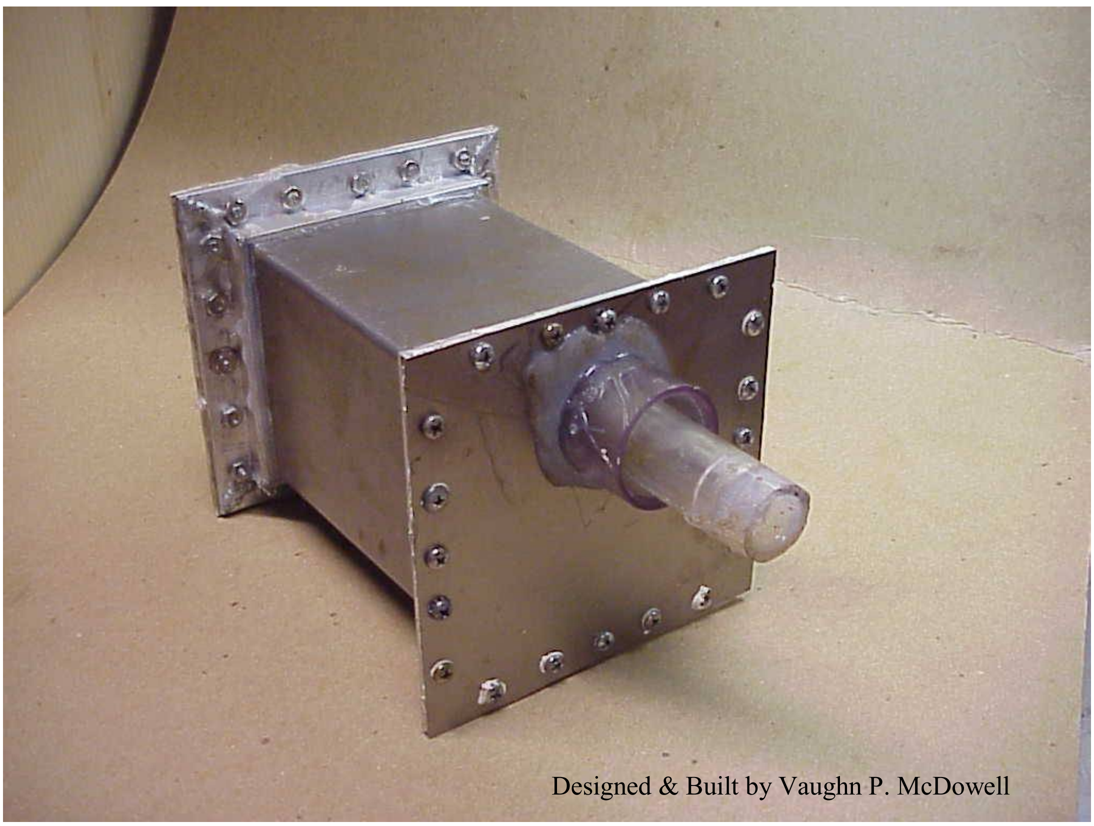
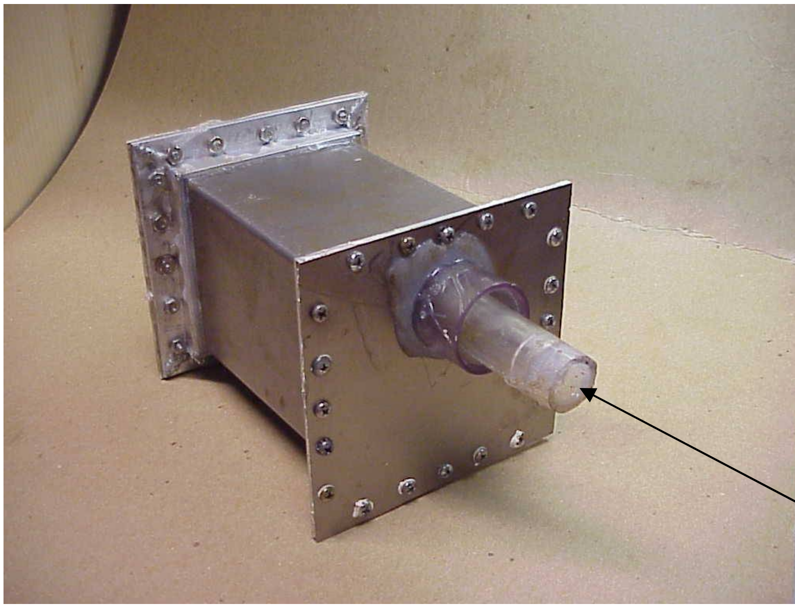
Experimental 3KJ + CCPS HV Tank/ Prototype

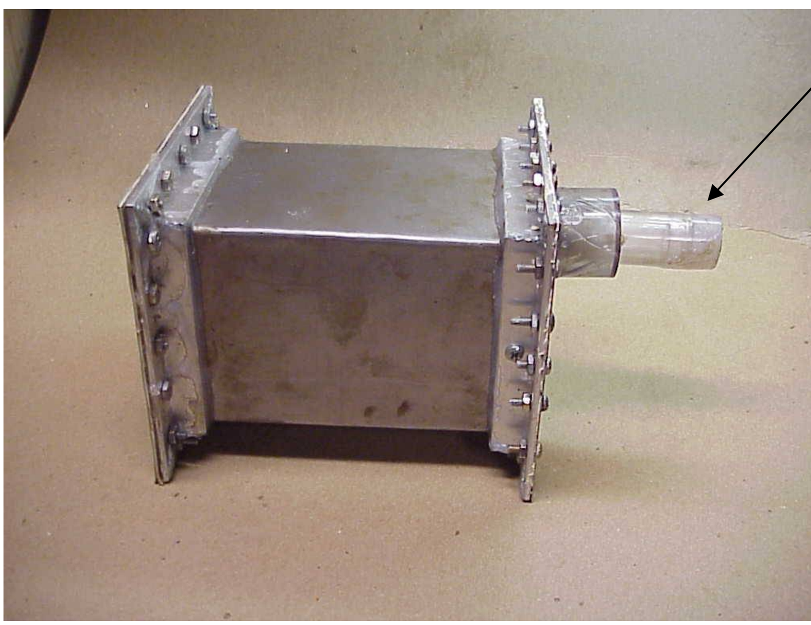


Oil filled HV Tank

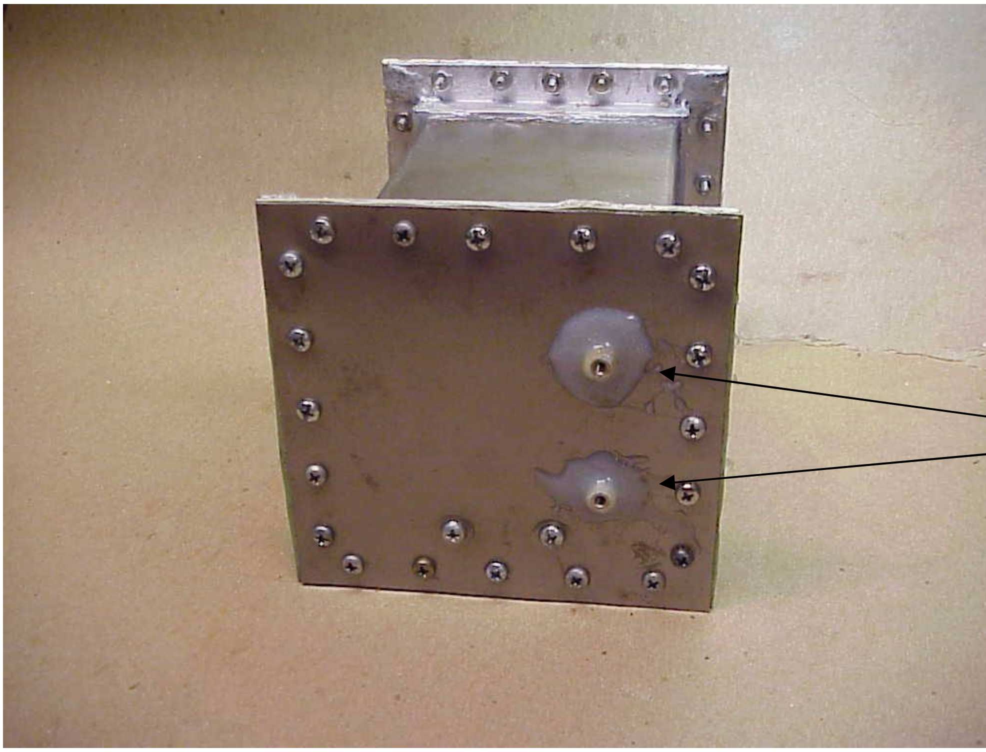


HV OUT

Side view

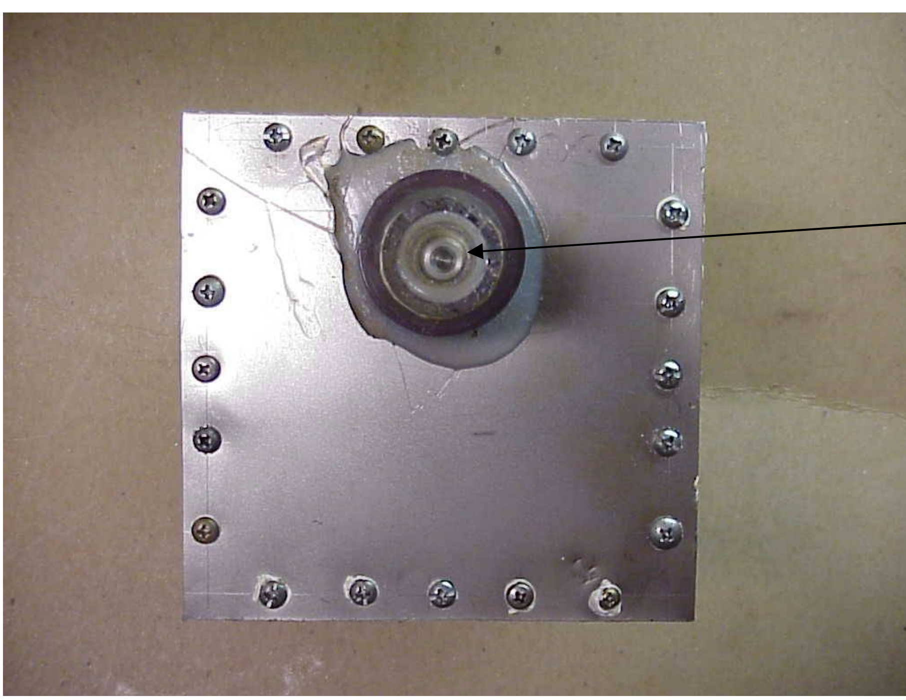


Rear View



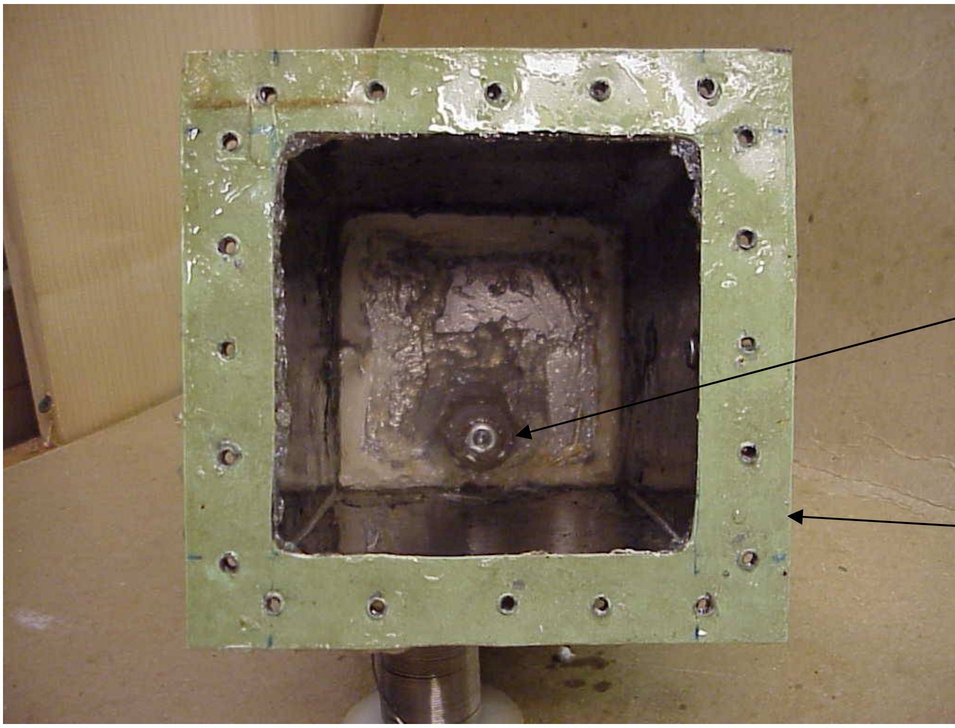
Transformer Primary

Front View



HV banana terminal

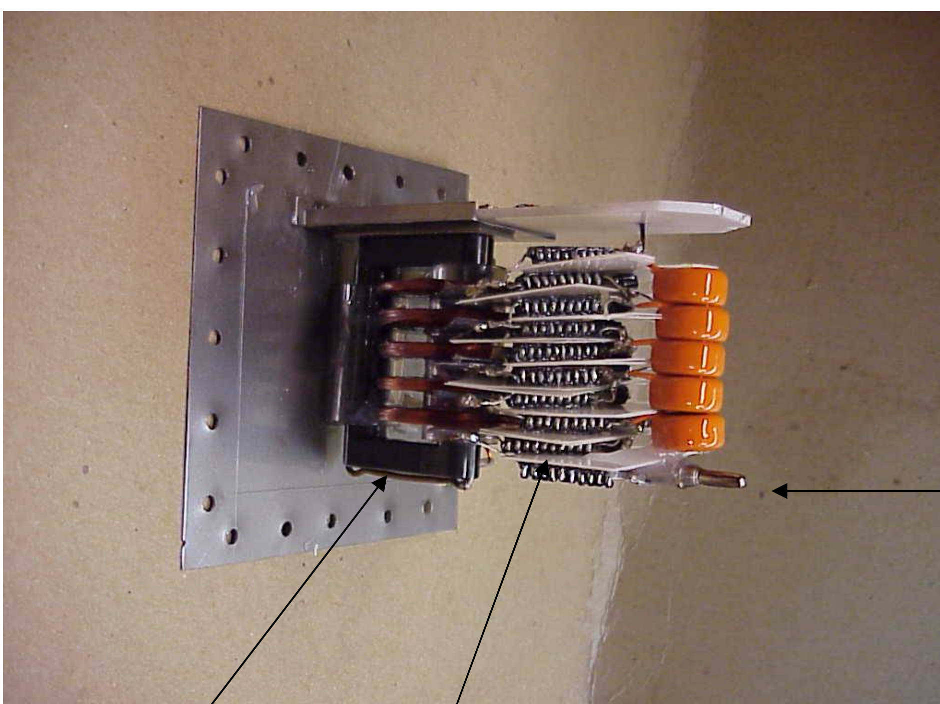
HV Tank



HV OUT banana socket
transformer assembly plug IN

Oil gasket

Transformer assembly \ side view

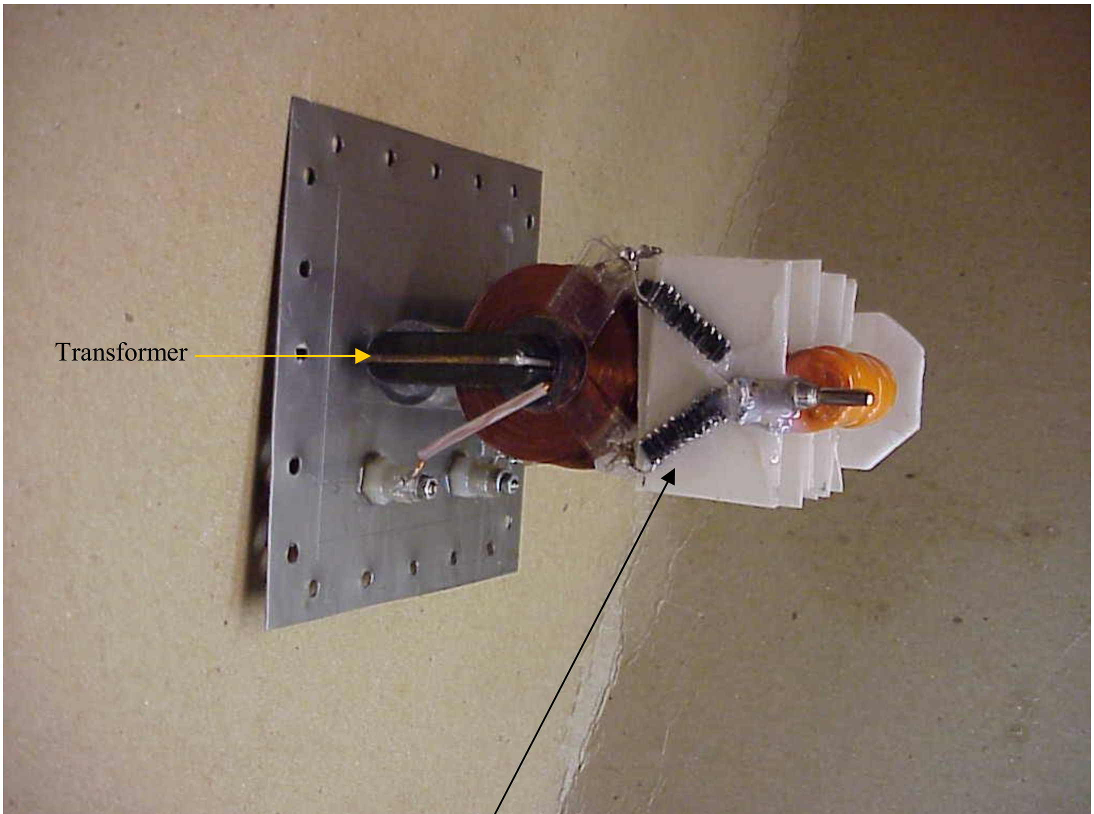


HV out banana plug

transformer

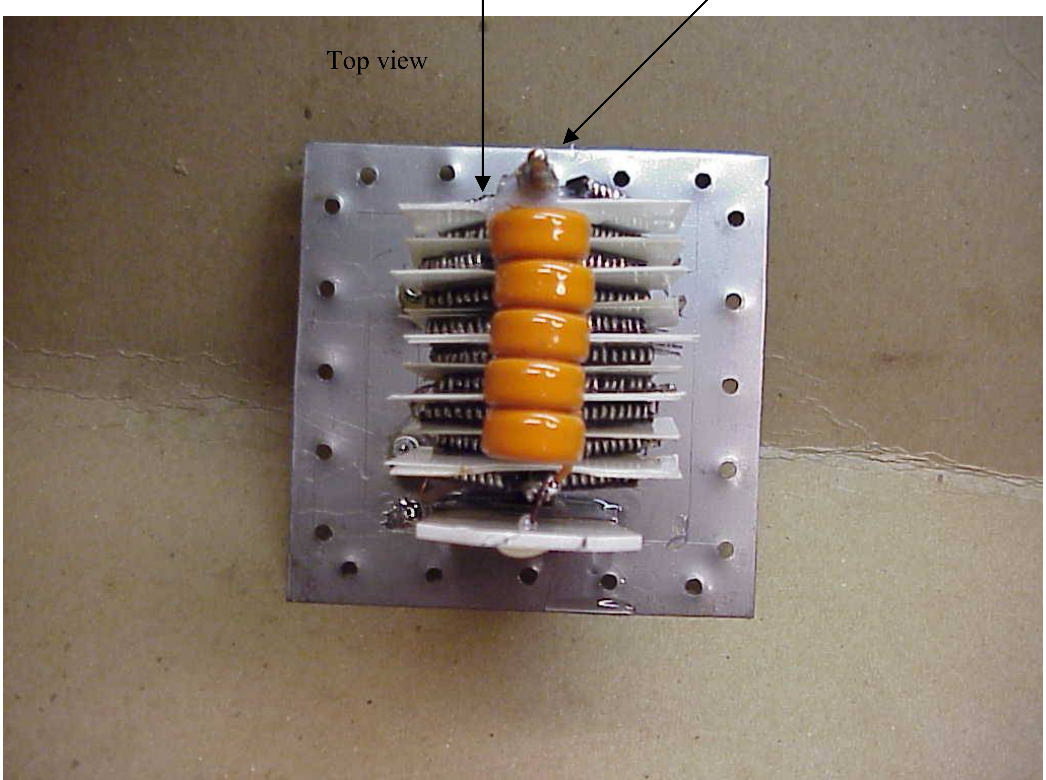
HV Bridge rectifiers

Side view

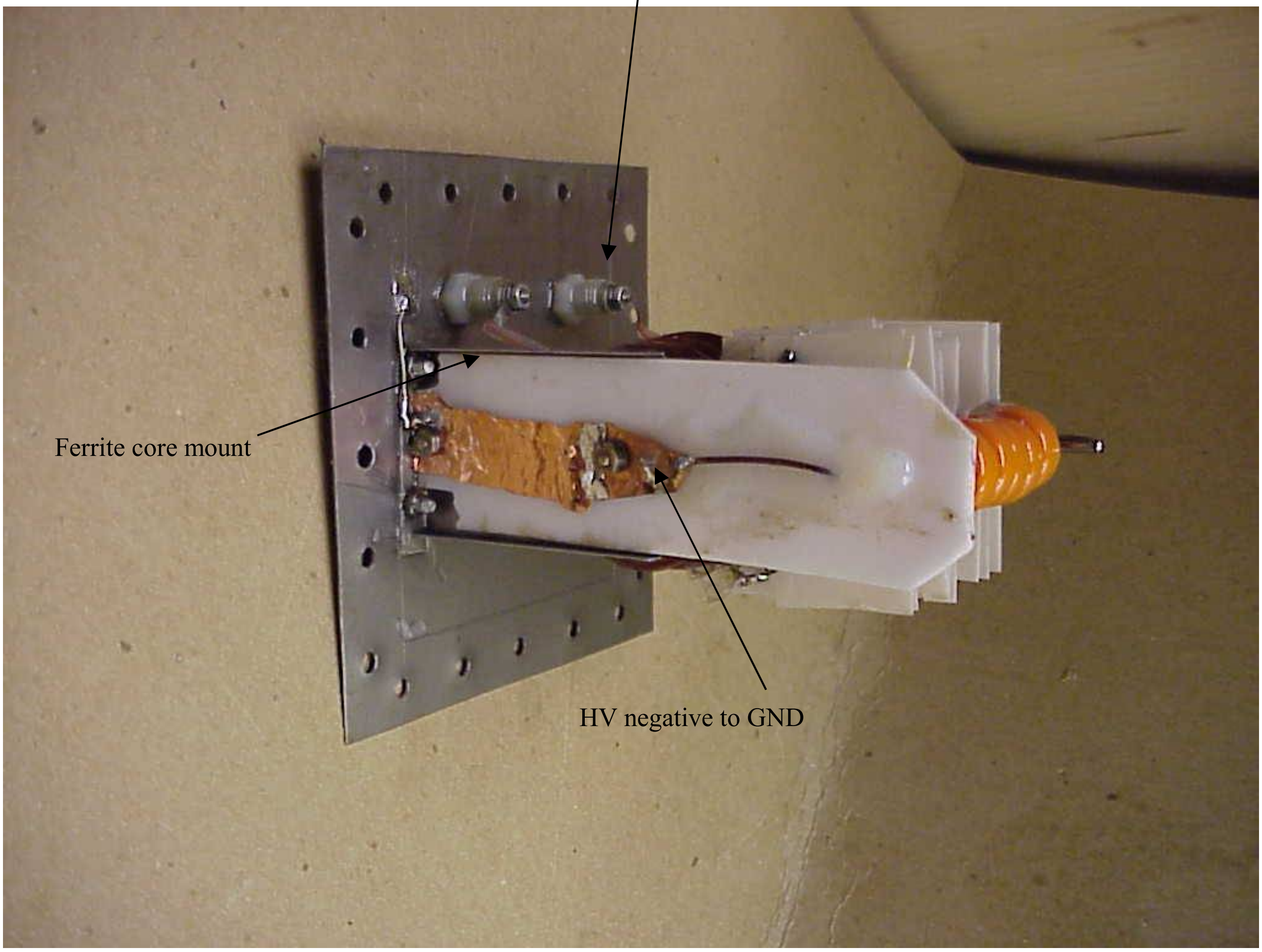


Bridge rectifiers

HV banana terminal



Top view


Primary terminals
Ferrite core mount
HV negative to GND

Background:

Referring to the ……. two references* are given regarding series resonance HVPS and to MAGNETS ferrite power rating equations etc(http://epaper.kek.jp/l02/papers/mo471.pdf). The first provides methods for calculating the required series resonance L & C for specific charging rate; switching & resonance frequency. Based upon the desired HV out vs voltage in the transformer turns ratio can be determined. The latter reference provides information regarding the power rating of a ferrite transformer core and the number of turns.

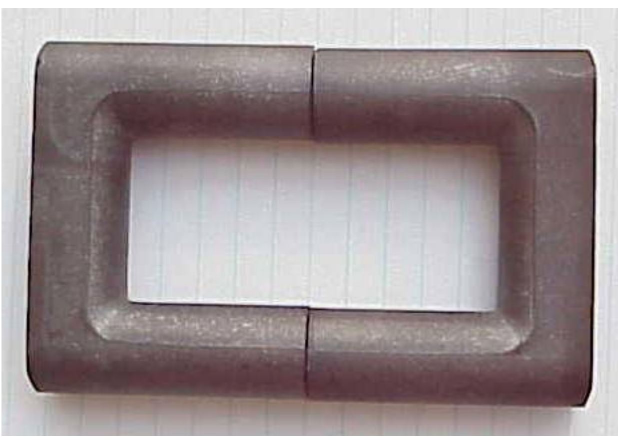
Purpose:

The above information is being used for designing a 10kJ/s CCPS; the core are on order; in the meantime a small ferrite UU core (from this investigator's at home scavenged parts) was targeted to test out the above information in designing and constructing a series resonance CCPS; compare theory to construction.

The Ferrite Core:

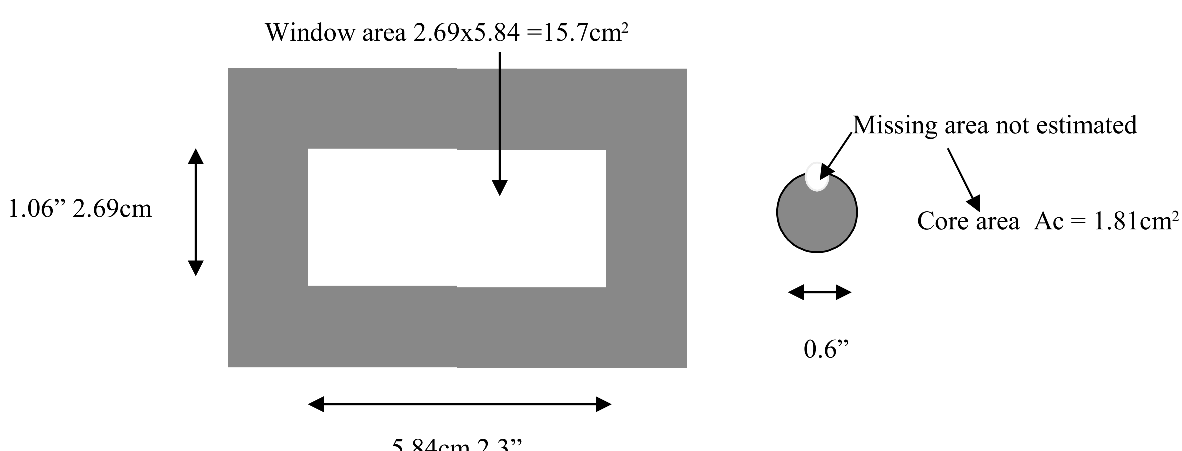
The actual core is already in use in the transformer design; dis-assembling would be inconvenient until testing is completed; the photo shown below is a similar type core (used for illustrative purposes):

Ferrite UU Core



Single U core

Actual dimensions measured are illustrated below:



Hence $W_aA_c = 28.5cm^4$

* Note:

1) "Development of a Capacitor-Charging Power Supply for a Smart Modulator", J.S. Oh, S.D. Jang, Y.G. Son, M.H. Cho, W. Namkung

2) "Development and Application of an Inverter Charging Supply to a Pulse Modulator", J.S. Oh, S.D. Jang, Y.G. Son, M.H. Cho, W. Namkung

INITIAL DESIGN

Estimate Core PWR Rating @ 50kHz (……..):

$$Po = \frac{WaAc\ B\ f}{K'\ 10^8} = [28.5 * 1600 * 5E4]/[5.3E\text{-}3 * 10^8] = 4.\ 3\ kJ/s$$

Target 2kJ/s CCPS => Determine LC

Calculate Resonant Capacitor:

> joules per switching cycle =>> 2E3watts/5E4 hz= 0.04joules/cycle

/__ want 2kJ/s for V min = 300VDC =>> $Eo = 0.5C_R (2V)^2$

/__ $C_R = Eo/ [0.5 (2V)^2] = 0.04/[0.5 (600)^2 = 0.22$ µf

P = foEo = 5E4 X 0. 04 = 2000 Watts

Calculate Resonant Inductor: $f = [2\pi (LC)^{1/2}]^{-1} \Longrightarrow L = [C (2\pi f)^2]^{-1}$ =9.22E-6 F = 46µh

Comment ==> don't want the transformer primary stray inductance greater than this value

/_ $I_{AV} = 2/\pi * Ip$, $Ip = V_{DC}/ Z$, $E_R = 0.5C_R (2V_{DC})^2$

/_ $Z = (L/C)^{1/2} = (4.6 E\text{-}5/2.2 E\text{-}7)^{1/2} = 14.4$ OHMS

/__ Ip = 300/14.4 = 20.8 AMPS peak

/__ $I_{AV} = 2/\pi * 28.8 = 13.2$ AMPS avg

/__ $Po = 0.5\ V_{DC} * I_{AV} = 1/\pi (V_{DC}^2/Z) = f_R E_R$

/__ $Po = 0.5\ V_{DC} * I_{AV} = 0.5 * 300 * 13.2 = 1989$ W

/__ $Po = 1/\pi (300^2/14.4 = 1989$ W

/__ Po = 5E4 * 0.04 = 2000 W

Comment: cross check calculations ^^

Get Primary Turns:

I asked ….. to investigate the constant 4.44 used in the Faraday equation (……..) for applied sine waves to the primary (have series LC resonant drive) => E is the rms not peak ie if use 300VDC must use .707* 300 =212; at 50kHz switching frequency use +/_ 1600 Gauss

$E = 4.44\ BAc\ Nf \times 10^{-8}$ (sine wave) B => gauss, Ac => cm^2

300VDC IN

/__ N = 212 /[4.44 * 1.6E3 * 1.81 * 5E4 * 1E-8 = 33 T

Secondary Turns: @ 300 VDC IN assume 50 kVmax =>> 166:1 turns ratio ==>33 * 166.7 = 5500 turns sec

@ 350 VDC IN ==> 58.3kV max

Seemed to be a lot of turns ; decided to lower to 40kv for 300 VDC in

4e4/300 = 133:1 =>> 33*133 = 4400

if have 5 secondary pie windings ==>> 4400/5 = 880 turns each

Construction:

Primary ==> wrapped about two turns of mylar loosely on the core so that it could easily slip off; then 34 turns of # 18 magnet wire was wound on the mylar

Secondary ==> a relatively thick plastic tube (dimensions will be given later) fits over the primary winding to insulate the secondary from the primary; a pie coil winder was used to wind the five secondary pies (due to differences in the pie width the # turns varied
ie 800+ 780 +900+ 677+ 750 = 3907 hence 3907/34 = 115 :1 turns ratio

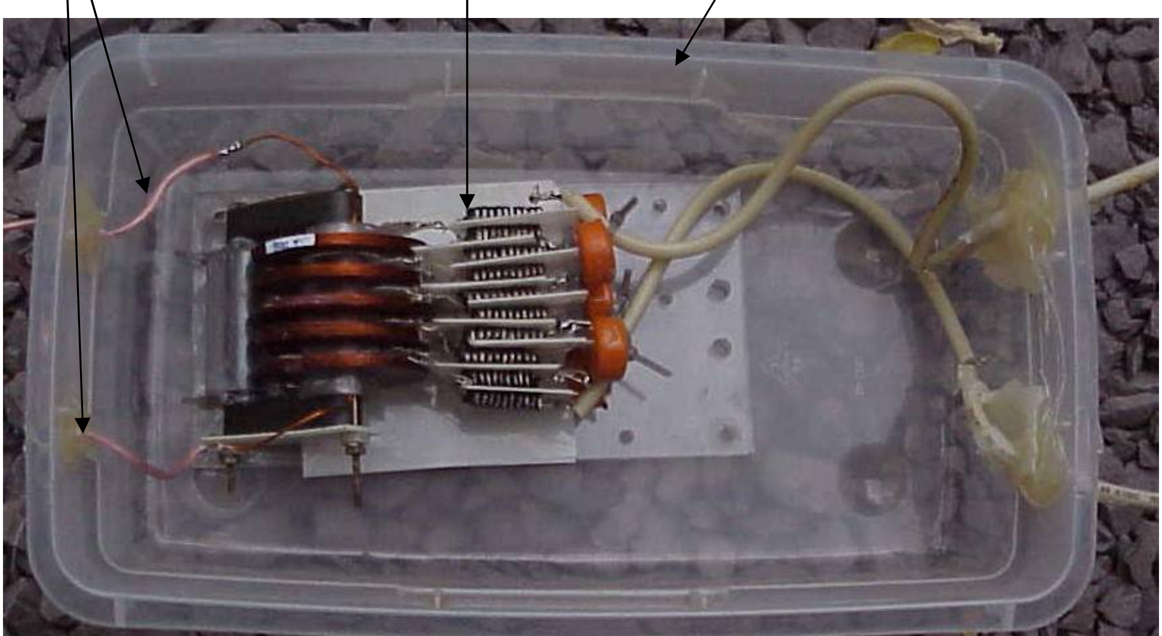
//__ 300VDC * 115 = 34.5kv ; 325VDC => 37.4kv
/__ good enough to test charging rate

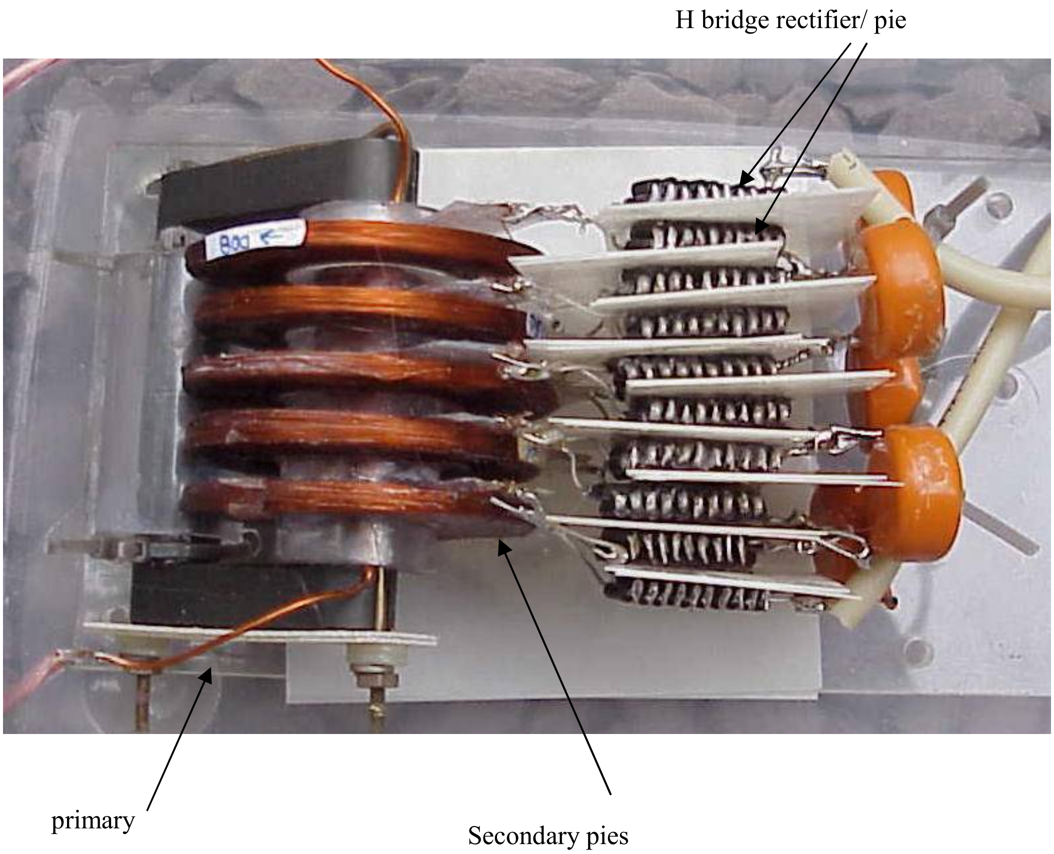
Measurements: > primary (open secondary) =>> 1mh primary stray inductances (each pie shorted) => 35µh
/__ I am not that good just lucky!

> measure resonance with a capacitor in series with the primary to determine resonant freq & to verify that if C is known then calculate L ==> see if it matches L stray as expected.

1µf => 29Khz res; 0.47 µf => 43Khz ==> L calculated close to L stray

> connected 0.47 µf to primary ==> to full H bridge drive (30VDC in); shorted HV out varied Fsw ==> AMP meter peaks at about 45kHz; next bring HV output wires close =>> get heavy HV arc





Comments:

> asked John to look into the equations used for estimating stray inductance; will help in design the coil distribution form and shape

> chose not to add external 11μh inductance to reach the targeted 46 μh ; use Lstray

> if use 0.4 μf for C and L stray then the LC impedance is 9.7 ohms; rasing the charging rate to 2.9kJ/s

/__ might be a bad idea if have severe residual magnetism walking to Bsat (IGBT killer)

/__ don't have current feed back to correct walking

> plan testing tomorrow "may the gods look favorable to me!"

Photo\ Transformer components

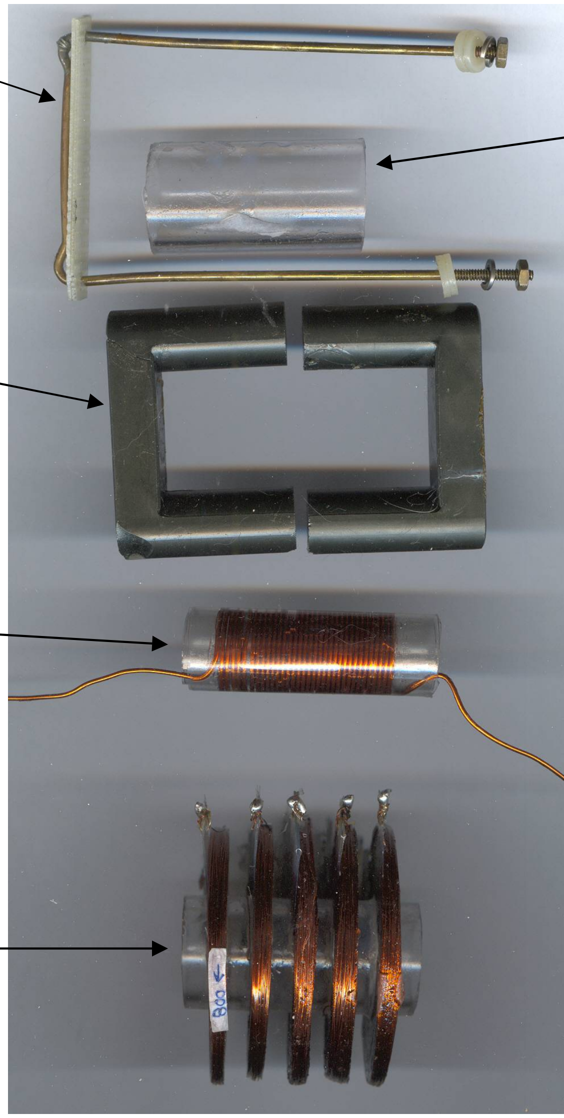
Ferrite UU clamp

Lower ferrite cover

UU ferrite core

primary

secondary



ACTUAL SIZE

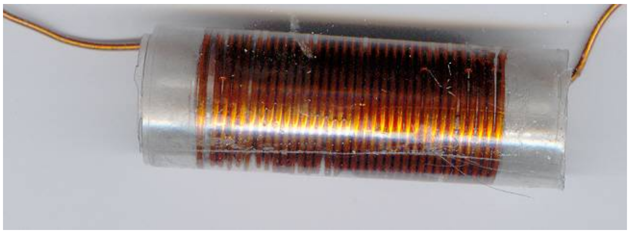
Side view

End view

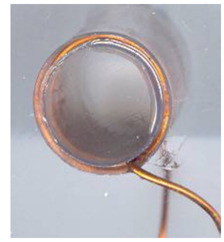
Ferrite UU core

PRIMARY ACTUAL SIZE

Side view



End view

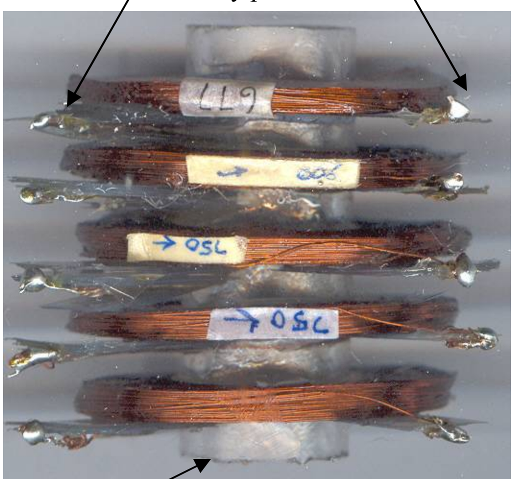


Pri => 34 turns

SECONDARY ACTUAL SIZE

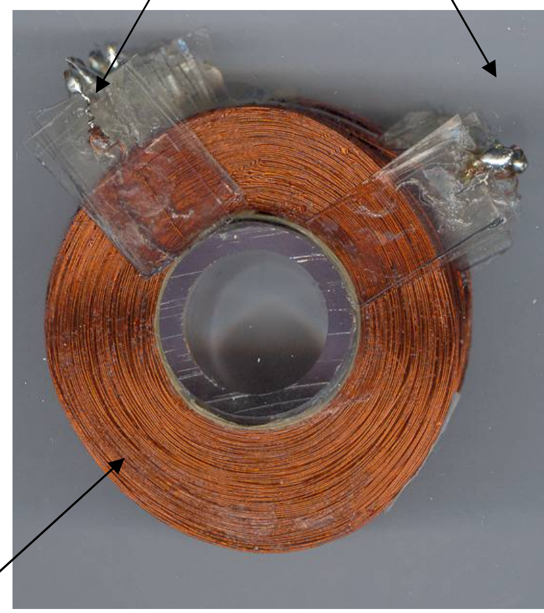
Secondary pie terminals

3907 turns total

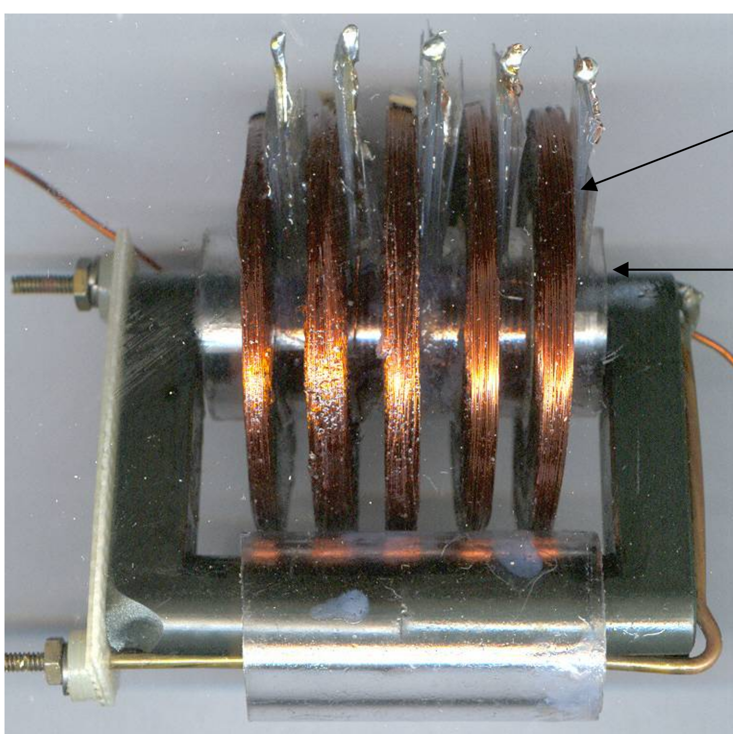


Plastic tube

Secondary pie terminals



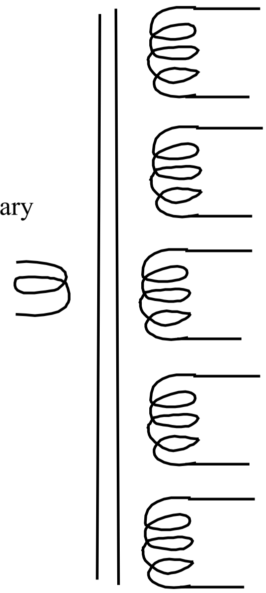
32 gauge magnet wire



secondary

primary

Transformer diagram



Measured primary inductance

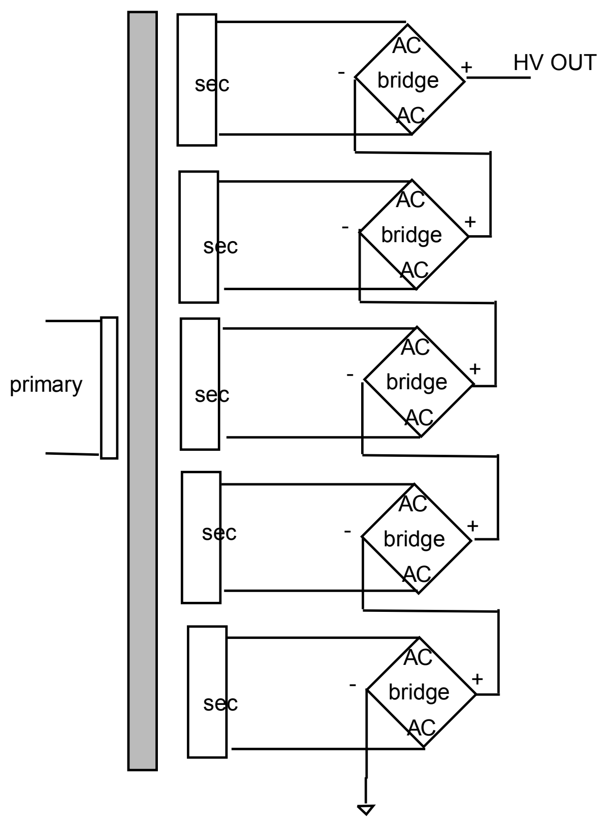
> all pies open

/__ 1.1 mh

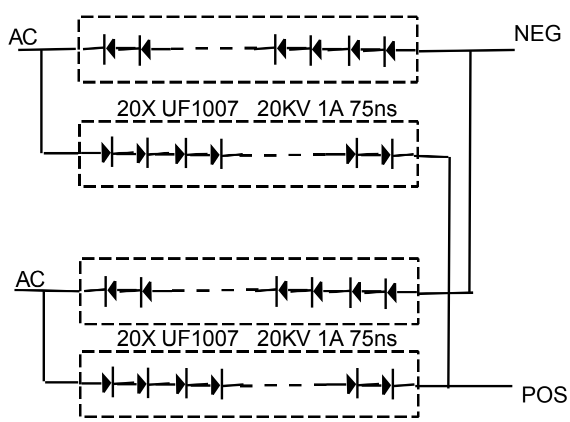
> each pie output terminals shorted

/__ 36 µh

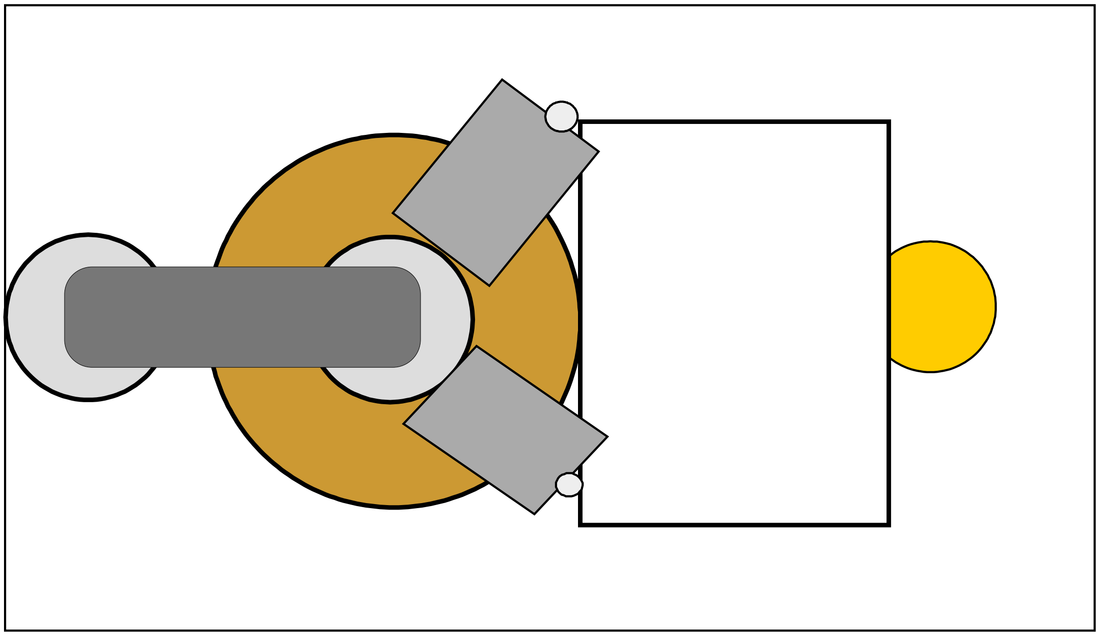
Schematic of Transformer Assembly



Each bridge assembly



Initial Oil Case Design



PIV	20 KV
I continuous	1 AMP
t recovery	70nsec
insulation & coolant - OIL