Getting the Most from Your Thermatool CFI Solid State Welder

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Introduction:

CFI Solid State Welders from Thermatool offer many advantages over the older, vacuum tube welders. They are far more efficient (typically 80% compared to only 65%), more reliable (they contain no finite life components such as the vacuum tube and operate at lower voltage levels for minimum voltage stresses on the insulation system), safer for plant personnel to maintain (again because of the lower voltage levels), and require less space (allowing a more efficient mill layout). They are also as easy to use as vacuum tube welders, but require some different set-up practices to make them operate at their best. This article explains how to get the best performance out of your CFI Solid State Welder!

Why are set-ups different for solid state welders than for vacuum tube welders? There are two fundamental reasons:

- First, solid state welders are more efficient than vacuum tube welders because they use a circuit called a "Resonant Tuned Inverter" to create the high frequency output. Vacuum tube welders use a "oscillator" circuit. In a solid state welder, the Resonant Tuned Inverter's operating frequency (the welding frequency) is determined by the inductance of the work coil. This, in turn, is determined by the coil geometry, weld "Vee" length, quality of the impeder, and tube material being welded - all difficult in practice to predict. While Thermatool's AutoMatch system goes a long way in compensating for variations in these factors, the work coil must be properly constructed so that the AutoMatch can vary over the range of expected process variations.

- Second, solid state welders operate at significantly lower voltage levels than vacuum tube welders. This results in fewer problems with coil arcs, and less heating of the weld rolls and other mill components. However, more caution must be taken in minimizing stray inductance in the coil set-up to insure enough voltage across the work coil.

Obtaining a good set-up for a CFI welder is very easy. Just follow the simple guidelines below.

Selecting and Making Work Coils, and Mounting in the Coil Holder:

Because of the lower voltages used in solid state welders, the high voltage coils used with vacuum tube welders generally do not work well with solid state welders. The guide provided in Appendix A shows good starting coil designs for CFI welders. To obtain the best performance, it is important these coils be fabricated to reasonable tolerances, about +/- 0.040 inches. Following the practices below will result in the best coil design. These practices are illustrated in Figures 1 and 2.

- The coils should be made with their leads spaced to just fit the coil holder. Large "loops" in the leads should be avoided. This minimizes stray inductance that will reduce the voltage at the "working" part of the coil.

- The coil leads should be as close to the "seam guide" end of the coil as possible, thus "offsetting" the "head roll" end of the coil. This practice will reduce interference between the coil and leads, and the mill's head roll assembly, thus achieving the shortest possible "Vee" length.

- The coil should be wound in the direction that causes the turn closest to the head rolls to start over the “Vee”. This also shortens the effective “Vee” length.

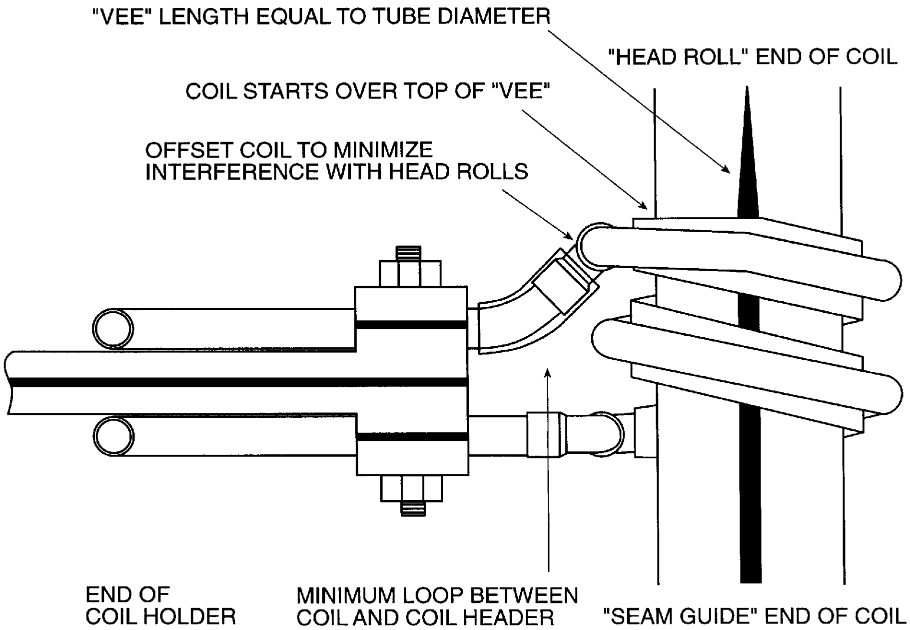


FIGURE 1 - How To Make <u>Good</u> Work Coils

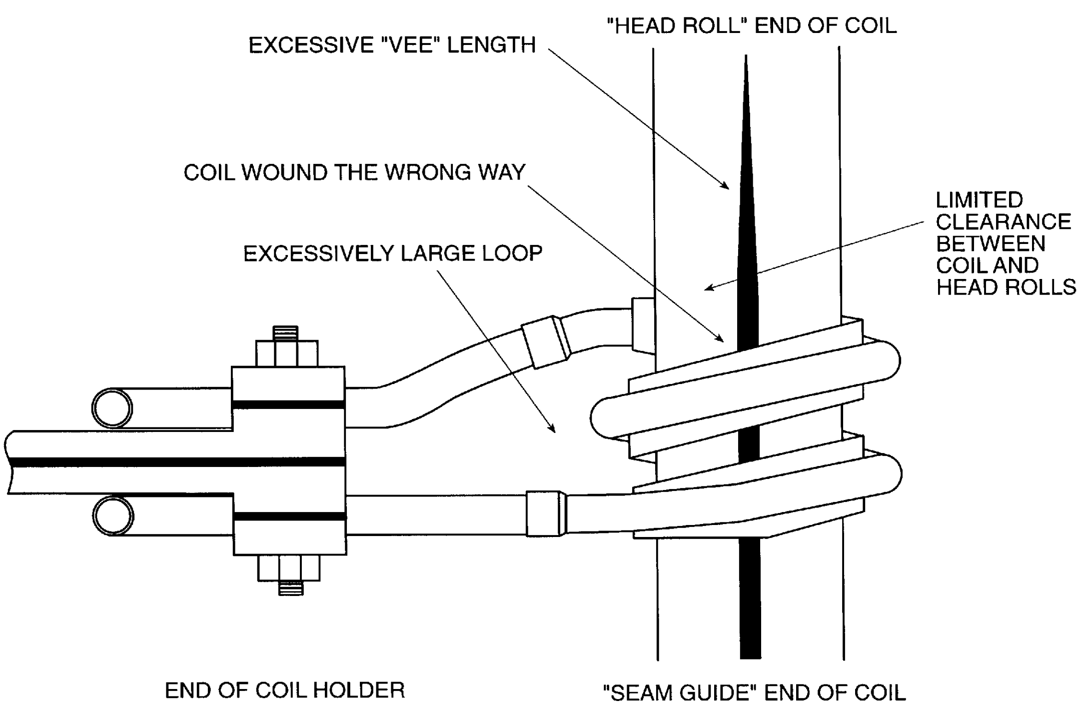


FIGURE 2 - How <u>NOT</u> To Make Good Work Coils

For some sizes in the 2 inch to 3 inch tube diameter range, both one turn and two turn coils are specified in Appendix A. For a particular tube making job, one coil will generally work better than the other. Generally, the one turn coil will work better with large mills operating at the small end of their tube diameter range, and the two turn coil will work better with small mills producing at the high end of their tube diameter range.

Tube material will also affect the work coil design. The coils in Appendix A are optimized for producing pipes or tubes made from low carbon steel - the most common pipes and tubes produced. High conductivity materials such as aluminum may require different work coil designs. These are available by contacting Thermatool Customer Service and explaining your application requirements.

The coils in Appendix A should work well for most pipe or tube wall thickness and for most "good" mill set-ups. However, the designs can be optimized for a particular tube making job and mill set-up as described in **Checking Coil Effectiveness**.

Selecting the Impeder:

The impeder is usually a ferrite rod inside of a fiberglass shield. The purpose of the shield is to protect the ferrite from damage and to channel the cooling water around the ferrite. However, it is the ferrite that controls the magnetic field generated by the work coil. Hence the dimensions of the ferrite, not the dimensions of the shield, affect the results of the process. The ferrite's diameter should be as large as practical. In large pipe or tube fabrication, where multiple ferrite rods are used or in cases where internal scarfing devices limit placement of the ferrite within the tube, the ferrite should be placed as close to the "Vee" as practical. The length of the impeder should be chosen so that the "head roll" end of the ferrite (not the end of the housing) extends about 0.125 to 0.25 inches beyond the apex of the "Vee" in the direction of the head rolls, and the "seam guide" end of the ferrite extends about two tube diameters in back of the work coil. This practice is illustrated in Figure 3.

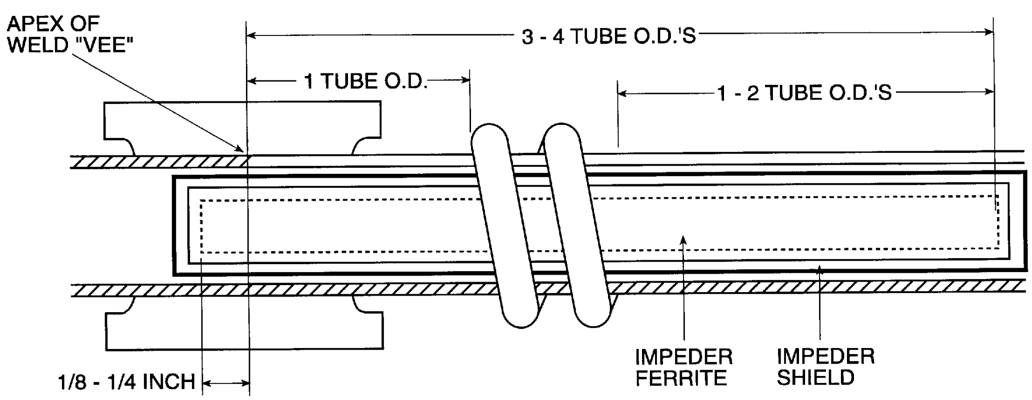


FIGURE 3 - How To Select The Impeder

Ample cooling water must be provided to prevent over-heating of the ferrite. This can destroy the ferrite and/or reduce its magnetic properties and hence, its effectiveness. A booster pump should be used with small impeders or return flow impeders to insure adequate water flow.

Impeder assemblies with electrically conductive end caps (such as brass) should be avoided. Electrically conductive end caps can be inductively heated by the magnetic field destroying the impeder's shield and ferrite.

For making small diameter tube (Outside diameter less than 0.75 inches), exposed ferrite impeders offer an efficient alternative. Because the tip of the impeder is exposed from the fiberglass shield, a larger diameter ferrite can be used. This is because the exposed tip extends into the narrowest portion of the tube, the welded part which is forward of the head rolls.

Setting-Up the Coil and Holder on the Mill:

The work coil must be mounted in the appropriate coil clamp for attachment to the welder. The best set-up is achieved by following the guidelines below. The correct mounting of the coil holder in the clamp is illustrated in Figures 1, and 2 . The correct "Vee" length is shown in Figures 1 and 4, and the correct way to mount the coil clamp to the welder and position the coil around the centerline of the mill is shown in Figures 5 and 6.

- The leads between the clamp and the coil should be made as short as possible. The gap between the coil clamp and the welder's nose piece can be adjusted to center the coil around the pipe or tube. Ideally this gap should be as short as possible, and certainly less than 2 inches (See Figures 5 and 6).

- The coil should be installed to obtain a "Vee" length (the distance between the "Head Roll" edge of the coil and the apex of the "Vee") of about one tube diameter. "Vee" lengths larger than about one and a half tube diameters will result in a poor load match situation and will require more weld power than the optimum "Vee" length. Achieving the shortest "Vee" length may require adjusting the angle of the coil leads and coil clamp so that they minimally interfere with the mill's weld box assembly. The location (height and side distance) of the HF Generator from the mill center line needs to be optimized to achieve the shortest "Vee" lengths for the particular mill configuration and tube product mix.

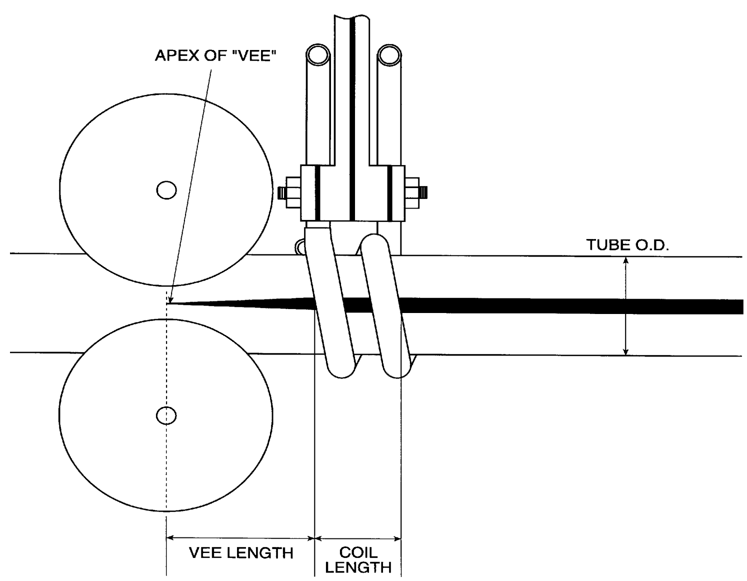


FIGURE 4 - How to Measure "Vee" Length and Coil Length

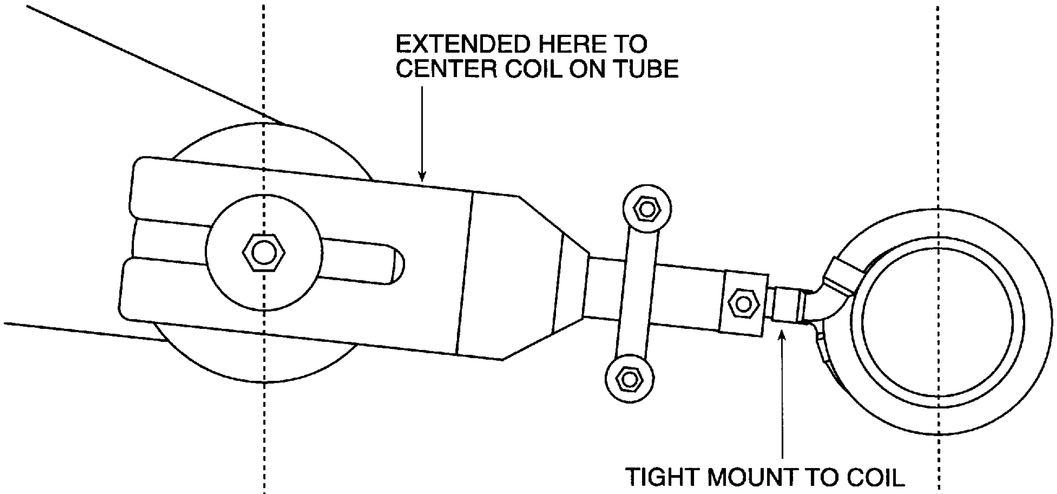


FIGURE 5 - How to Mount the Coil Holder on the Welder's Nose Piece

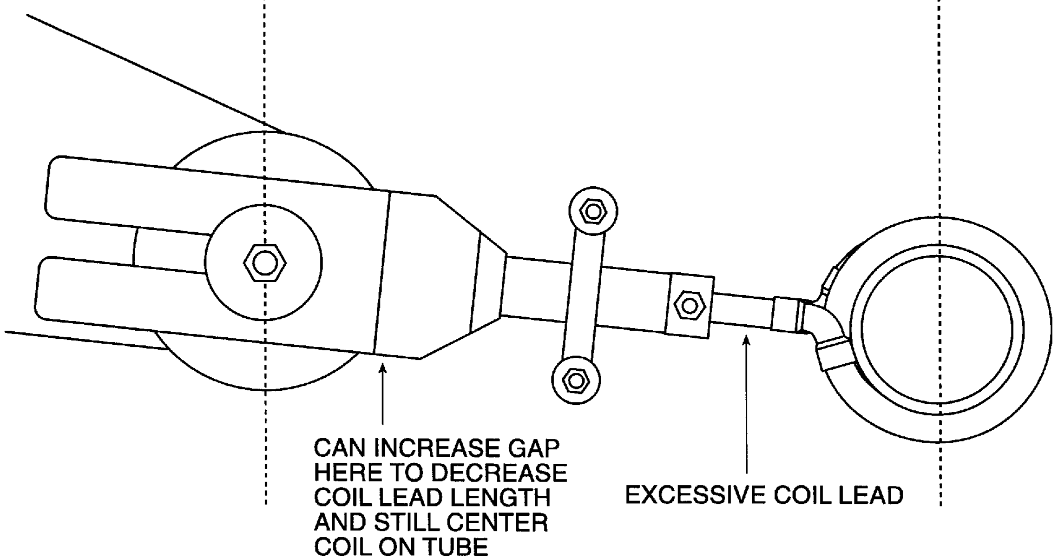


FIGURE 6 - How NOT to Mount the Coil Holder on the Welder's Nose Piece

Checking Coil Effectiveness:

Once the coil and impeder are installed and the mill is ready to run, the effectiveness of the coil and impeder set-up can be determined. To do this, place the AutoMatch system in the "Manual Mode", and position the Series Slug all of the way out (light on the "Series Out" push-button is lit) and the Parallel Slug all the way in (light on the "Parallel In" push-button is lit). Start the mill and welder at a mill speed that requires less than half power from the welder. Observe the Voltage and Current meters on the control console and verify the welder is operating in its Safe Operating Region. This is illustrated in Figure 7.

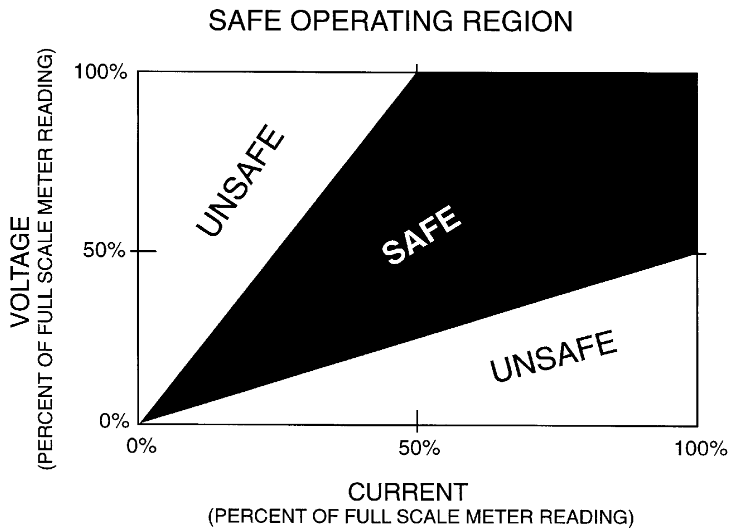


FIGURE 7 - How to Find the Safe Operating Region for CFI Welders

If the welder is not operating in the Safe Operating Region, shut down the welder and mill, and follow the instructions below to replace the coil or adjust the mill set-up so that the welder operates inside the Safe Operating Region. **Failure to do this can cause catastrophic damage to the welder!**

Once the welder is operating in the Safe Operating Region, check the welding frequency. It should be in the Nominal Frequency Range as shown in Table 1 below:

TABLE 1 - CFI Welder Nominal Frequency Ranges

Nominal Welder Frequency	Minimum Actual Frequency	Maximum Actual Frequency
400 kHz	360 kHz	420 kHz
300 kHz	270 kHz	315 kHz
200 kHz	180 kHz	210 kHz

If the Welding Frequency is higher than the Maximum Actual Frequency value in Table 1:

⇒ Make the work coil shorter or increase its inside diameter.

⇒ Increase the “Vee” length.

If the Welding Frequency is below the Minimum Actual Frequency value in Table 1:

⇒ Make the work coil longer or decrease its inside diameter.

⇒ Reduce the “Vee” length.

Now check the output Voltage and Current meters on the control panel. For convenience, we say that the Voltage and Current are “Equal”, or that the welder is in a “Matched” condition, if both meter needles are at the same angle. This is shown in the center of Figure 8 below. If the Voltage meter is reading higher than the Current meter, we say: “The Voltage is Higher than the Current”, or if the Current meter is reading higher than the Voltage meter, we say: “The Current is Higher than the Voltage”. These cases are also illustrated in Figure 8.

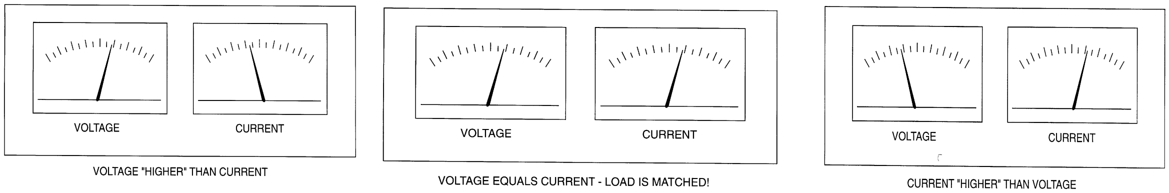


FIGURE 8 - How to Read the Voltage and Current Meters

Observing the meters with the load matching inductors positioned “Series Full Out” and “Parallel Full In”, the welder should be nearly “Matched” (Voltage “Equal” to Current) or the Current should be Higher than the Voltage. If the Voltage is substantially Higher than the Current:

- If the welding frequency is at or below the Nominal Welder Frequency (See Table 1):

  ⇒ Make the work coil longer or decrease its inside diameter.

  ⇒ Reduce the “Vee” length.

- Or if the welding frequency is above the Nominal Welder Frequency (See Table 1):

  ⇒ Make a work coil with one more turn than the existing work coil. Note that the new coil should be one and a half to twice as long as the existing work coil.

The adjustments described above interact somewhat, so correcting the welding frequency may affect the readings of the Voltage and Current Meters, and vice versa. Once the work coil and mill set-up have been adjusted to provide a welding frequency in the range shown in Table 1 and a suitable Voltage and Current relationship as described above, the AutoMatch feature will be able to correct for on-going variations in the welding process. The AutoMatch feature may now be switched to “Automatic Mode” so that load match and welding frequency will be optimized automatically.

If the product to be manufactured will be run at a mill speed that requires very low power from the welder (less than a quarter of its rated output power), it is desirable to deliberately force the Voltage to be Higher than the Current (See Figure 8). Doing this will minimize the ripple at the welder’s output and thus improve the quality of the weld. This can be accomplished by operating the AutoMatch feature in “Manual Mode” and increasing the voltage by driving the Series Slug “In” and then correcting the welding frequency by driving the Parallel Slug “Out”. Care must be taken to insure that the welder is always operated in its “Safe Operating Range” as shown in Figure 7.

Recording the Mill Set-Up:

Once an acceptable work coil, impeder, and mill set-up have been determined, it is desirable to record this information in a log book so these conditions can be repeated the next time the job is to be run. The data that should be recorded are:

Coil Inside Diameter
Coil Length
Number of Coil Turns

Impeder Diameter
Impeder Length

“Vee” Length

and when the mill is producing product at the desired speed, the following data should also be recorded:

Mill Speed
Welder Power
Welding Frequency
Welder Output Voltage
Welder Output Current

Keeping a log will greatly help in reproducing the welder’s set-up at a later date and will aid in solving problems if weld quality is lost during the production run.

Conclusion:

CFI Solid State Welders are easy to operate. However, because the welding frequency is more dependent on work coil design and the coil voltages are lower than those for vacuum tube welders, different practices must be used to design the work coil and to perform the mill set-up. Mastering these practices will insure the best performance from your CFI welder and “trouble-free” operation for years to come.

APPENDIX A - RECOMMENDED WORK COILS FOR CFI WELDERS

Table A-1: Standard Coils for CFI Welders: 50 to 350 kW Power Rating

Tube O. D. In.	Tube O. D. mm	Coil I. D. In.	Coil I. D. mm	Coil Length In.	Coil Length mm	# of Turns	Coil Type - See Fig.	Copper Tubing O.D. In.	Thermatool Part # (See Note Below for Specifying Mill Direction)
0.50	13	0.75	19	1.00	25	2	A-1	0.25	WL0025-005
0.625	16	0.94	24	1.00	25	2	A-1	0.25	WL0025-006
0.75	19	1.06	27	0.75	19	2	A-1	0.25	WL0025-003
0.866	22	1.25	32	0.75	19	2	A-1	0.25	WL0025-004
1.125	29	1.65	42	2.50	64	2	A-2	0.375	WL0210-003
1.25	32	1.81	46	2.50	64	2	A-2	0.375	WL0210-004
1.50	38	2.01	51	3.00	76	2	A-2	0.375	WL0210-005
1.75	44	2.28	58	3.54	90	2	A-2	0.375	WL0210-006
2.00	51	2.56	65	4.41	112	2	A-2	0.375	WL0210-007
2.25	57	2.83	72	4.41	112	2	A-2	0.375	WL0210-008
2.50	64	3.15	80	1.84	47	1	A-3	0.375	WL0029-002
3.00	76	3.54	90	1.84	47	1	A-3	0.375	WL0029-003
3.125	79	3.74	95	1.84	47	1	A-3	0.375	WL0029-004
3.50	89	4.13	105	1.84	47	1	A-3	0.375	WL0029-005
4.00	102	4.72	120	2.63	67	1	A-3	0.375	WL0029-006
4.50	114	5.51	140	3.00	76	1	A-3	0.375	WL0029-007

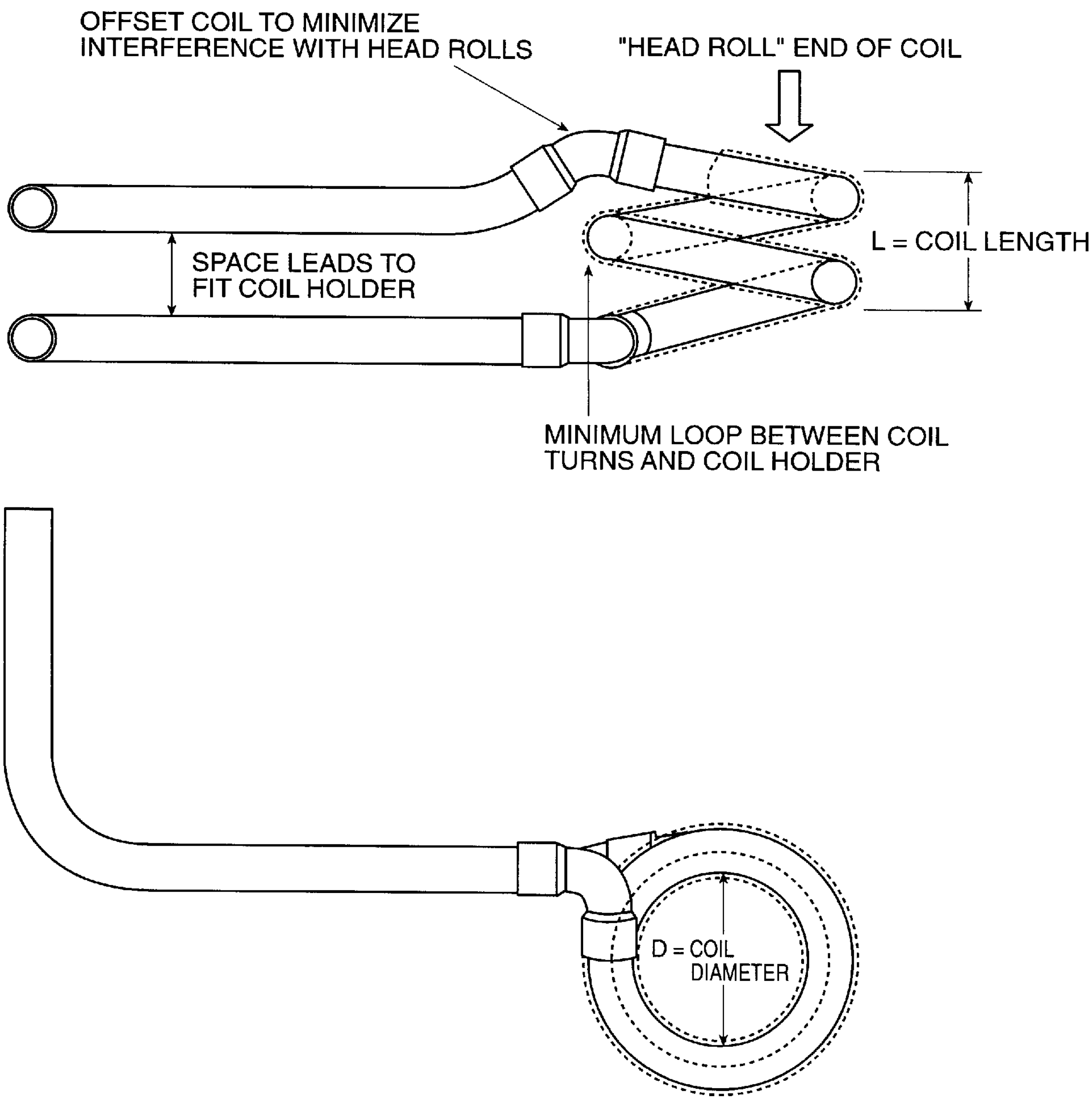
Note: Add Suffix “LH” for a Left to Right Mill and Suffix “RH” for a Right to Left Mill to the Thermatool Part Numbers Above. This will insure the coil is wound in the correct direction for your mill!

Table A-2: Alternate Coils for CFI Welders: 50 to 350 kW Power Rating

Tube O. D. In.	Tube O. D. mm	Coil I. D. In.	Coil I. D. mm	Coil Length In.	Coil Length mm	# of Turns	Coil Type - See Fig.	Copper Tubing O.D. In.	Thermatool Part # (See Note Below for Specifying Mill Direction)
0.50	13	0.75	19	1.00	25	3	A-1	0.25	WL0025-001
0.625	16	0.94	24	1.00	25	3	A-1	0.25	WL0025-002
0.75	19	1.31	33	2.50	64	3	A-2	0.313	WL0210-001
0.866	22	1.50	38	3.50	89	3	A-2	0.313	WL0210-002
1.00	25	1.42	36	1.05	27	2	A-1	0.375	WL0026-001
1.125	29	1.57	40	1.25	32	2	A-1	0.375	WL0026-003
1.25	32	1.77	45	1.44	37	2	A-1	0.375	WL0026-002
1.50	38	1.97	50	1.90	48	2	A-2	0.375	WL0027-001
1.75	44	2.36	60	2.95	75	2	A-2	0.375	WL0027-002
2.00	51	2.56	65	3.54	90	2	A-2	0.375	WL0027-003
2.25	57	2.76	70	4.41	112	2	A-2	0.375	WL0027-004
2.375	60	2.95	75	1.84	47	1	A-3	0.375	WL0029-001

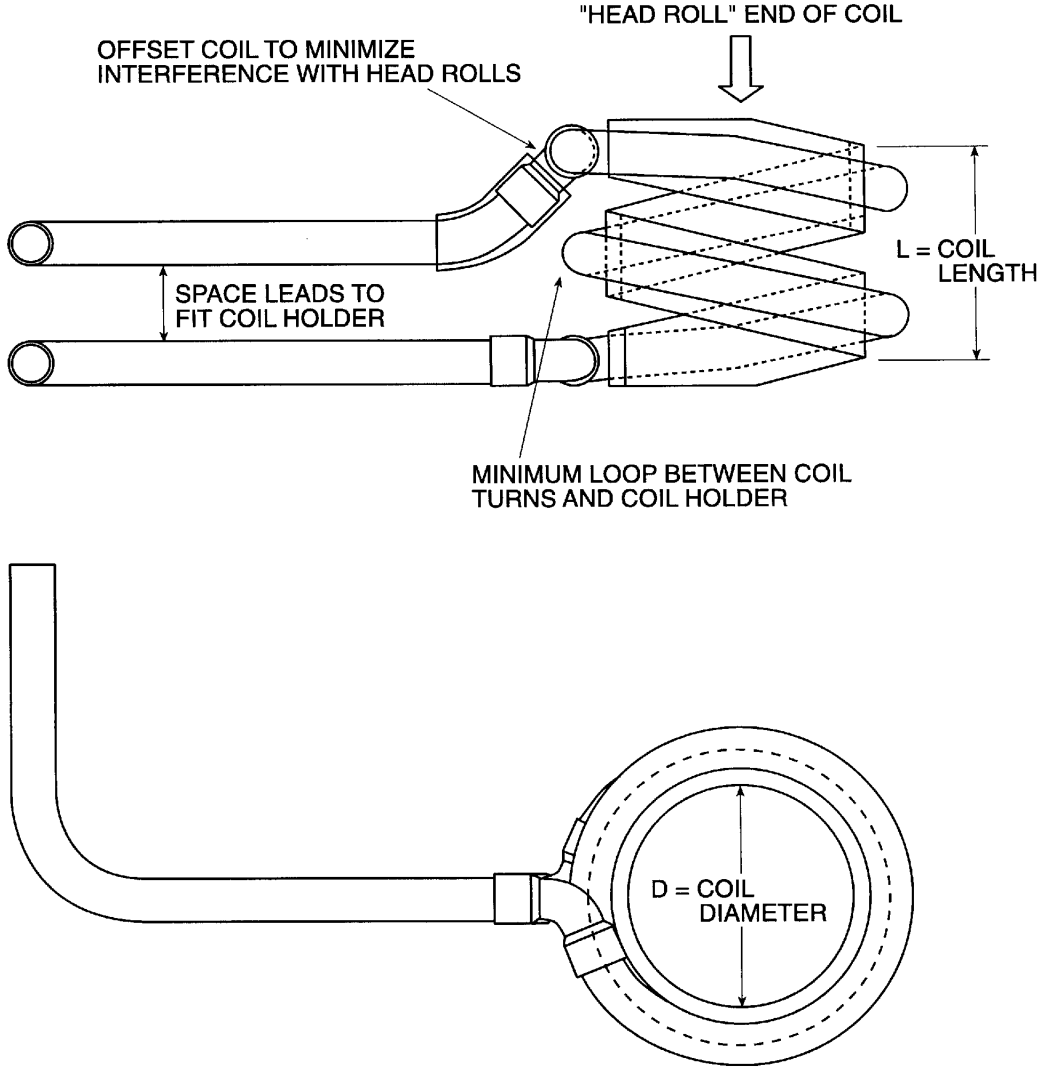
Note: Add Suffix “LH” for a Left to Right Mill and Suffix “RH” for a Right to Left Mill to the Thermatool Part Numbers Above. This will insure the coil is wound in the correct direction for your mill!

FIGURE A-1: GEOMETRY AND CRITICAL DIMENSIONS FOR TUBULAR COILS



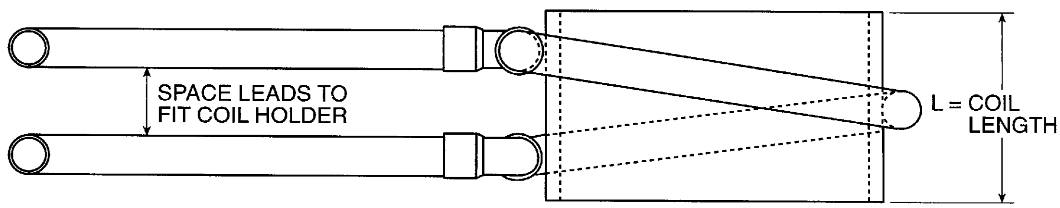
TUBULAR COIL

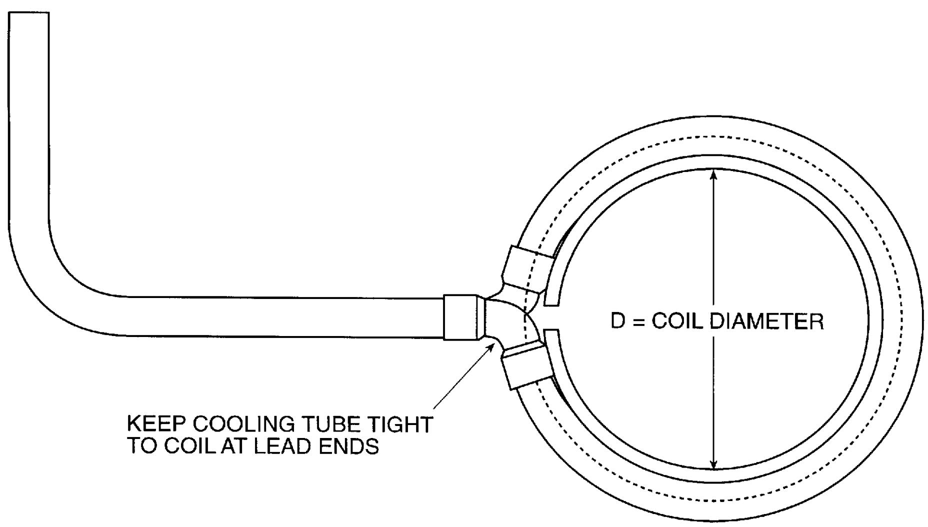
FIGURE A-2: GEOMETRY AND CRITICAL DIMENSIONS FOR BANDED TUBULAR COILS



BANDED TUBULAR COIL

FIGURE A-3: GEOMETRY AND CRITICAL DIMENSIONS FOR SINGLE TURN COILS





SINGLE TURN BANDED COIL