Fermilab

Particle Physics Division
Mechanical Department Engineering Note

Number: MD-ENG-*076* Date: *2/18/05*

Project Internal Reference: ***400***

Project: ***CMS Low Voltage***

Title: Power ***Supply Rack Stack / Housing, Cooling Evaluation***

Author(s): ***Ed LaVallie***

Reviewer(s):

Key Words:

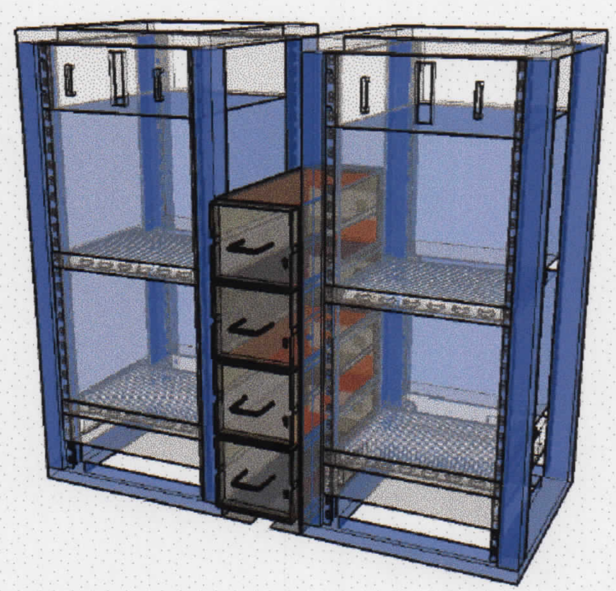
Abstract Summary: ***As this project has been terminated at least for the moment, included is a summation to this point, on the chance that it could be restarted a some future date.***

Applicable Codes:

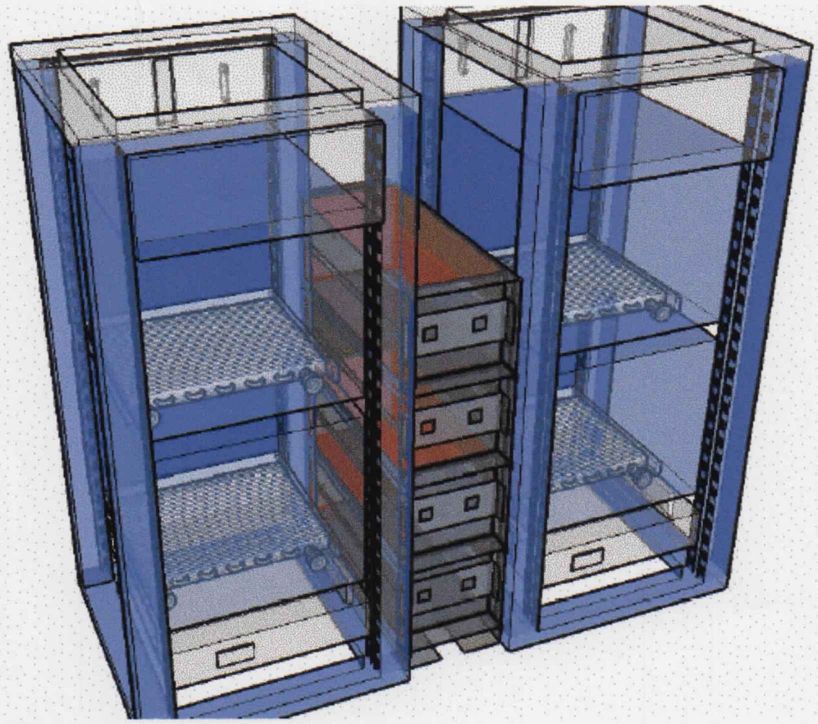
Summation Engineering Note (at project stoppage) 02/01/05
CMS LV Power Supply
48V AC-DC Converter
Housing/Rack Stack/Cooling status, to date

Persons involved on this project are: Sergei Lusin (Project Manager at CERN), Leon Beverly, Walter Jaskierny, David Huffman, Johnny Green (Electrical Eng.) and now I, Ed LaVallie (Mechanical Eng.).

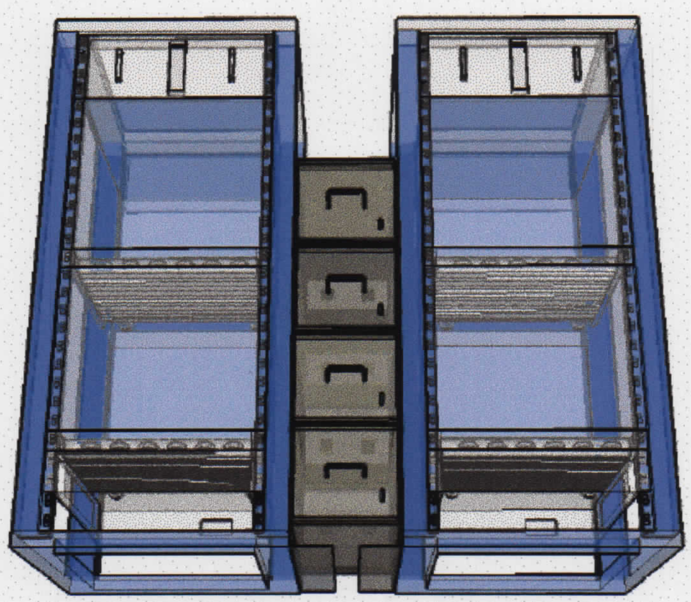
My initial contact with Sergei was during the first week of December 2004, via: phone from CERN at which time he verbally gave me a rundown on what he was trying to accomplish accompanied by a half dozen 3D sketches he forwarded through e-mail. Sketches P1 thru P3 refer to a short stack which I believe is a special case, P4 thru P6 are some detail of a standard rack stack (see attachments), which he indicated should be used as a general guide. Sergei also,via. e-mail sent me some links to allow me to access information on CERN experimental racks which I was unable to do initially. To make a long story short I had to become part of the collaboration to gain access to this information which I did. (a lengthily process). Drawings finally imported from CERN were Rack 9056-01 and Rack 9056-02 and not included in this electronic note version.



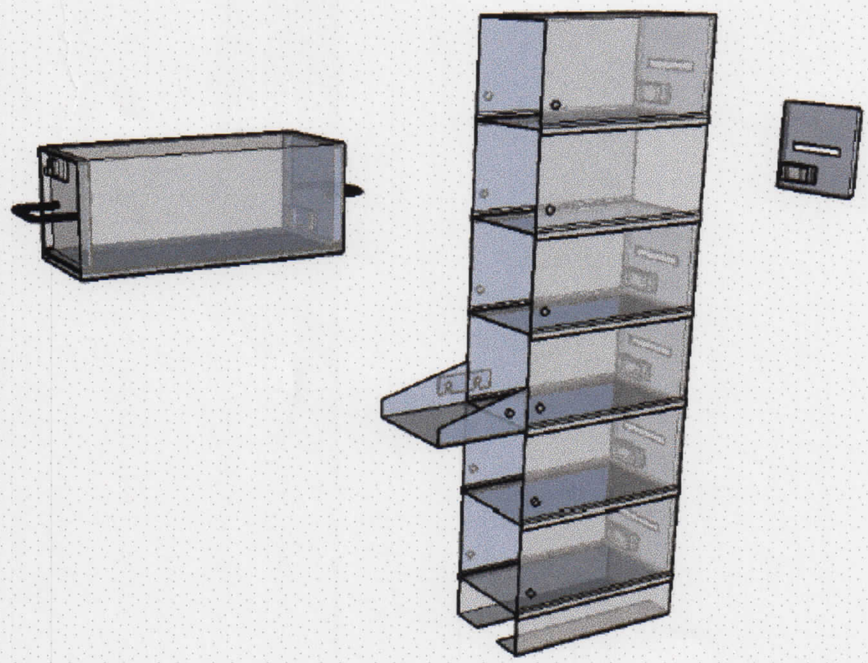
Lusin Drawing P1



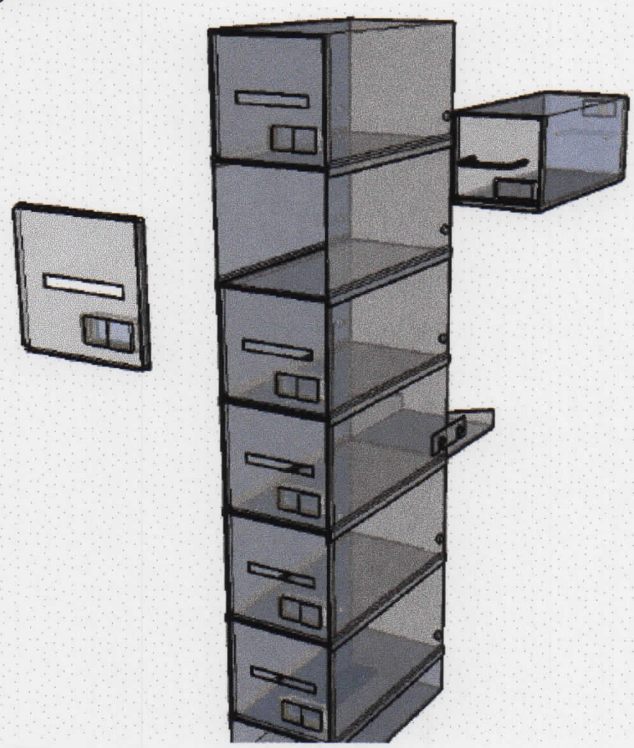
Lusin Drawing P2



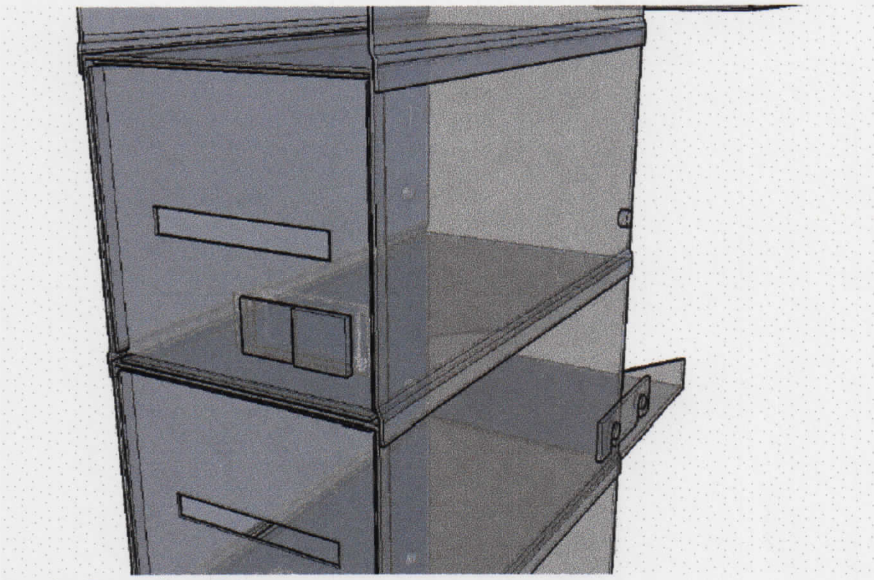
Lusin Drawing P3



Lusin Drawing P4



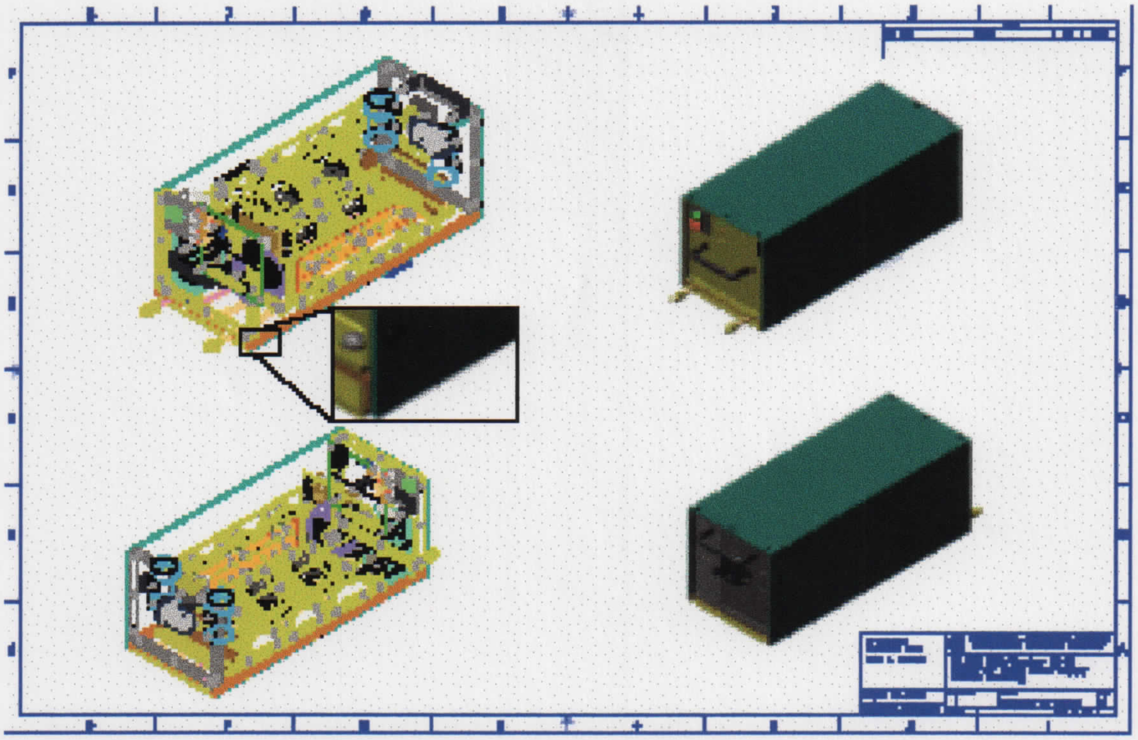
Lusin Drawing P5



Lusin Drawing P6

From the outset of my involvement and even now at closeout, all existing prototype power supplies assembled to date of this voltage are what I will refer to as internally cooled (water cooling that is integral to the power supply itself). With this kind of a scheme all water connections need to be made up from the aisle (loading side, front) of a rack stack, as access to the rear in most locations would I'm told be near impossible. Upon removal of any power supply for whatever reason, water would need to be disconnected. Details of these power supply parts are at link listed below supplied by Dave Huffman. As there are many details I will only include the assembly drawing #3892.136-MD-330512 (below).

http://www-ppd.fnal.gov/EEDOffice-w/Projects/CMS/LVPS/ecal/m3000.html



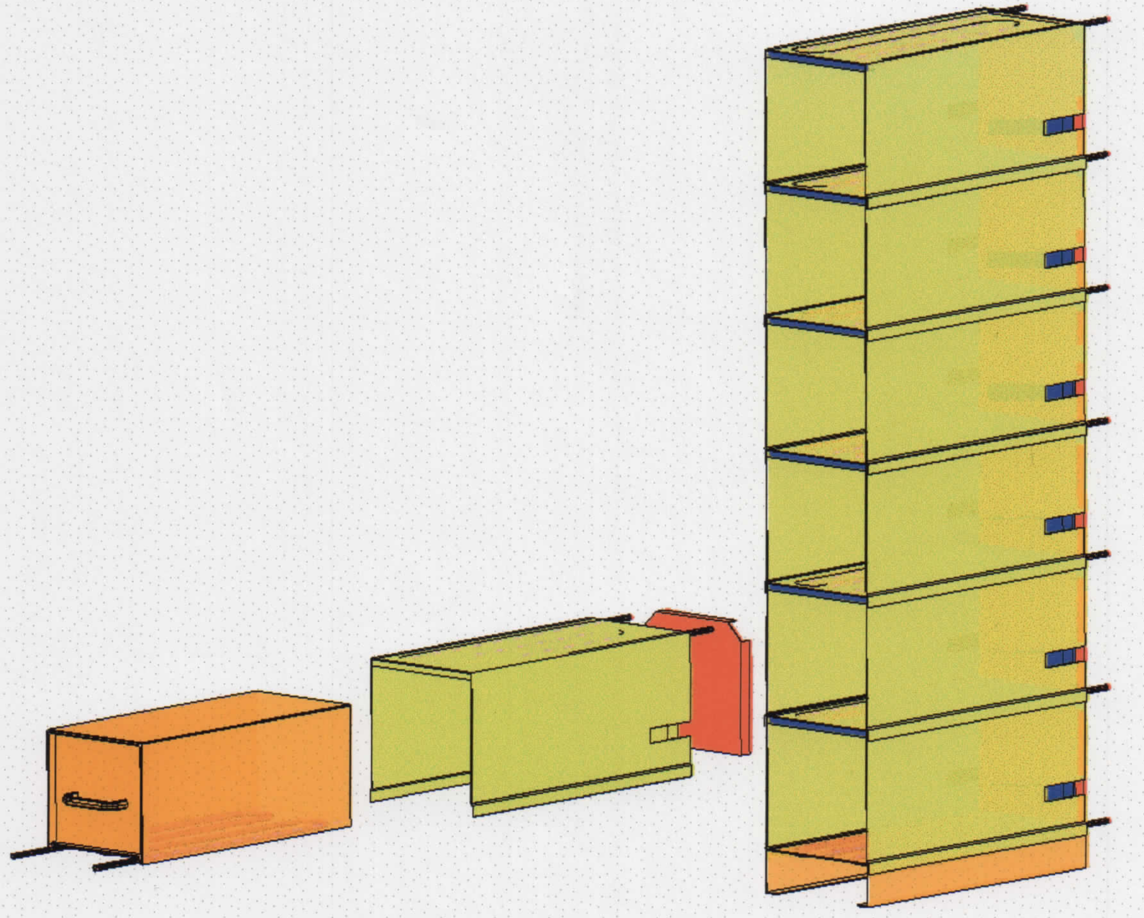
Regardless of this current internal water supply status, it has been further stated that there would potentially be space saving and connectivity advantages to external water cooling (water cooling would be integral to the rack stack, not the power supplies). This type of cooling would require intimate contact between power supply component mounting plates and stack housing cooling plates. To my knowledge, no heat transfer testing has been completed for this type of approach. As the power supplies are still in a state of flux both of these avenues need to be explored and evaluated. Note: typically power supplies are air cooled using fans, but due to the strong magnetic fields around the experimental magnetic, I'm told motor driven fans would not work, thus the need for water cooling.

For information purposes it has been stated that the quantity of power supplies required would be in the hundreds, therefore mass producing power supplies as well as stack housings would definitely need to be a consideration in the design (cost per unit/ simplicity of fabrication). At this point I do not know the exact quantity required. It has also been stated that as the rack stacks, either internally or externally cooled would in most cases be sandwiched between structurally substantial experimental electronics racks which they serve, that these racks could be used to stabilize the rack stack column as necessary.

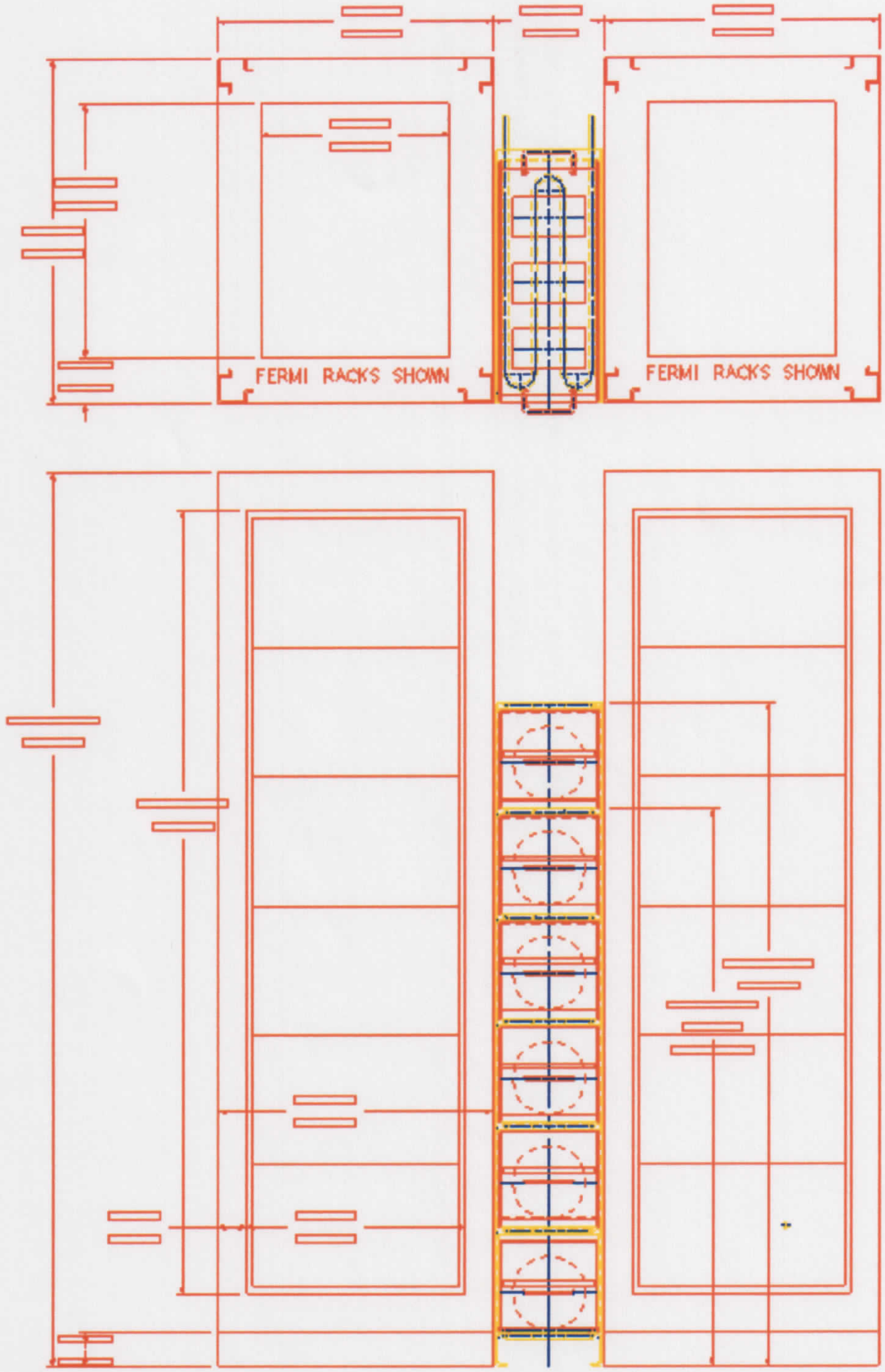
After looking at the sketches received and getting some general dimensions from the existing prototype Power Supply I looked into standard commercially available structural cross sections from which to make the housing surround, which proved to be fruitless in steel or aluminum. I also looked into forming a non standard aluminum extrusion (square or rectangle) for this purpose but the crossectional dimensions of the prototype Power Supply were slightly too large (extrusion shape must fit into a 12" diameter circle to be feasible). Had the cross section fit this would have been a simple cost effective way to go with a large quantity (diminishing die cost per unit). I was also hoping to use a closed section for strength and stability as opposed to a sheet metal open section formed and spot welded as the CERN sketches suggested. As it turn's out the sketches are more then a guide, but the direction that Sergei wants to go in, due to simplicity (few parts), and I am being asked to make it work.

As the sketches I received are dimensionless conceptual thoughts, I will look at the existing prototype power supply and use that as a start point for the design of rack stacks. As geometry, clearances and a guidance system to make up a non-visible electrical connection are the first issues to be addressed; anything I propose will be conceptual in nature.

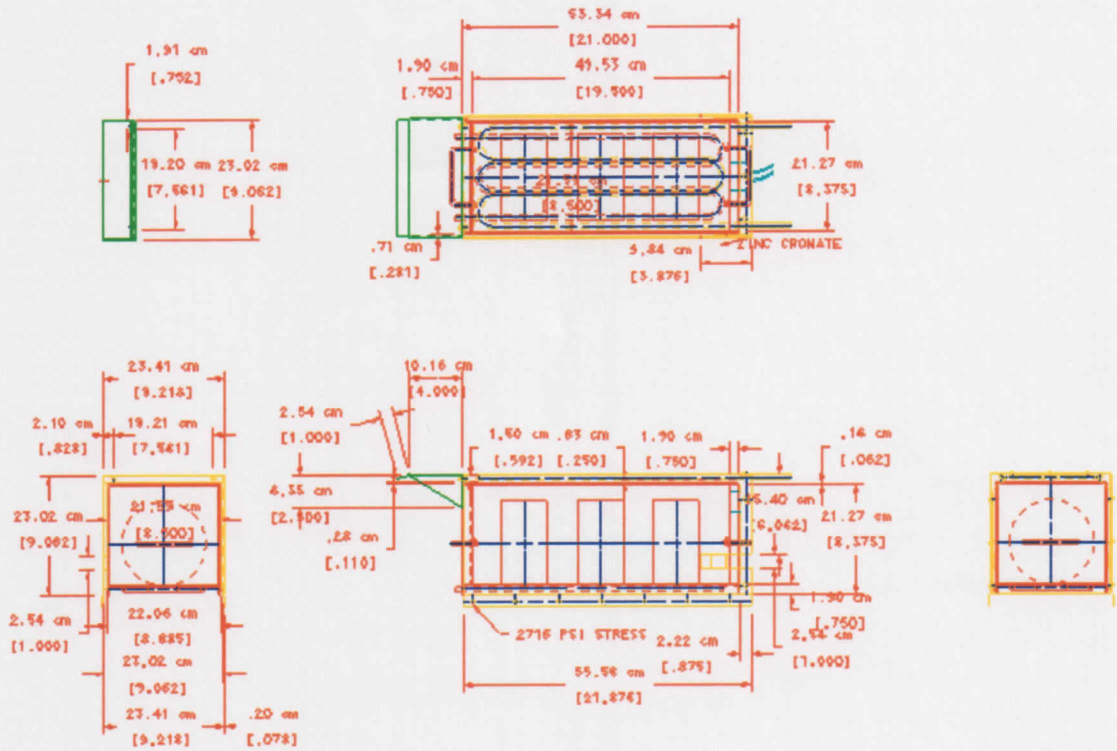
Now, the first scheme I looked at was externally cooled power supplies (cooling in stack racks) as this had the advantage of not disconnecting/reconnecting water for service or exchange. Sergei wanted to define & fabricate a prototype, standard 6 unit standard rack stack for show and tell at CERN. As no externally cooled power supply exists as yet, I was asked to base the design on individual slots capable of accommodating an internal cooled power supply which does exist at this time and the larger due to its internal cooling circuit. As for an externally cooled power supply this would require a feasibility, cost study, and heat transfer testing to understand if this is a viable alternative. With this kind of approach the experiment would get a look at both schemes in regard to cooling geometry requirements prior to carrying out such a study. My initial observation was that if we adhere to a formed sheet metal enclosure it would be very difficult to make intimate contact between a formed piece to which the cooling is attached and the mounting plate for power supply components even using some very pliable heat transfer material which was suggested (tight tolerance requirements). See assembly and sketches for external cooled rack stack attached.



Externally Cooled Rack (cooling internal to rack stack itself)



Externally Water Cooled Rack Stack Arrangement



Externally Cooled Rack Assembly

Perhaps due in part to my skepticism about heat transfer and what appeared to be an increasing need to have something designed, fabricated, built and shipped I was stopped on this approach and asked to concentrate entirely on a bare bones standard rack stack for an internally cooled power supply, front loaded, without cooling or any guidance system to make up the plug in hidden electrical connection.

I immediately moved in this direction with the following being the direction and results:

1. No water cooling would be provided with this scheme.

2. No guidance system would be provided with this scheme, with exception to punched hole in back closure panel for relief of power supply lifting handle which will act as a crude guide due to handle radius and a relatively close fit.

3. And a typical standard rack stack would be made up of 6 units.
To that end

4. Six power supply surrounds would fabricated from formed sheet metal (steel), with flanges both sides of front face, a formed top front edge for structural stability and punched holes appropriate for joining/assembly purposes utilizing rivets.

5. Six back closure panel would be fabricated from formed sheet metal (steel), with flanges all sides for structural stability and punched holes for joining/assembly purposes using rivets. This back panel would also have punched holes appropriate for the attachment of electrical connector and lifting handle clearance guide

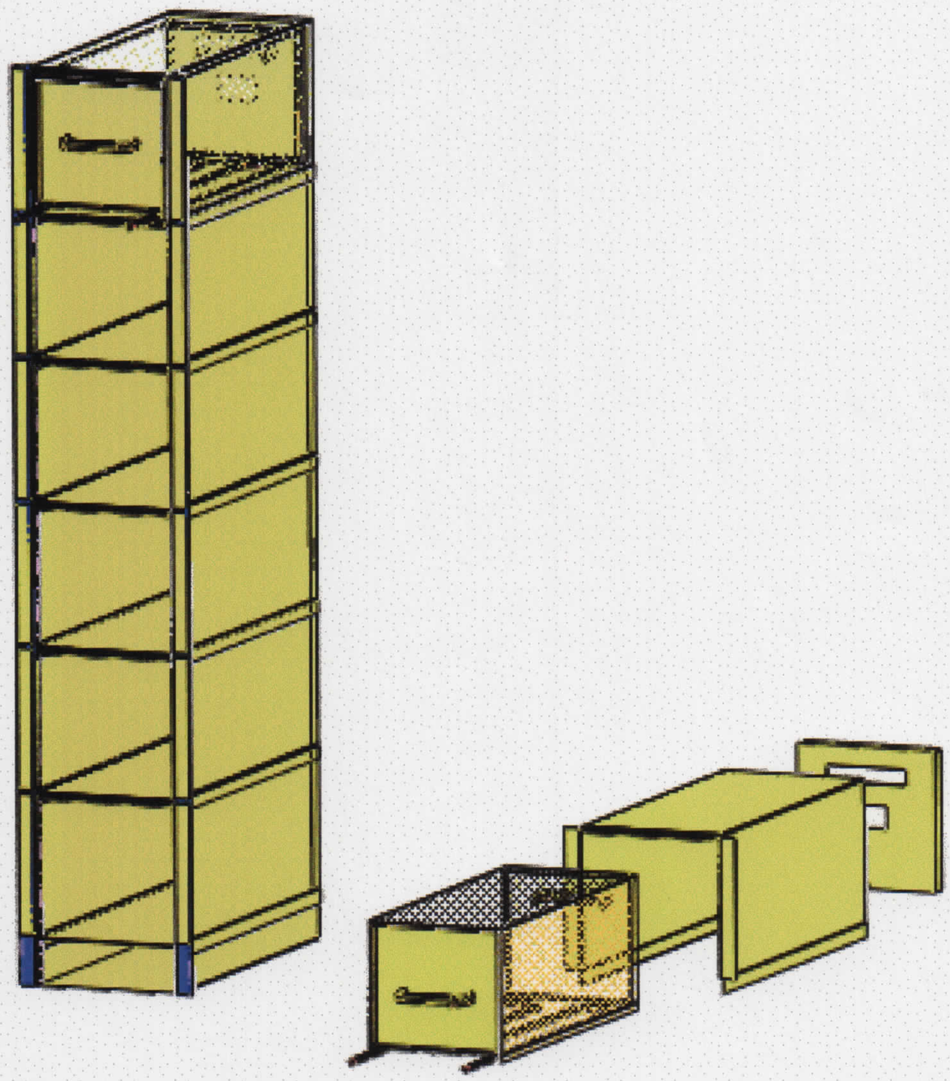
6. Two angles at front face would also be needed for structural and assembly purposes and would be, 1 x 1 x 1/8 also requiring holes appropriate for assembly with rivets and hardware for loading tray.

7. Items #4, #5 and #6 would be joined to each other by means of rivets, making up a standard 6 unit assembly, special cases are not addressed herein.

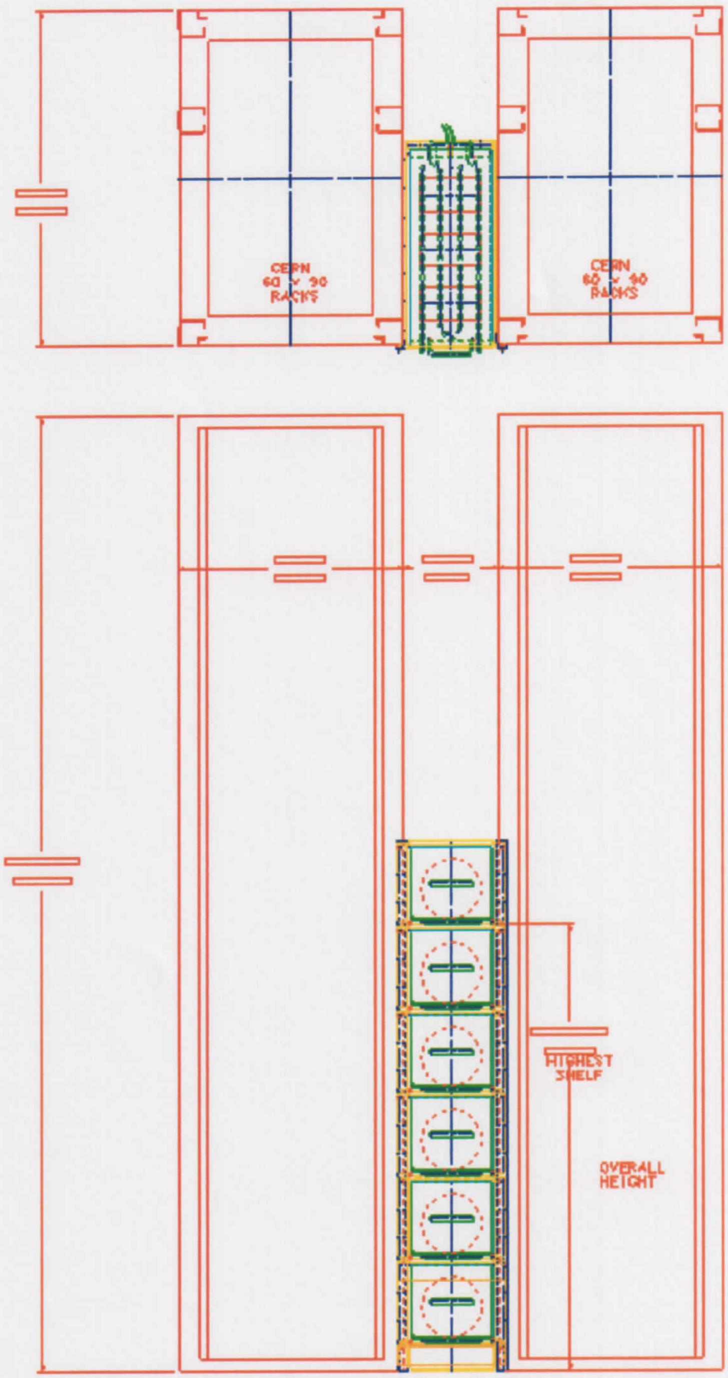
8. As space will be tight there is a need for a loading tray for purposes of inserting and withdrawing power supplies from slots which would also be fabricated from formed sheet metal (steel), again with slotted holes appropriate for attachment. This particular item would not be permanently mounted but be used universally on all rack stacks. Some quantity will be needed, unknown at this time.

As this is a summation (project stoppage) I have listed the following sketch attachments illustrated to date for reference:

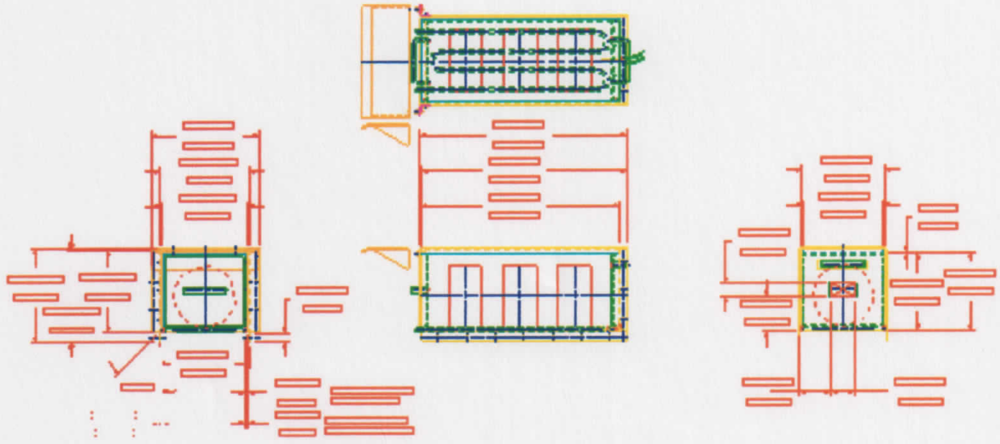
a. Assembly sketch of standard rack stack sandwiched between two CERN experimental racks.
b. Assembly of an individual unit.
c. Drawing of a surround.
d. Drawing of back closure.
e. Drawing of typical angle (right and left will be required)
f. Drawing of a tray.



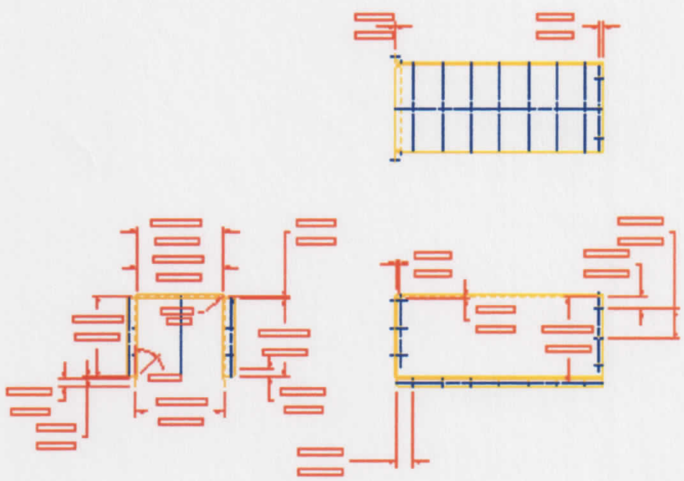
Internally Water Cooled Rack Stack Arrangement



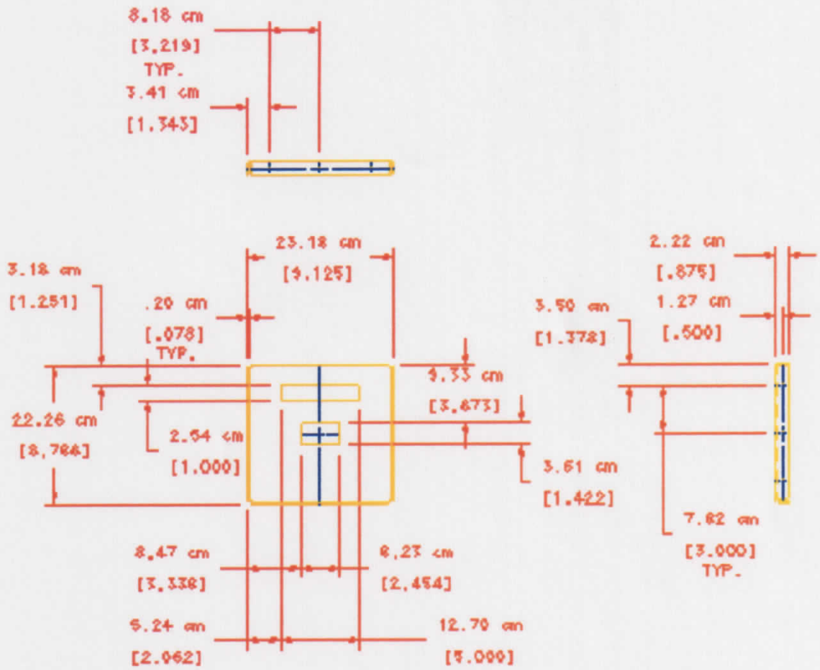
Internally Cooled Rack Stack Arrangement



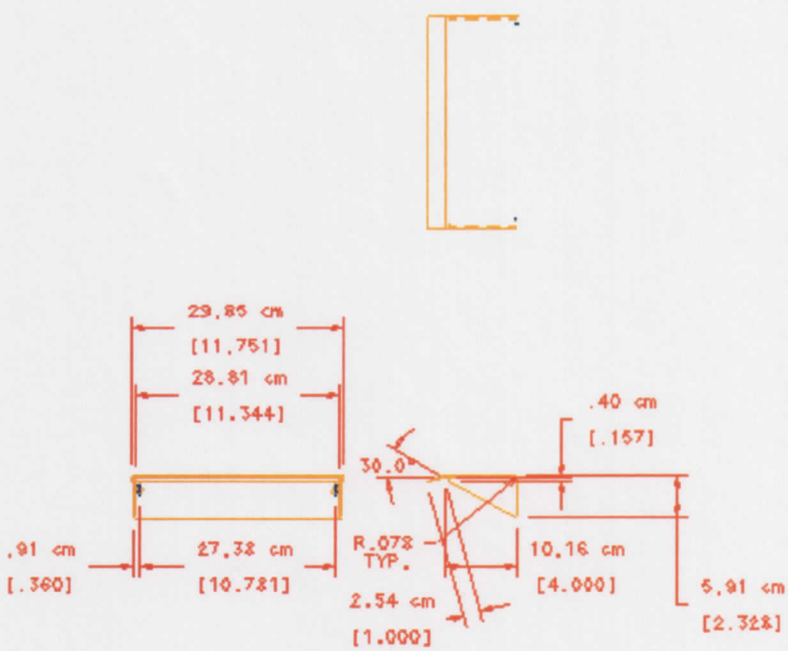
Internally Water Cooled Rack Assembly



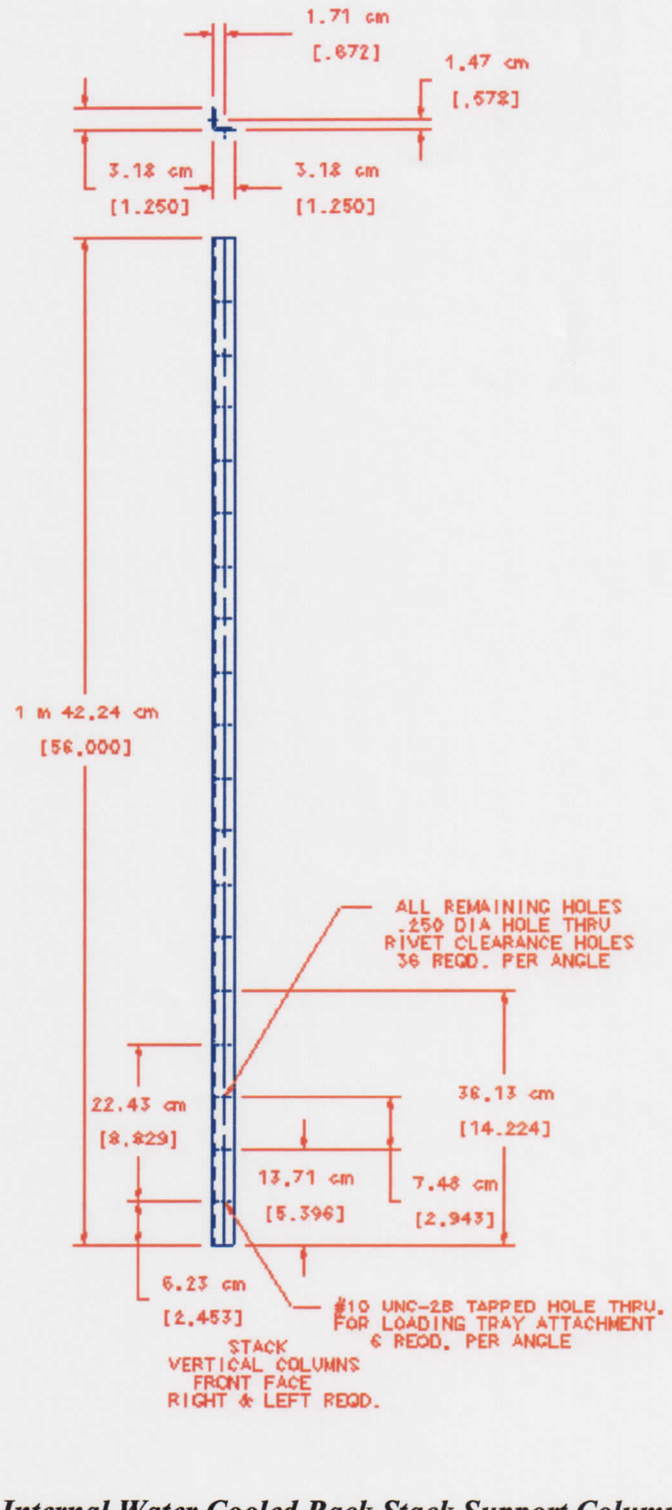
Internally Water Cooled Rack Surround



Internally Water Cooled Rack Back Panel



Internally Water Colled Rack Loading Tray



Internal Water Cooled Rack Stack Support Columns

As a design has never been finalized all information her-in is for reference purposes only, including the following preliminary calculations.
Estimated weight of one power supply 110#, per Dave Huffman

Estimated weight of current single formed sheet steel slot enclosure surround (9" x 10" x 22"), utilizing .08" material.

(10 + 9 + 10) x 23 x .08 x .281 = 15#
11 x 11 x .08 x .281 = 2.72#
Total weight of enclosure = 18#

Estimated weight of vertical angle iron 1 x 1 x 1/8 x 56.5" long 4.7' x .8# = 3.77# ea.

Estimated weight of standard stack rack with power supply = (110 + 18 + 4 + 4) x 6 units = 816# plus unknowns (hoses electrical etc) say 1000#

Proposed material due to good forming characteristics and surface finish: A-366 Commercial Quality, low carbon, cold rolled steel with electrodeposited Zinc and Type 2 Yellow Cromate for corrosion resistance and appearance. 52000 Tensile, 32000 Yield

Sheet steel front quadrant particulars using TK Solver (Roark & Young).

Status	Input	Name	Output	Unit	Comment
					Roark's Formulas for Stress and Strain
					Properties of Sections
					Section 2: Rectangle
		DIAGRAM	'y		Generate section diagram? ('n = no)
	2	axis			Neutral Axis (1,2)
	.08	t1b		in	Side b
	11	t1d		in	Side d
		A	.88	in^2	Area, A
		t1y	.04	in	Centroid to Extremity, y
		I	4.6933E-4	in^4	Area moment of inertia, I
		I%c	1.1733E-2	in^3	Elastic Section Modulus, I/c
		t1r	2.3096E-2	in	Radius of Gyration, r
		Z	.0176	in^3	Plastic Section Modulus, Z
		SF	1.5		Shape Factor, SF
		t	.08	in	Depth

Compressive load on weakest sheet metal quadrant (front 11" x .08") F/A = (1000# / 4) / 0.88 = 284 psi Slenderness ratio (from above/no reinforcement) = L / r = 9 / .023 = 391.3, too large must be <120

Slenderness ratio (front quadrant with break, 11" x 1" x .08") = l / r = 9 / .154 = 58.44 < 120, OK

$r = \sqrt{I / A}$
$= \sqrt{.02264 / .954}$
$= .154$

$A = t (a + b - t)$
$= .08 (1 + 11 - .08)$
$= .954$

$y = a - ((t (2c + b) + c^2 \} / \{ 2 * (c + b)))$
$= 1 - \{\{.08 (2*.92 + 11) + .92^2 \} / \{ 2 (.92 + 11) \})$
$= .921$

$I = \frac{1}{3} \{t*y^3 + b (a - y)^3 - (b - t) (a - y - t)^3 \}$
$= \frac{1}{3} \{.08* .921^3 + 11 (1 - .921)^3 - (11 - .08) (1 - .921 - .08)^3 \}$
$= .02264$

Slenderness ratio for 1" x 1" x 1/8" angle iron (continuous vertical support) = l / r = 56 1/4 / .417 = 134.89, marginal >120, try 1 ¼" x 1 ¼" x 1/8" angle.

$r = \sqrt{I / A}$
$= \sqrt{.0408 / .2344}$
$= .417$

$A = t (2 * a - t)$
$= .125 (2 * 1 - .125)$
$= .2344$

$y = a^2 + (a * t) - t^2 / 2 (2a - t) \cos 45$
$= 1^2 + (1*.125) - .125^2 / 2 (2*1 - .125) \cos 45$
$= .4184$

$I = \frac{1}{3} \{t * y^3 + a (a - y)^3 - (a - t) (a - y - t)^3 \}$
$= \frac{1}{3} \{.125 * .4184^3 + 1 (1 - .125)^3 - (1 - .4184 - .125)^3 \}$
$= .0408$

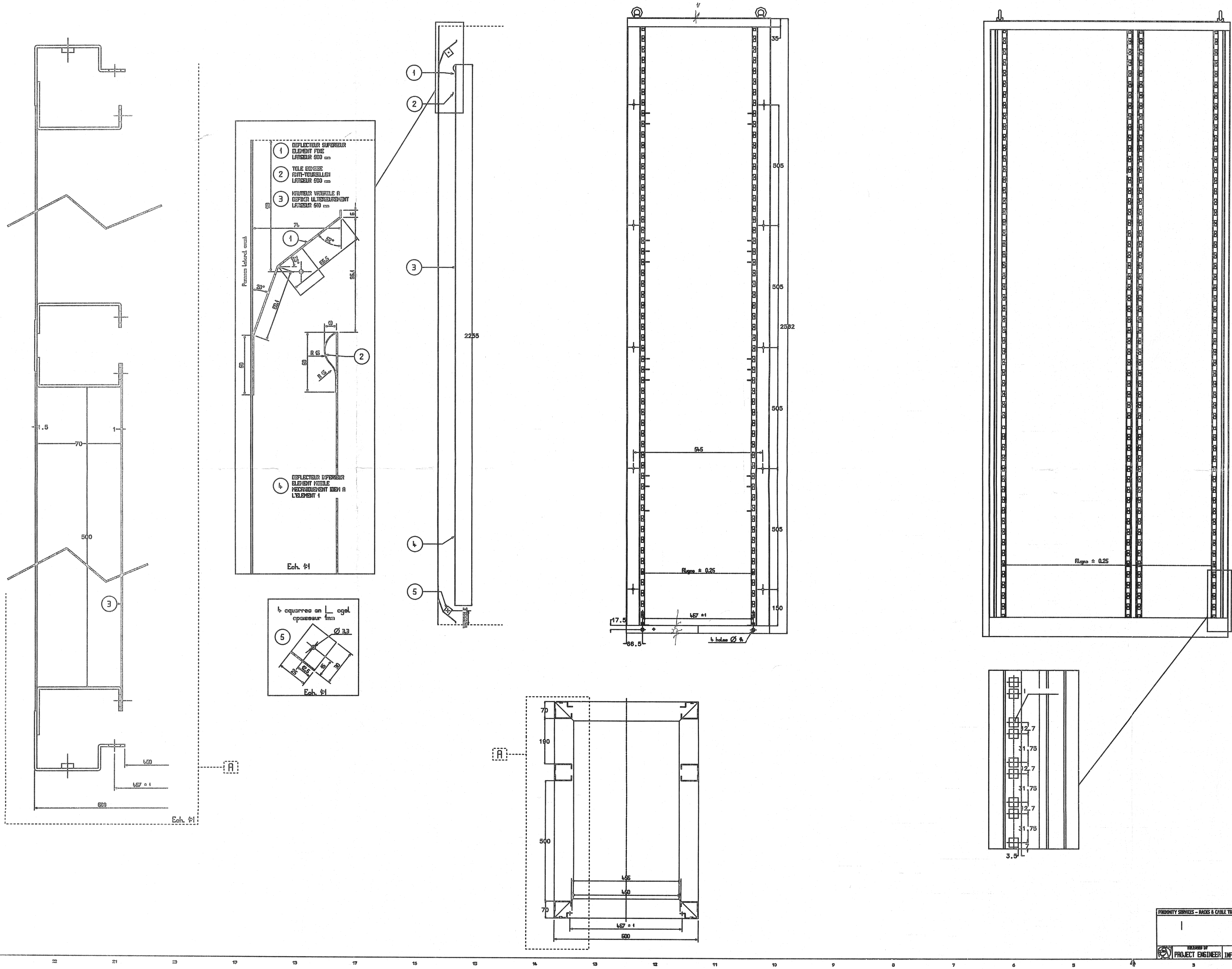
Slenderness ratio for 1 ¼” x 1 ¼” x 1/8” angle = $l / r = 56\ 1/4 / .7699 = 73.06$, OK < 120

$r = \sqrt{I / A}$
$= \sqrt{.176 / .2969}$
$= .7699$

$A = t\,(2a - t)$
$= .125\,(2 * 1.25 - .125)$
$= .2969$

$y = a\text{^}2 + (a * t) - t\text{^}2 / 2\,(2a - t) \cos 45$
$= 1.25\text{^}2 + (1.25 * .125) - .125\text{^}2 / 2\,(2 * 1.25 - .125) \cos 45$
$= .507$

$I = ⅓\ \{t * y\text{^}3 + a\,(a - y)\text{^}3 - (a - t)\,(a - y - t)\text{^}3\}$
$= ⅓\ \{.125 * .507\text{^}3 + 1.25\,(1.25 - .507)\text{^}3 - (1.25 - .125)\,(1.25 - .507 - .125)\text{^}3\}$
$= .176$



FROXIMITY SERVICES – RACKS & CABLE TRAYS FOR THE DETECTOR

SCALE 1:1 1:5 2:1

REPLACE/REPLACES

PROJECT ENGINEER | FOR INFORMATION | – | 0 | B

Coupe A-A (Ech. :1:1)
Profondeur 20mm
Pièce pour anneau de levage
PORTE
TROU EMBOUTI POUR VIS M5
TROUS 10x10
PROPOSITION POUR FIXATION DU RACK AU SOL
A PREVOIR EN FACE AVANT ET ARRIERE
Rond plein Ø 10 souder sur pièce en L
Intérieur rack
Extérieur rack
Pièce en L
trou M10 pour vis de serrage
IPN 100 supportant le rack
2 Trous contre fraisés pour vis a tete con. spec. type VHS M13 328-M x16 Ac. zingue (Bossard-Zug)
Section A-A
Section B-B
MONTANTS ARRIERES
MONTANTS INTERMEDIAIRES
MONTANTS AVANT
PROXIMITY SERVICES – RACKS & CABLE TRAYS FOR THE DETECTOR
PROJECT ENGINEER
FOR INFORMATION