1,951	2	3,902	24	46,824
20 x 84	1,690	2	3,380	26	43,940
20 x 72	1,436	3	4,308	33	47,388
18 x 96	1,559	3	4,677	30	46,770
18 x 84	1,358	3	4,074	34	46,172
18 x 72	1,171	3	3,513	40	46,840

Conversion Factors

Factors for Conversion to International System (SI) Units

Property	To Convert From	To	Multiply By #
CTE	per °F	per °C	1.79986
Density	lb/ft^3	g/cm^3	0.01603
Electrode Consumption	lbs/ton	Kg/MT	0.5
Energy	Btu's	kWh	0.0002928
Force	lbf	Newtons(N)	4.448
Length	Inches	mm	25.4
Strength	psi	MPa	0.006895
Resistivity	Ohm-in	µ-ohm-m	25400
Torque	ft-lbs	N-m	1.3558
Velocity	ft/min	mm/sec	5.079
Weight	Short ton	Metric Ton	0.9074



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