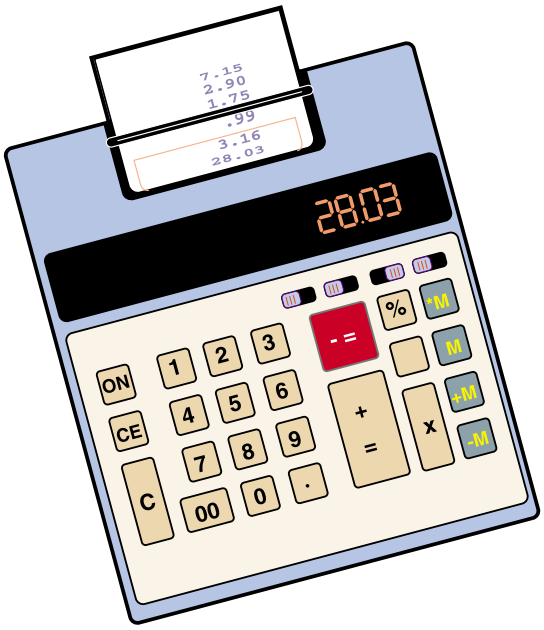
# Duke Power Heat Flux Calculator

**created by Alan Privette**




## Important Warning

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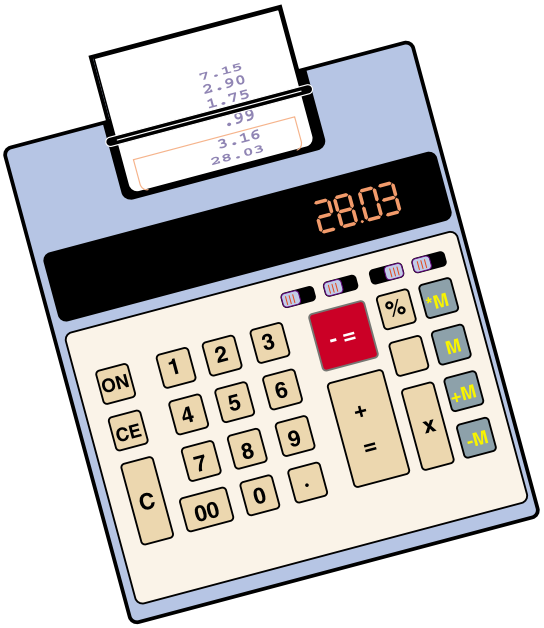
# Duke Power Heat Flux Calculator




## created by Alan Privette

***HEAT FLUX CALCULATOR:***

The following information is required to properly evaluate each potential arc hazard:

① Determine the available fault current
② Arc Gap (estimated)
③ Supply Voltage
④ Minimum distance from the arc center line to the worker
⑤ Arc Duration, the amount of time an arc exists (in cycles)
⑥ Additionally, you need to consider whether your work involves equipment (electrical panel, motor control, etc), which is located within a confined space (Arc-in-a-Box) or is single or multi-phase (Phase-to-Phase)

Using these varaibles and available software, the incident arc energy in cal/cm$^2$ for a given arc hazard can be calculated.

A useful example of such software is the shareware DOS computer program, Flux.exe[1]. You can find a copy of the program on our web site, www.arcflash.com.

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There is also a commercially available software program, ***ARCPRO II,*** developed by Kenectrics, formerly Ontario Power Technologies, Toronto, Canada. This can be purchased from their agent in the USA.

***Heat Flux Calculator***

KINECTRICS

Enter the values for your arc parameters into the software programs to calculate the incident energy (cal/cm$^2$). The software assumes a single-phase arc in an open configuration (You can correct this assumption with a correcting factor). For example, the incident energy for a 10000 ampere fault current with a 12 inch arc gap on a 7200 volt system with the worker 12 inches away from the arc center line for 10 cycles is 12.76 cal/cm$^2$. As a guide, Figures 1 through 5 contain the input screens and Figure 6 contains the output screen from the software for this calculation. You then need to consider the additional variables of confined space (Arc-in-a-Box) or is single or multi-phase (Phase-to-Phase), and apply a suitable multiple to the results of the Calculator to better approximate your actual conditions.



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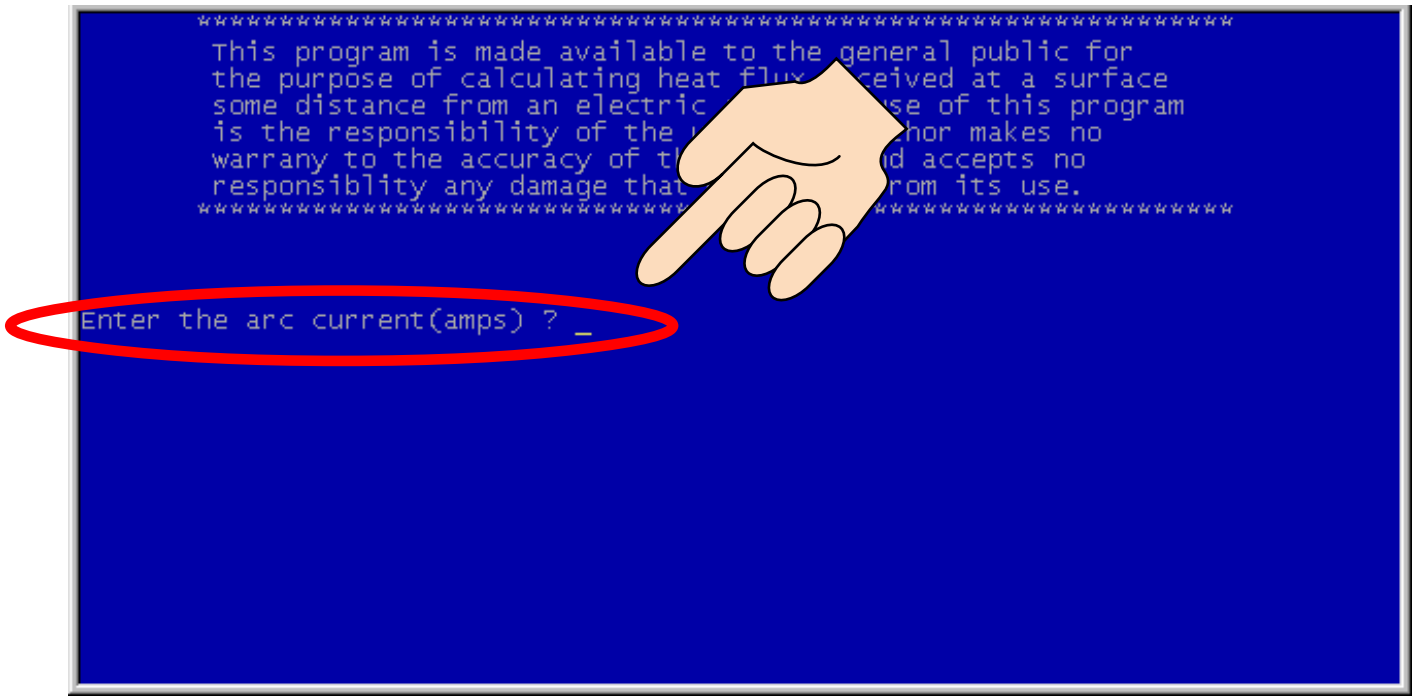



## FIGURE 1: Initial Screen for Fault Current Entry

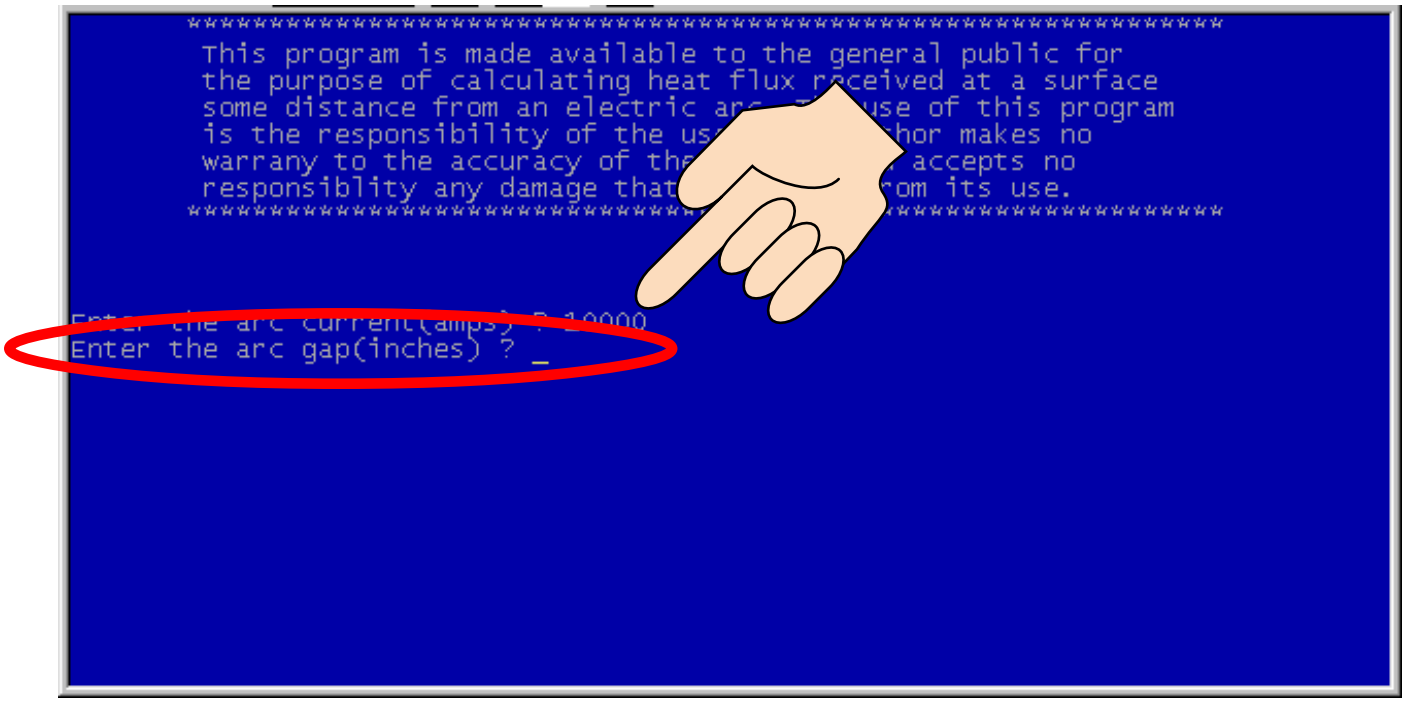
The software program contains an introductory screen and then prompts you to enter you fault current value.

For our example, the fault current is 10000 amperes.

**Enter 10000**

*What are typical arc currents?* Available fault current depends on the size of the transformer and what is feeding the transformer. Most fault currents will range between 2000 amperes (2kA) and 50000 amperes (50kA), but could reach 150 kA and higher. The available fault current depends on the rating of the transformer.

*Am I correct to say that the units are kVa?* No! The term kVa stands for 1000 Volt amperes. This is usually used to refer to the size of the transformer; for example, a 750 kVa transformer. Based on the impedance of the transformer and the low side voltage rating, the available fault current could be calculated.




## FIGURE 2: Input Screen Asking for Arc Gap

After you enter the available fault current, press enter. The program then prompts you to enter the arc gap in inches. The arc gap is dependent upon the type of equipment; i.e. you may be estimating for a cutout or possibly the distance between buss bars. For our example, the arc gap is 12 inches.

## Enter 12

*What is a realistic Arc Gap?* . Arc gap is dependent upon the voltage of the system and of the equipment. Below find a table of estimated arc gaps. Use these to initiate your investigation. However, you should attempt to determine appropriate values for your system.

Note: Consider the following as a starting point:

| Service Voltage | Arc Gap |
|---|---|
| 120 V to 240 V | 0.5 to 2 inches |
| 240 V to 600 V | 1 to 4 inches |
| 600 V to 49000 V | 4 to 12 inches. At this voltage level it depends more on the equipment design; a cutout installed on a pole will usually allow a 12 inch arc to form. |
| 49000 V to 500000 V | the arc gap is dependent on the equipment and how contaminated the air is. Arcs that are 1 to 20 feet in length are possible. You should base your estimated arc gap on your specific conditions. |

If the arc is enclosed in a piece of equipment, look at the bus to bus to cabinet spacing to find a starting arc gap distance; and since the arc will bow and the electrodes will melt, you may want to increase the arc gap length by 50%.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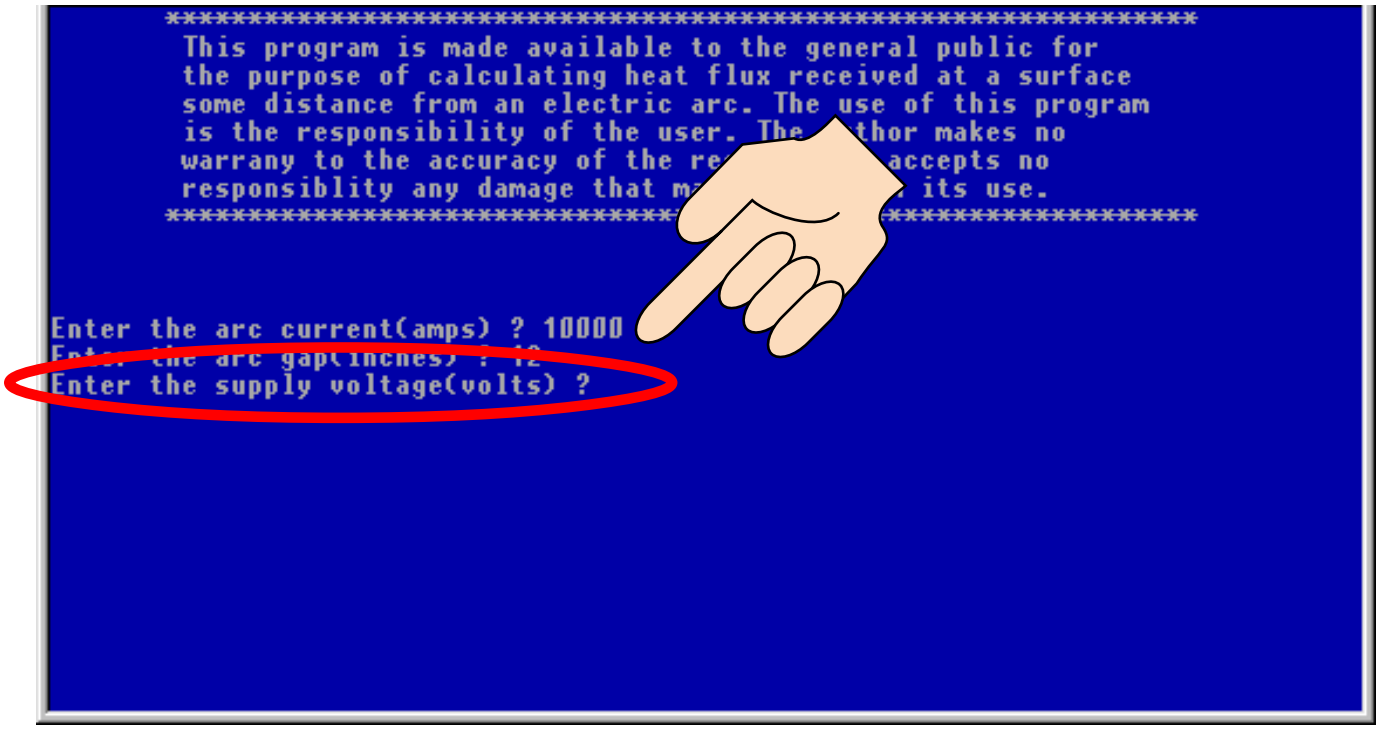



## FIGURE 3: Input Screen Asking for Supply Voltage

After you enter the distance for the arc gap in inches, press enter. The program then prompts you to enter the supply voltage in volts. The Program will indicate when there is not sufficient voltage to support the arc**. If this occurs, you may want to artificially decrease the arc gap value or increase the voltage value to obtain a calculated value. In some environmental or work conditions, an arc of longer length may be sustained than the voltage would normally allow under planned conditions.

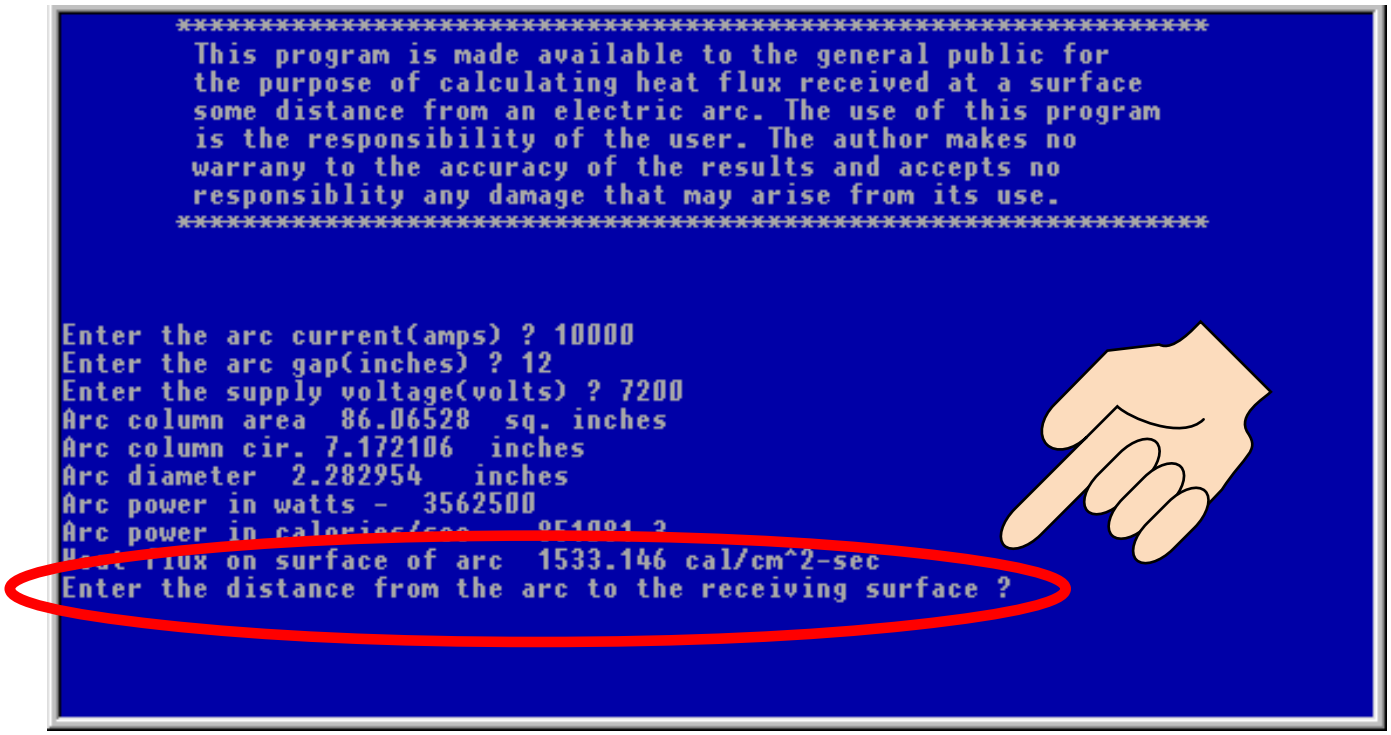
For our example, the supply voltage is 7200 volts.

**Enter 7200**

*Are the units in kV?* No! The units here are Volts. If you know the number of kV, with which you are working , simply multiply your number of kV by 1000 to obtain your voltage.

**** PLEASE NOTE !**

Upon entering your voltage, if the Heat Flux Calculator appears to **lock-up** or state that "**you have insufficient energy to sustain an arc**", you may want to artificially decrease the arc gap value or increase the voltage value to obtain a calculated value. You will need to reset the software to run another calculation. The example we often use: If a tool is dropped between two phases of electricity within a panel, this will dramatically lessen the arc gap. You are simply inputting an arc gap variable to create an arc, not to determine if the arc incident is feasible.




## FIGURE 4: Input Screen For Distance From Arc to Worker

After you enter the supply voltage, press enter. The Program displays some of the arc properties on the screen and then prompts you to enter the distance from the arc to the receiving surface in inches.

For our example, the distance from the arc to the receiving surface (worker) is 12 inches.

**Enter 12**

*Why is distance an issue?* The closer you are to the arc source, the higher the energy, to which you are exposed. In fact the energy exposure increase exponentially. If you are 24 inches away from the arc source (rather than the 12 inches in the example above), your exposure is only ¼ of that of 12 inches.



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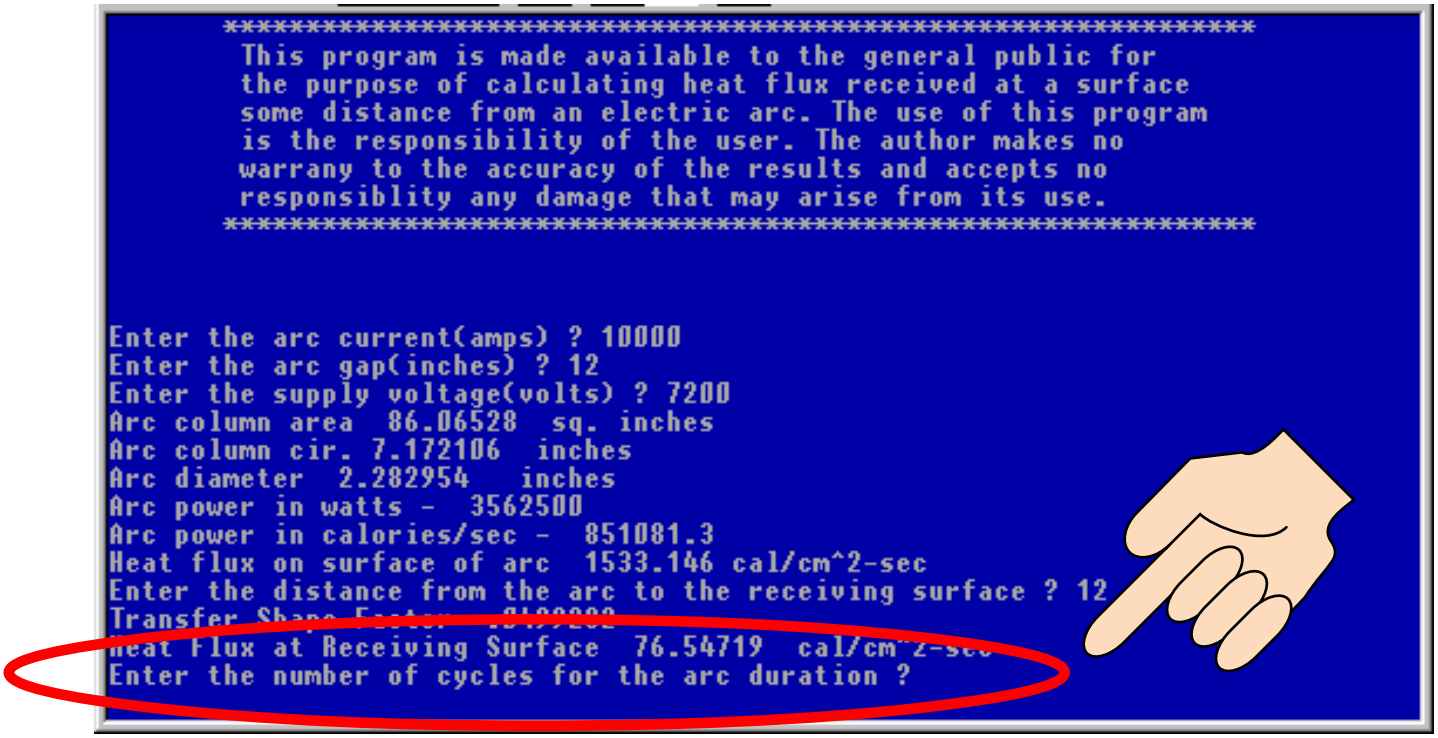


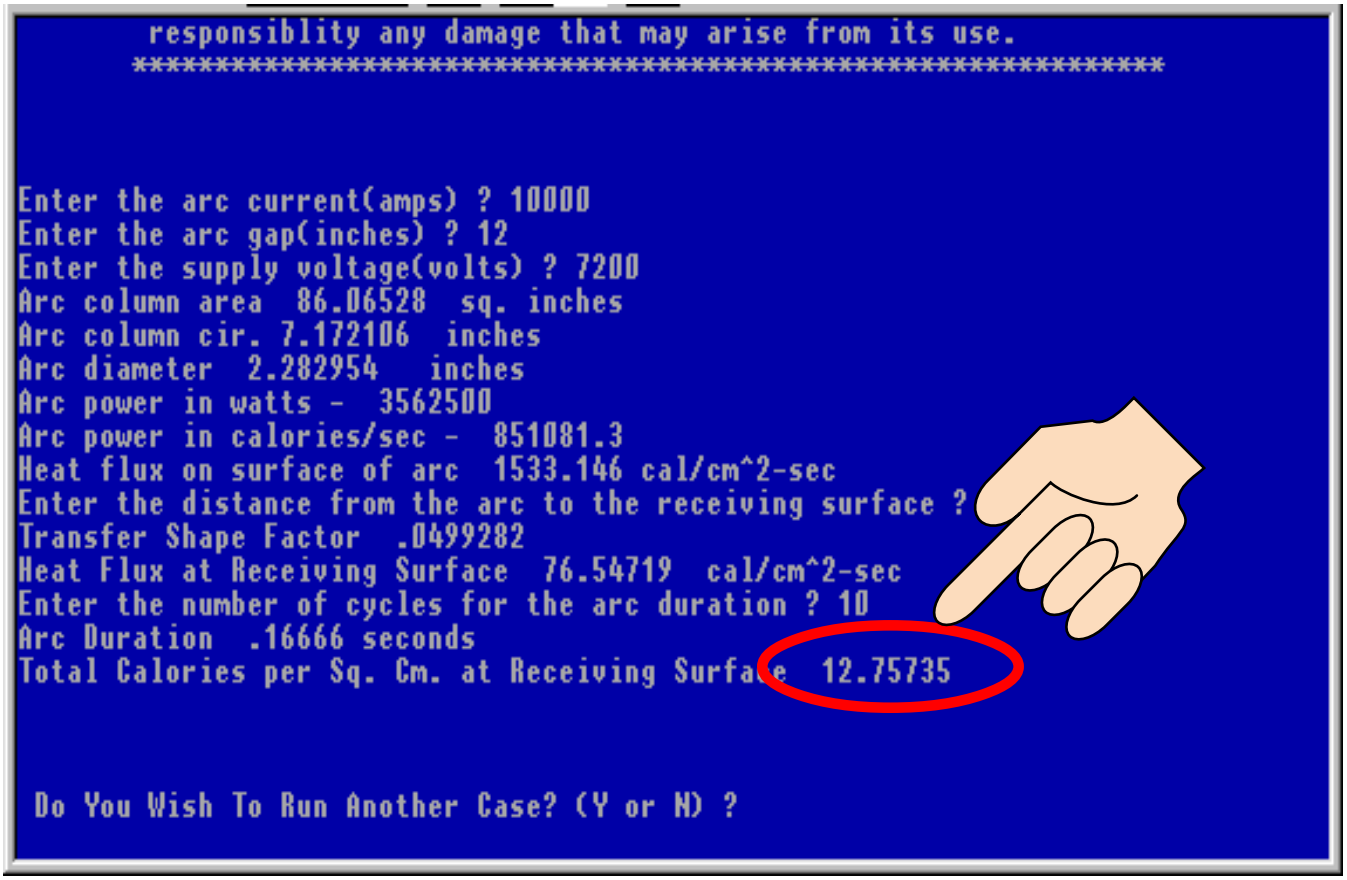

## FIGURE 5: Input Screen For Arc Duration

After you enter the distance from the arc to the receiving surface, press enter. The program displays the heat flux generated by the arc and then prompts you to enter the arc duration in cycles. Whether or not your system is protected by a breaker, fuse, etc., you must enter the number of cycles for how long the arc will be present.

For our example, the arc duration is 10 cycles.

**Enter 10**

*Where do I find this information?* Look to your protective scheme/plan to determine the clearing time for your fuses, breakers, etc. Fuses and breakers are time and load dependent. You may need to contact the manufacturer to obtain the necessary time/load curves for the specific equipment you are using. Additionally, your electrical contractor/installer is an additional source to obtain this needed information.




## FIGURE 6: Output Screen

After you enter the number of cycles for the duration of the arc, press enter. The program displays the incident energy in cal/cm$^2$ at the receiving surface.

**For our example, the calculated value is 12.76 cal/cm$^2$.**

To run another example, enter **Y** and repeat the instructions shown in Figures 1 through 5.

[1] Privette, Alan, Report Prepared for the ASTM F-18 Committee Task Force on Electric Arc Test Method Development, June 10, 1992.



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# Beyond the Heat Flux Calculator:

The Duke Power Heat Flux Calculator is a useful, cost effective tool to assist you in your arc flash hazard assessment. Yet it makes two (2) assumptions that may not correlate to many real world applications you may have. Based upon the work conditions and equipment upon which you are working, you may need to consider these additional variables when computing your potential arc exposure.

## Assumption #1: Single Phase Incident.

The Duke Power Heat Flux Calculator assumes the arc incident is being sustained by a single phase source (phase to ground). Yet if you are working on an electrical service panel where three phases are present, you can expect the instant the arc occurs, the conductive plasma generated by the arc will immediately involve all three phases. To correct for the involvement all three phases, multiply the incident energy value from the Heat Flux Calculator by a factor of 2.8 (**Phase-to-Phase** multiple). This applies to situations in which the conductors are not insulated nor isolated from each other. However, this factor does not take into consideration if an arc is initiated within an enclosure. If the arc occurs within a box or recessed panel more than 12 inches in depth, refer to the multiplier factor used for three phase arcs within an enclosure ( "Arc-in-a-Box") discussed below.

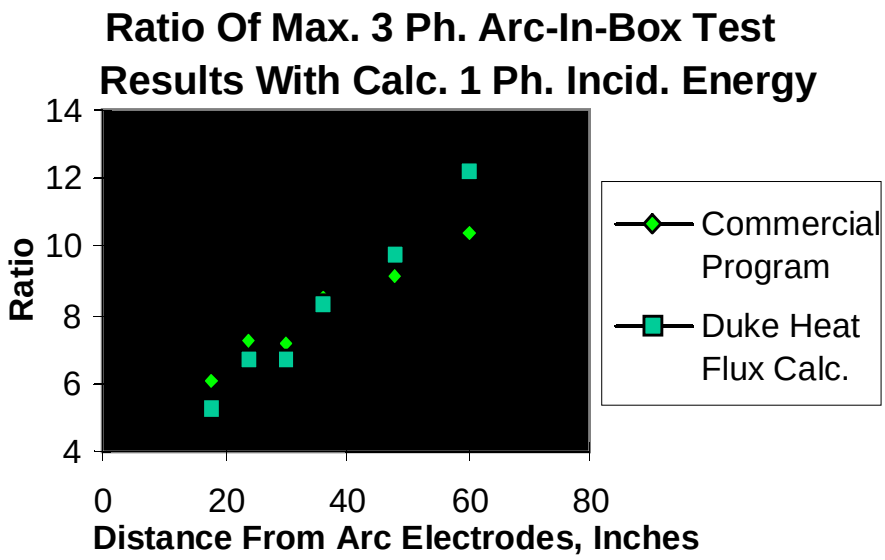
## Assumption #2: Open Space.

The Duke Power Heat Flux Calculator additionally assumes the energy of the arc is not confined, but free to dissipate its energy spherically (that is into the open space to the front & back, up & down and left to right). When working in outdoor utility substation, the circumstances of the arc may approximate these open air conditions.

However, if you are working within a confined space (such as a utility room or closet) or worse the arc incident occurs within a confined space (such as a recessed panel or motor control center), the ability of the energy to dissipate can be quite limited. In the example of a motor control, which may have an opening of 2 feet by 2 feet and be 2 feet deep, the energy has no escape but straight at you, thus amplifying dramatically the resulting energy exposure compared to that calculated by the Duke Power Heat Flux Calculator alone. You may need to consider this additional variable in your computations. This variable is often referred to as the **Arc-in-a-Box** multiple. This multiple attempts to include the amplified results of the arc being "directed" at the user by the confinement of the arc.

Below find data reported in the "Electric Arc Hazard Assessment and Personnel Protection," 2000 IEEE IAS Rome Conference Record. These ratios take into account both the Arc-in-a-Box variable and the Phase-to-Phase variable. As you will note, the results have the ability to dramatically effect the results of the Heat Flux Calculator, when used alone. A result of 7 cal/cm² from the Heat Flux Calculator could be magnified to a result easily in excess of 30 cal/cm² when these two "real world" conditions are factored into your computations.

**Important Note:** These factors were created for this IEEE paper for only one set of test conditions and changing the conditions can change the factor, e.g. the size and shape of the box can change the factor.



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