CONVERTERS POWER ESTIMATION

Most transducer suppliers would giver higher power than I am giving here. What I am doing is that I take the cubic mm and divide this with 1.3 and turn this into watt. I have over the years learned that this gives the most accurate numbers, with a safe margin, in order to run continues.

P = (Total volume of piezoceramics in mm^3) / 1.3 (=) Watts

$$P = \frac{V\left[mm^3\right]}{1.3\left[\frac{mm^3}{W}\right]} = 0.77\left[\frac{W}{mm^3}\right] \bullet V\left[mm^3\right]` = 0.77\left[\frac{W}{cm^3}\right] \bullet V\left[cm^3\right] (=) \left[W\right]$$

There are certain rules that have to be meeting to do this. Each mm height can take up to 200 volt (many says 500 volt, but that is peak); in order to do this it is there has to be a minimum amount of height.

If you take Branson, Dukane, they will never be able to do this because the height of the ceramic is not enough and then there is Hermann or Sonotronic they claim that they can do 1200 watt with the 35, 40 kHz transducers, but they have only 4mm in height of the ceramics and that so they are working over the limit and I know that for instance at Kraft Food in USA, they have a lot of transducers that blows out from Hermann.

I forgot to say that I have tested this theory over and over again, and I know, that you can do this a number of time, with higher power than my calculation, but when we are talking about 2 years warranty. I would never do this.

Like your Branson clone transducer, you should be able to draw 3.700 watt, but your bolt is to weak and this was the main reason why I went from 1/2” to 5/8” bolt, because I so that the bolt could not hold on to the G force.

If I ever want to go higher than 5000 watt, I need to go to bigger ceramics and bigger bolt ¾”

I forgot the mention one transducer. You remember the Branson 803, with 6 ceramics 40 x 20 x 5, they only used it for powers up to 1500 watt and the main reason for this, where that they original used a 3/8” bolt. I am repairing some right now and I am changing to ½” bolts.

Piezoelectric-Transducer Power Calculation (received from China... to be verified):

We calculate the maximal transducer power using the approximating formula:
P = TFV (W)
P is operating power of the transducer (W)
T is a constant: For continuous operating, **T** = (2. until 2.5).
For pulsed operating, **T** = 7
F is operating frequency in kHz
V is the total volume of implemented piezoceramics. (cm3)

Example:
2 pcs. Piezoceramic welding transducer,
Piezoceramics total thickness: 2 x 0.5 cm = 1 cm
P = TFV
F = 20 KHz
$V = \pi(\text{Outside}\Phi/2)^2 \times \text{thickness} - \pi(\text{inside}\Phi/2)^2 \times \text{thickness} =$
$= 3.14\times(2.5/2)^2 \times 1 - 3.14\times(1/2)^2\times 1 = 4.1cm^3$
Continual operation: T = 2, P = 2 × 20 × 4.1 = 164w
Pulsed operation: T = 7, P = 7 × 20 × 4.1 = 574w

Chinese equation is very crude since it does not account for:
1. Quality (loss tangent) of ceramics
2. Ceramic location with respect to node
3. Flatness and finish of interfaces
4. Drive voltage or current needed to achieve the required output amplitude. (Some designers don't build enough gain into the converter. Then the converter must be driven too hard in order to achieve the required output amplitude, which results in high ceramic loss.)
5. Ceramic preload. Excess preload pressure increases the ceramic loss.
6. Efficiency of cooling. This depends, in part, on the volume of air flow. Also, the cooling will be less effective if the front driver is titanium rather than aluminum.
7. Duty cycle. The equation accounts for duty cycle by the factor T. However, T is given a fixed value (7) for pulsed operation, regardless of whether the pulsed duty cycle is 90% or 10%.
8. Other factors?

<u>**Sample calculations of the required dynamic transducer input force**</u>

$$\text{RMS Output Force on working face of the horn} = ma = 781{,}514.67\ \text{m/sec}^2\ (\text{RMS}) * 0.00115425\ kg = 902.06\ \text{N}$$

$$\text{Output Power} = \frac{1}{2} * \frac{\text{total work done (Joules)}}{\text{the time taken (seconds)}} = \frac{J}{t} = \text{watts}$$

$$\text{Output Power} = \frac{1}{2} * \frac{902\ N * 0.000070\ \text{meters}}{1/20000\ \text{Hz}} = 631.4\ \text{watts}$$

With a 9:1 step up ratio on the booster/horn assembly then the input amplitude = 70 / 9 = 7.8 microns.

Input force - The booster and sonotrode assembly has a 9:1 mechanical step up ratio from input to output. Hence the input force required = O/P * step up ratio = 900N * 9 = 8100 N

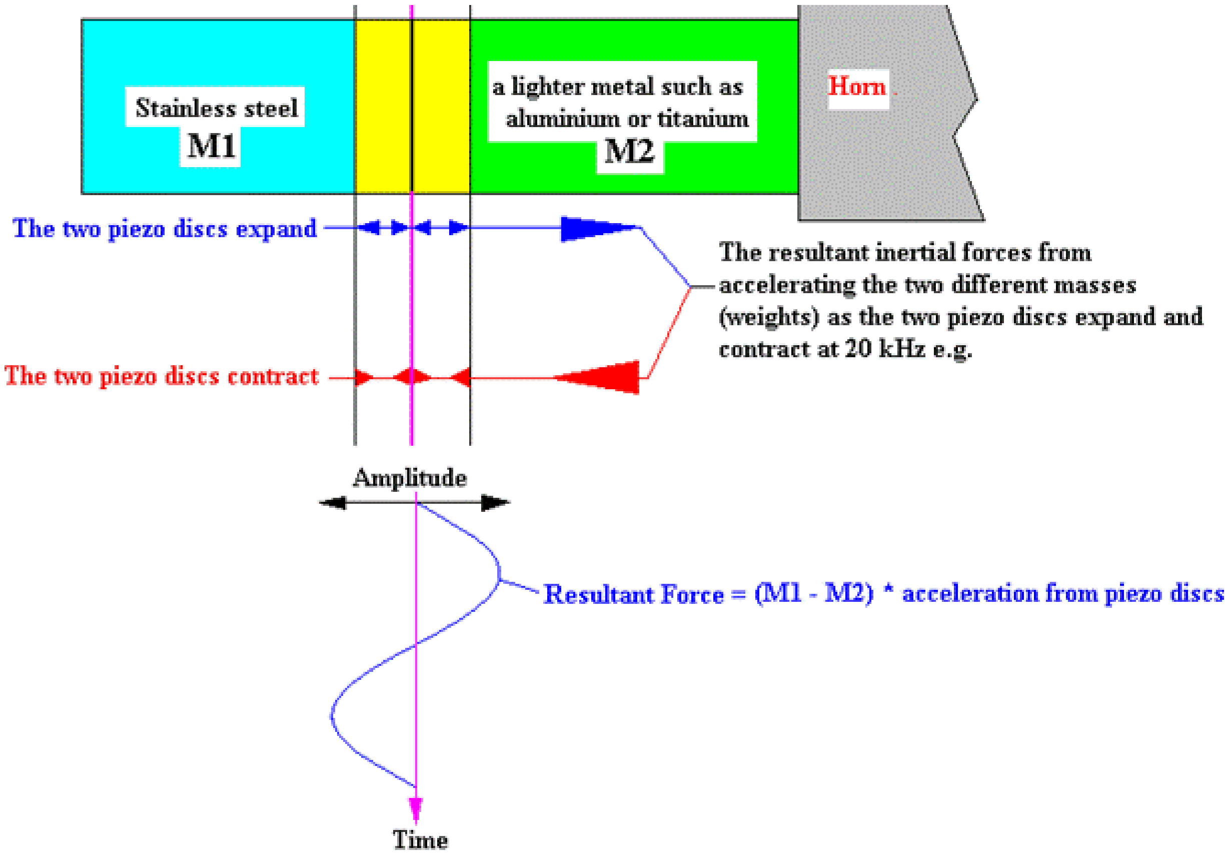
The maximum acceleration value of the transducer output face at 20 kHz and 7.8 microns amplitude =

$$\text{Maximum acceleration} = -\omega^2 A \sin\left(\omega * \frac{T}{4}\right) = 123173\ \text{m/sec}^2$$

$$\text{RMS acceleration} = 123{,}173 * 0.707 = 87083.31\ \text{m/sec}^2$$

Now we need 8100 RMS Newtons of input force - and we have available an RMS acceleration of 87083.31m/sec^2 **- hence the unbalanced mass on the transducer required to generate that force is:**

$$F = ma \text{ — Then the unbalanced mass} = \frac{F}{a} = \frac{8100\ \text{N}}{87083.31\ \text{m/sec}^2} = 0.093\ \text{kg}$$



Stainless steel
M1
a lighter metal such as
aluminium or titanium
M2
Horn
The two piezo discs expand
The two piezo discs contract
The resultant inertial forces from accelerating the two different masses (weights) as the two piezo discs expand and contract at 20 kHz e.g.
Amplitude
Resultant Force = (M1 - M2) * acceleration from piezo discs
Time

Amplitude Reference

An ultrasonic weld is governed by the following formula: E = P x T, where E = energy, P = power, and T = time. Power is a function of force times velocity: P ~ F x V. Force is derived from pressure and down speed, and velocity is derived from frequency and amplitude. (See Figure 1.)

Amplitude is defined as the peak-topeak longitudinal displacement at the face of the horn. (See Figure 2.) It

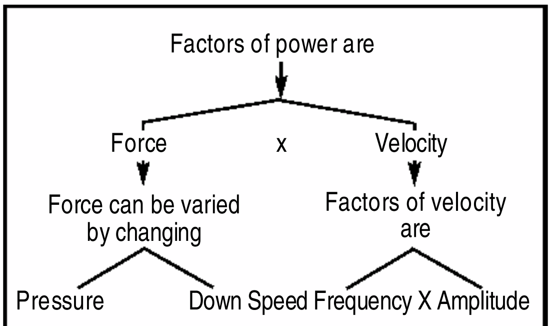


Figure 1

has the most impact on the ultrasonic process, in that the heat generated at the joint interface is based on the *square* of the amplitude. Therefore, small increases or decreases in amplitude have a greater affect than changes to other parameters, because the results are magnified by the square rather than incrementally.

One can calculate amplitude by using static gain factors of the

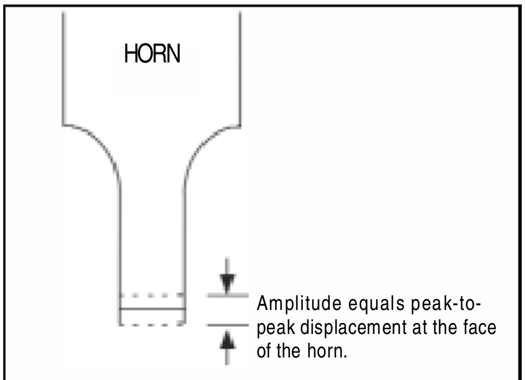


Figure 2

components that make up an acoustic stack: the converter, booster, and horn. (Gain is the ratio of output amplitude to input amplitude of a horn or booster.) To arrive at approximate stack amplitude, multiply the amplitude of the converter by the gain factors of the booster and horn. (See Figure 3.) For example:

Depending on the material and ultrasonic process utiized, different amplitudes will be necessary. Amplitude can be measured in either thousandths of an inch or microns

$$Amplitude_{output} = Amplitude_{converter} \times Gain_{booster} \times Gain_{horn}$$

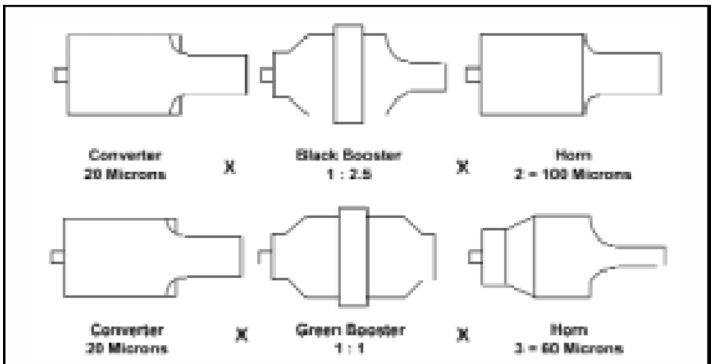


Figure 3

(0.001" = 25 microns).

Amplitude guidelines based on material and process have been arrived at through research and practical experience. The matrix on the reverse side of this page should be used as a ***guideline*** to determine amplitude for the setup of your particular application, based on the frequency of the equipment.

AMPLITUDE REFERENCE GUIDE for ULTRASONIC WELDING (in M icrons (µm))

Resin	***Frequency***			
Amorphous	**15 kHz**	**20 kHz**	**30 kHz**	**40 kHz**
Acrylonitrile Butadiene Styrene (ABS)	36-84	30-70	24-56	18-42
Acrylonitrile Styrene Acrylate (ASA)	36-84	30-70	24-56	18-42
Polycarbonate (PC)	72-120	60-100	48-80	36-60
PC/ABS	72-120	60-100	48-80	36-60
PolycarbonateÆolyester	60-1 20	50-100	40-80	30-60
Polyetherimide (PEI)	84-120	70-100	56-80	42-60
Polyethersulfone (PES)	84-1 20	70-100	56-80	42-60
Polymethyl Methacrylate (Acrylic, PMMA)	48-84	40-70	32-56	24-42
Polyphenylene Oxide (PPO)	60-1 08	50-90	40-72	30-54
Polystyrene (PS)	36-84	30-70	24-56	18-42
Polysulfone (PSU)	84-120	70-100	56-80	42-60
Polyvinyl Chloride (rigid PVC)	48-96	40-80	32-64	24-48
Styrene-Acrylonitrile (SAN)	36-84	30-70	24-56	18-42
Semi- Crystalline				
Cellulosics (CA, CAB, CAP)	72-1 20	60-100	48-80	36-60
Liquid Crystal Polymer (LCP)	84-1 44	70-120	56-96	42-72
Polyoxymethylene, Polyacetal (POM)	84-1 44	70-120	56-96	42-72
Polyamid (Nylon, PA)	84-144	70-120	56-96	42-72
Polybutylene Terephthalate (Polyester,	84-144	70-120	56-96	42-72
Polyethylene Terephthalate (Polyester,	96-144	80-120	64-96	48-72
Polyetheretherketone (PEEK)	84-1 44	70-120	56-96	42-72
Polyethylene (PE)	108-144	90-120	72-96	54-72
Polyphenylene Sulfide (PPS)	96-1 44	80-120	64-96	48-72
Polypropylene (PP)	108-144	90-120	72-96	54-72