THE DESIGN OF A MANUAL BRIQUETTING PRESS

By: Bob Bergeron

Primary Advisor: P. Jutras
Secondary Advisor: E. Perraton

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INTRODUCTION

It is realized all over the world that with the depletion of fossil sources and the resulting price hike, the importance of finding alternate energy sources is bound to increase. Energy sources are not interchangeable. It is true that man seeks the cheapest and most efficient energy, but depending on the wealth, resources, and geographical location of the region, this energy source will differ from one place to another. For example, an alternate source of energy in North America is nuclear energy. This source of energy however, is not (at least for the present) the solution to the energy crisis in rural areas of developing countries. Appropriate technology is required in the third world.

While no single source of energy will resolve the energy problems of the third world, a combination of alternatives can meet at least part of the needs.

One of the suggested alternatives is biomass conversion. The production of methane from waste for example, is a growing but still young method of converting biomass to useable energy. Another type of biomass conversion is biomass shredding and compression commonly known as briquetting. It has been demonstrated that the denser the briquette, the higher the heat value of the resulting briquette (Micuta 1981).

Hence, this project will be responsible to provide the reader with the design of a prototype of a briquetting press. The press will be manually operated to better serve the needs of the decentralized inhabitants of the rural areas in developing countries. At the same time, the press will transfer high pressure to provide a more efficient briquette.

In addition, this paper will provide a litterature review which should

help to properly assess the energy requirements of the developing countries. The potentials of briquetting will also be analysed in the review. Equations, calculations and the prototype will be included along with prototype design improvements. Finally, a conclusion will be included to establish if the design met the original needs.

ASSESSING ENERGY REQUIREMENTS IN THE RURAL AREAS OF DEVELOPING COUNTRIES

The developing nations account for 60% of the world's population. This population of 2½ billion accounts for hardly 10% of the global consumption of energy. Another astounding figure is the difference between the types of energy being consumed. More than 5/6 of all the energy obtained from fossil fuels, hydroelectric and nuclear power is used by the 12 hundred million inhabitants of the rich countries; less than 1/6 of these remaining types of energy are used by inhabitants of the poor countries. The reverse distribution occurs when it comes to the traditional sources of energy, these being: human and animal labor, firewood, crop residues and animal waste. " In the rural areas of most developing countries the dependence on wood and other non-commercial fuels such as animal dung and crop residues is often total, " (Srivastava., FAO 1981).

Of course, the acquisition of these energy potentials requires work. " In the rural areas of Ghana, a large number of women and children are seen cutting and carrying wood to their homes. No doubt the cost of charcoal ($6.52 per sac of 72 lb) is too high for most families, " (Brown. N.L. 1978).

With rapid population growths, the need arises for increases in supplies, conservation and efficient utilization. The United Nations, realizing the gravity of the situation decided in December, 1978 to organize an 'International Conference on New and Renewable Sources of Energy' in order that awareness of the situation is created amongst people and new methods for solving the energy problem are worked out.

The conference showed that alternate sources of energy should find

wide application in future and become economical once the technologies suitable for their exploitation are fully developed. In future, both industrialized and rural societies are likely to turn to: sunlight, wind, hydropower and biomass, (Chaturvedi.P., 1982).

To efficiently develop new sources of energy for rural areas of developing countries, it would be helpful to inquire what most of their energy supply is being used for. Once this is known, the door is open to suggest an alternate energy supply.

Of course, there are a variety of uses for energy. One of the many breakdowns is shown in table 1.

Table 1. The use of energy in rural India and Bangladesh
(daily per caput 1000 kcal)

	India	Bangladesh
Agriculture	1.57	1.32
Domestic activities and food processing	4.55	3.38
Lighting	.30	.20
Pottery, brick-making & metal work	.47	.06
Transportation & other uses	.22	.22
Total	7.11	5.18

(Brown, 1978)

Energy used in agriculture is usually human or animal labor with a small percentage of the energy originating from commercial supplies. Notice the high values for domestic activities and food processing. In

many rural areas at least one member of the family must spend most of his or her working time gathering fuel for cooking and for space and water heating. With the high demand for fuel and human energy in the domestic category, the thought of an alternate energy supply source could become a pleasant addition.

Increasing the quality and quantity of the fuel supply is needed, not only because of a growing population, but also because energy used for cooking in the rural areas of developing countries is used very inneficiently. For example, assuming one wishes to compare the task of boiling water in India and in North America. It is estimated that to boil the water in India only 10% of the fuel would serve directly to boil the water. The other 90% is wasted because of several factors: the inefficiency of the stove and the fact that the fire must be started before placing the pot on the fire, plus the fire still burns when the water boils. With a gas stove, according to Revelle (Brown, 1978), an estimated 30% of the fuel would be directly used for boiling.

The idea of briquetting could very well help the inhabitants of rural areas in underdeveloped countries. Not only could it increase the net energy supply, but it offers an added efficiency. Briquetting is aimed directly at the problem. It creates a non- commercial fuel source and with the proper ingredients, the briquette becomes a fuel with a much higher heat output per pound than untreated wood.

A United Nations conference held in Nairobi in 1981 established an interesting way of cathegorizing energy supplies. Basically; some energy sources can only be comprehended by elite techniciens, others can be assembled in remote villages using local labor and indigenous materials. Some centralized some dispersed, some diminish the gap between rich and poor, others

accentuate it, (Chaturvedi, 1982). Briquetting can be considered as a source of energy that is easy to assemble, it is decentralized and it narrows the gap between the rich and the poor. Decentralization is an option that is prefered according to 'Worldwatch Study'.

> " Energy sources may not dictate the shape of society but they do limit the range of possibilities and dispersed solar sources are bound to be found to be more compatible than centralized technology. " (Chaturvedi, 1982)

Although the energy problem for the rural areas of underdeveloped countries is far from being solved, it would seem evident that briquetting might be a step in the right direction. A unit could be devised which is small (preferably portable), using parts that are cheap and easily accessable.

Is the potential there? A decentralized source of energy more efficient than its raw materials. According to the 'Synthesis Report' from the previously mentioned UN conference:

> " Biomass conversion technologies have reached the point of economic viability and their next stage is of widespread practical demonstration, provided that there are no conflicts with food production, their potential is good even in the short term prospective. "
>
> (Chaturvedi, 1982)

THE POTENTIAL OF BRIQUETTING

It is woodwaste, or rather wood residue that constitutes the considerable potential biomass energy source. Ghana harvest approximately 10 million cubic meters of wood every year. It is apparent that in the country as a whole, most families use firewood for cooking. It is estimated that 3.1 out of the 10 million m^3 of wood cut every year is unused. It is either left behind to rot or wasted in the form of sawdust, (Brown, 1978).

Wood waste is available in three basic cathegories: i) forest harvest waste ii) cull trees iii) process plant waste. In Ghana, the energy alternative is available for families living near sawmills; wood waste may be obtained for a small charge.

Of course, the briquetting of sawdust would be impossible for regions having a scarce or depleated wood supply, as is the case for several underdeveloped regions. Alternatives are available; most fibrous organic biomass have the gross energy suitable for this purpose. Straw is probably the best alternative because of its availability and fibrous consistency. With a decline in bedding requirements due to better housing methods, straw can become even more abundant in the future. The gross energy values for various straws ranges from about 7,000 btu/lb for oat straw to about 7,700 btu/lb for bean straw. In a paper published by the Texas Agricultural Experimental Station, a cost analysis was done for pelleting cotton gin trash! An estimated 7,000 btu/lb could be available from gin trash, (Moore D.S. 1982). The point basically, is that many more materials aside from wood could have this potential for briquetting.

Using sawdust as an example, what is really the advantage of burning

a briquette instead of plain sawdust? Firstly, combustion requires oxygen and fuel. A log on an open fire will burn better if oxygen is abundant. A log laying flat on the ground will not burn efficiently. The same occurs with sawdust. Sawdust reacts like a log without abundant oxygen because it lays flat when it burns. When oxygen is not abundant, only partial combustion takes place. Partial combustion is depicted by excess smoke. Wood consists of volatile gases and fixed carbon. Volatile gases are mostly burned in the beginning of combustion. When oxygen is abundant during the burning of these gases, the result is a flame; when oxygen is not abundant, the result is smoke. Smoke indicates the escaping of the gases without total combustion; therefore smoke is an indicator of inefficient burning. The briquette will not smoke like sawdust, especially if the briquette is placed on a grill. When the gases have been combusted the remainder of the log is carbon which burns with a much greater energy density, (White L.P. 1982). The carbon does not flame but rather, it glows.

A briquette in fact does not increase the potential energy output of the raw material but rather, it increases the available energy output of this material.

Secondly, the binders used at times to hold the briquette together can increase the energy output. A number of binding agents have been tried including bitumens, resins and gums. Some wood with high resin contents bind naturally if heated under pressure but this gives only a weak bond, as do most of the additives. A process in the United States (Terry, 1978) uses thermoplastic resin as a binding agent. The addition of the plastic material also considerably increases the energy content of the material - it is claimed from 8,000 btu/lb for raw wood, to at least 18,000 btu/lb for pellets. These burn at higher temperatures than untreated wood, resulting in more complete burning and less residual ash. The thermoplastic used can be obtained from waste.

Thirdly; handling, transportation, and storage are all more desirable

when sawdust is pellitized.

Moisture content is another important parameter for an efficient briquette.

> " ... the biomass should contain sufficient gross thermal value to volatise the water that is present, to raise it to the temperature of the flue gases and to keep the combustible material sufficiently hot to enable combustion to continue. "
>
> (White L.P. 1982)

Fernand Blanchard of CRIQ (Centre de Recherche Industrielle du Québec) estimates an ideal moisture content for a briquette is between 10-20%. Anything less than this does not allow the fibres to hold together. Anything greater than this results in heat used (or wasted) to evaporate the excess water.

We have now briefly discussed the availability and possibility of different biomass materials capable ofundergoing the briquetting process. We've also mentioned advantages of briquettes, effects of moisture content and the advantages of a binding agent. Of course, there is still much that remains to be said on these subjects however, a more detailled discussion on these matters is beyond the scope of this paper. Hopefully, the need and the potential of briquetting have been stressed in this brief discussion.

SPECIFIC GOALS OF THE DESIGN

It has been established that the rural areas of developing countries are in need for energy efficiency and supply improvements. For the relatively poor, the surrounding resources are all that is available and all that is affordable. For these isolated or decentralized poor inhabitants, nuclear power and others are not the answer to their energy crisis. Instead, a decentralized and simple energy unit is preferred in this situation. A briquetting unit is suggested to make use of waste and thus make the surrounding resources more plentiful.

The briquetting unit should ideally be:

-- Simple to build

-- Simple to operate

-- Made from parts readily available in developing countries

-- inexpensive

With this in mind, one must back away from sophistication and gadgetery. These designs become expensive and require special labor and tools to build the unit. Complexity, even if the efficiency of the briquette is slightly raised, usually entails extra costs and this will defeat the purpose.

CRIQ has done reasearch for ' Forenaque ', the first industrial wood briquetting factory in Québec. The briquettes at Forenaque are constructed by means of a piston slamming sawdust into a cylinder. The process basically resembles the method in which pistons move in a car engine. These movable parts require energy beyond the strength of a man; this will also defeat our purpose. For this reason, our manual briquetting unit will be driven with a hydraulic jack. The briquette will therefore be formed with the strength of an average human arm without any external energy required.

According to CRIQ, the formation of the briquette can require up to 15,000 psi. Between 3,000 and 5,000 psi are sufficient if a binder is used to hold the sawdust together.

The cylinder chosen in this design is 1.8 inches inside diameter; the hydraulic jack used is a Canadian Tire 8 ton jack.

The resulting pressure is:

$$\frac{16{,}000 \text{ lb}}{\frac{\pi (1.8)^2 \text{in}^2}{4}} = 6{,}288 \text{ psi}$$

As a security measure, it was insured that the walls of the cylinder were at least capable of withstanding this pressure. But since sawdust does not react like water, the radial pressure should never reach this point. Most pipes can withstand approximately 30,000 psi, so the cylinder will not fail.

SOME USEFULL EQUATIONS

The following equations and parameters, originating from 'The Handbook of Steel Construction' (1980), will be necessary for the design calculations.

Tension Members

Wherein the connections are made either by means of bolts or by welding, the resistance of a tension member be taken as the lesser of the following two cases:

i) $Tr = \phi\ An\ Fy$
when $An/Ag \geq Fy/Fu$

or $Tr = \phi\ (Fu\ An/Ag)\ An$
when $An/Ag < Fy/Fu$

ii) $Tr = .85\ \phi\ An\ Fu$

Tr = tensile resistance

Fu = tensile strength

Fy = yield strength

Ag = gross CS area

An = net CS area
= Ag - (CSA of bolt + 4mm)

ϕ = performance factor
= .9

$Tr \geqslant Tf$

Tf = force in member from factored loading

The only members in tension in this design are the two hollow tubes For these tubes, the selected steel has the following properties:

Fu = 400 MPa
Fy = 250 MPa

Beams

-- The factored shear resistance is given by the equation:

$Vr = \phi\ Aw\ Fs$

Vr = factored shear resistance

Aw = CSA of beam

Fs = .66 Fy

ϕ = performance factor = .9

Asside from the previously mentioned hollow section, all other members in the design are resisting shear such that:

$Vr \geqslant Vf$

Vf = shear force in member from factored loading

The steel selected has the following properties:

Fu = 250 MPa
Fy = 400 MPa

except for the two top rods and the top horizontal cover plate:

Fu = 300 MPa
Fy = 450 MPa

-- The factored moment resistance is given by the equation:

$Mr = \phi\ Fy\ S$

Mr = factored moment resistance

ϕ = performance factor = .9

Fy = yield point

S = section modulus

These same beams are all resisting a bending moment such that:

$Mr \geqslant Mf$

Mf = Bending moment in member from factored loading

Bolts

-- The bolts in the design are all resisting shear. The shear resistance of a bolt is given by the equation:

$Vr = .6 \phi n m Ab Fu$

Vr = factored shear resistance

ϕ = performance factor
= .67

n = number of bolts

m = number of shear planes in the joint

Ab = CSA of bolt

$Vr \geqslant Vf$

Vf = shear force in bolt from factored loading

The bolts used have the following properties:

Fu = 450 MPa

-- The bearing capacity of the bolt can be represented by the resistance of the plate adjacent to the bolt. The bearing resistance of the plate can be given by the following equation:

$Br = \phi t n e Fu$

Br = bearing resistance of plate from factored loading

ϕ = performance factor
= .67

t = thickness of thinest plate in contact

Fu = tensile strength

n = number of bolts

e = location of bolt with respect to the unloaded edge of the plate

MINIMUM EDGE DISTANCE
FOR BOLT HOLES

Bolt diameter	At shear edge
5/8"	28 mm
3/4"	32 mm
1⅛"	51 mm

This table will be necessary later to find the minimum edge distance for bolt holes.

To avoid confusion, the calculations are presented in such a way that they follow an orderly pattern similar to a chain reaction from one free body diagram to the next.

More specifically:

Reaction i: hydraulic jack reacts on horizontal cover plate;
find plate thickness to resist shear & bending.

Reaction ii: horizontal cover plate reacts on rods;
find rod diameter to resist shear & bending.

Reaction iii: rods react on verticle cross plates;
find plate height to resist shear & bending,
also find min edge distance and bearing resistance.

Reaction iv: vertical cross plates react on bolts;
find bolt diameter to resist shear,
also find min edge distance and bearing resistance.

Reaction v: Bolts react on hollow section;
find hollow section dimensions to resist tension.

Reaction vi: hollow section reacts with bottom bolts which react with bottom verticle cross plates;
find heigth of plates to resist shear & bending.

One will notice that in certain cases, the calculations and the relevant dimensions on the prototype (or the blue print) do not necessarily

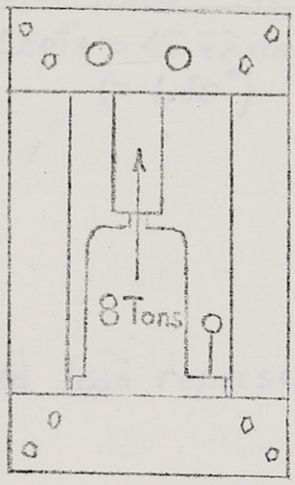
correspond. The reasons are two fold.

a) Some innacurate assumptions were made at the beginning of the design.

b) The lack of availability of some desired steel dimensions at the machine shop.

More on this later when ' improvements ' are discussed.

CALCULATIONS



As seen in the simple representation of the prototype, the hydraulic jack is offset to the left. As a result, the stress on the structure will be greater on the left side. To avoid lengthy calculations, the reactions on the left hand side only will be calculated. The same hollow section, bolts and rods will be used on the right hand side. This should serve to reduce production costs of the unit should the oppertunity arise. For example, buying and drilling for two similar but different diameter bolts will most likely be more expensive than the over-design costs as a result of using uniform dimensions on both sides of the structure.

The components of the structure were considered to be simply supported because it is a more conservative choice for our structure and the connections consisting of only two bolts still have a relative amount of play when the load is applied.

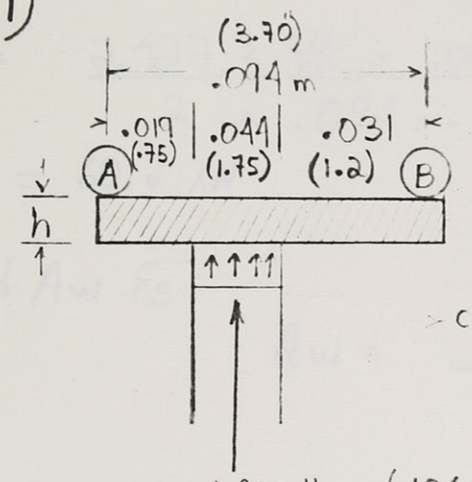
The steel obtained for the prototype was labelled according to the English unit system; that is to say, the hollow section measures 2"x2"x1/8" and more confusingly it also measures 50.8mmx50.8mmx3.175mm. To reduce this confusion, the blueprint is drawn using the scale of inches. The calculations however, seemed to be somewhat simpler in metric, so the dimensions in this section are given in metric and also in English units (in parentheses) so that the relation can be made between the freebody diagrams and the blueprint.

Jack capacity = 16,000 lb x 1.5 = 24,000 lb

(Adams et al, 1979)

Reaction i)

ref: Front view



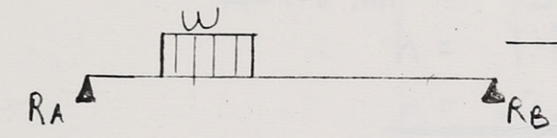
→ rods

→ horizontal cover plate (h = ?)

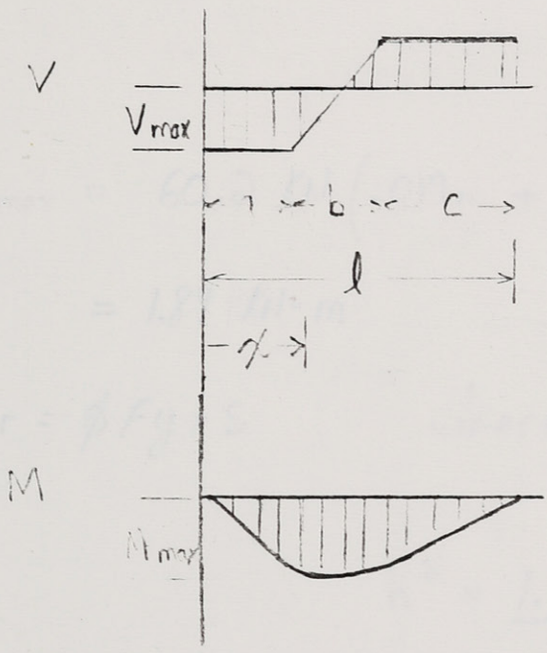
(Depth = 45.72 mm (= 1.80"))

→ cylinder

24,000 lb (106.8 KN)



→ inverted load representation



$$V_{max} = \frac{wb}{2l}(2c + b)$$

$$M_{max} = R_A\left(a + \frac{R_A}{2w}\right)$$

$$R_A + R_B = 24{,}000$$

$$R_B(.094) = 24{,}000\,(.019 + .044/2)$$

$$R_B = 10{,}468 \text{ lb} \quad (46.6 \text{ KN})$$

$$R_A = 13{,}532 \text{ lb} \quad (60.2 \text{ KN})$$

$$\rightarrow w = \frac{106.8 \text{ KN}}{.044 \text{ m}} = 2{,}427.3 \text{ KN/m}$$

$$V_{max} = \frac{2{,}427.3 \frac{kN}{m} \times .044m \left(2 \times .031m + .044m\right)}{2 \times .094m}$$

$$= 60.2\ kN$$

$$V_r = \phi A_w F_s$$

$$A_w = \frac{60.2 \times 10^3\ N}{.9 \times .66 \times 300\ N/mm^2}$$

$$A_w = 337.8\ mm^2$$

$$337.8\ mm^2 = 45.72\ mm \times h$$

$$h = 7.4\ mm$$

$$\underline{h = .3\ in}$$

$$M_{max} = 60.2\ kN \left(.019m + \frac{60.2\ kN}{2 \times 2{,}427.3\ kN/m}\right)$$

$$= 1.89\ kN\text{-}m$$

$$M_r = \phi F_y \times S \qquad \text{where} \quad S = \frac{bh^2}{6}$$

$$h^2 = \frac{1.89 \times 10^6\ N\text{-}mm \times 6}{.9 \times 300\ N/mm^2 \times 45.72\ mm}$$

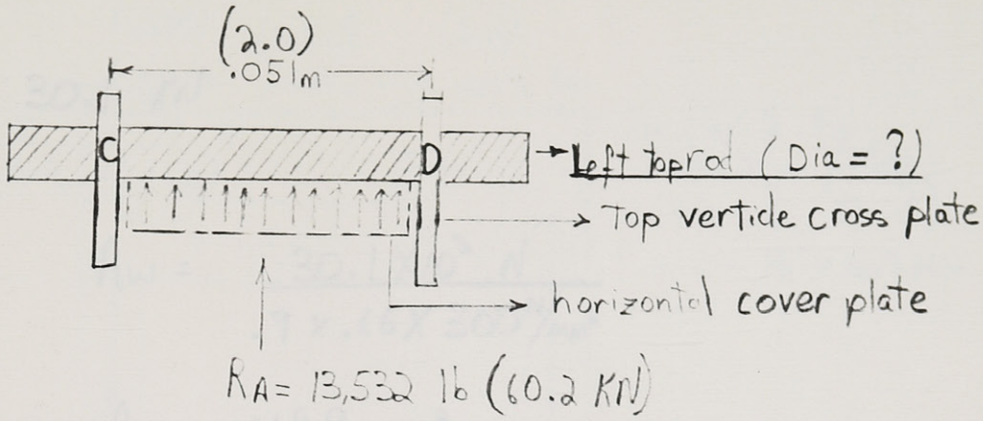
$$h = 33\ mm$$

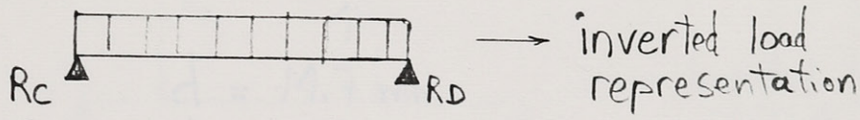
$$\underline{h = 1.2\ in}$$

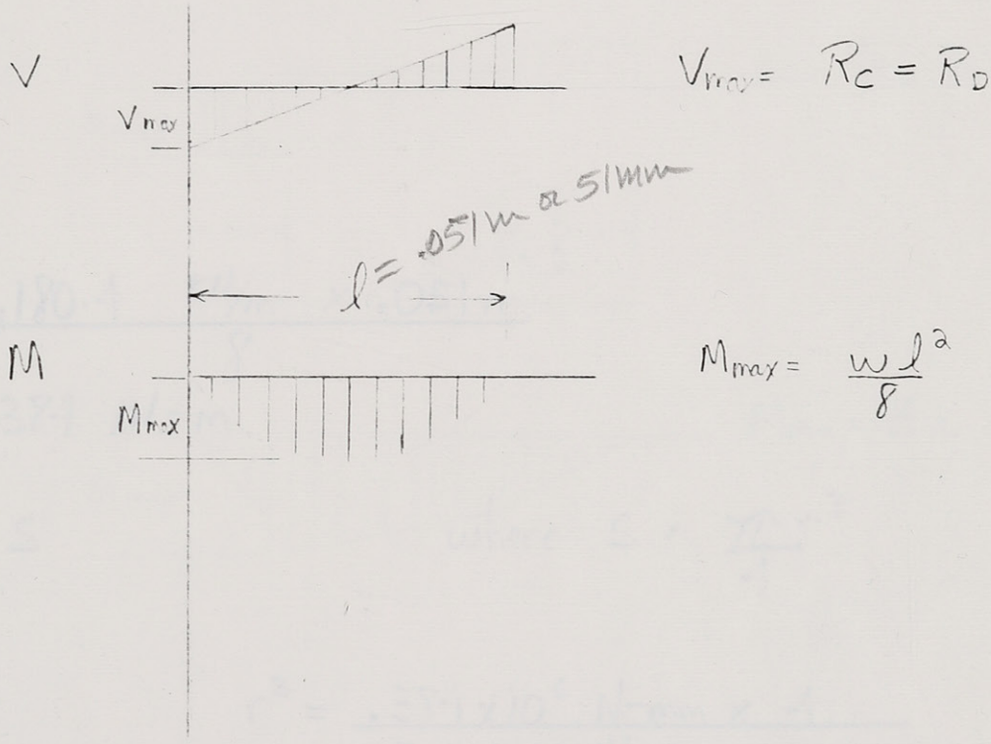
$\therefore$ Minimum height = 1.2 in

Reaction ii)

ref: side view







$$R_C = R_D = \frac{R_A}{2}$$

$$R_C = R_D = 30.1 \text{ KN}$$

$$\longrightarrow w = \frac{60.2 \text{ KN}}{.051 \text{ m}} = 1{,}180.4 \text{ KN/m}$$

$V_{max} = R_{C,D} = 30.1 \text{ kN}$

$V_r = \phi A_w F_s$

$$A_w = \frac{30.1 \times 10^3 \text{ N}}{.9 \times .66 \times 300 \text{ N/mm}^2}$$

$$A_w = 168.9 \text{ mm}^2$$

$$168.9 \text{ mm}^2 = \frac{\pi d^2}{4}$$

$$d = 14.7 \text{ mm}$$

$$\underline{d = .58 \text{ in}}$$

$$M_{max} = \frac{4180.1 \text{ kN/m} \times (.051 \text{ m})^3}{8}$$

$$= .384 \text{ kN-m}$$

$M_r = \phi F_y \times S$ where $S = \frac{\pi r^3}{4}$

$$r^3 = \frac{.384 \times 10^6 \text{ N-mm} \times 4}{.9 \times 300 \text{ N/mm}^2 \times \pi}$$

$$r = 12.2 \text{ mm}$$

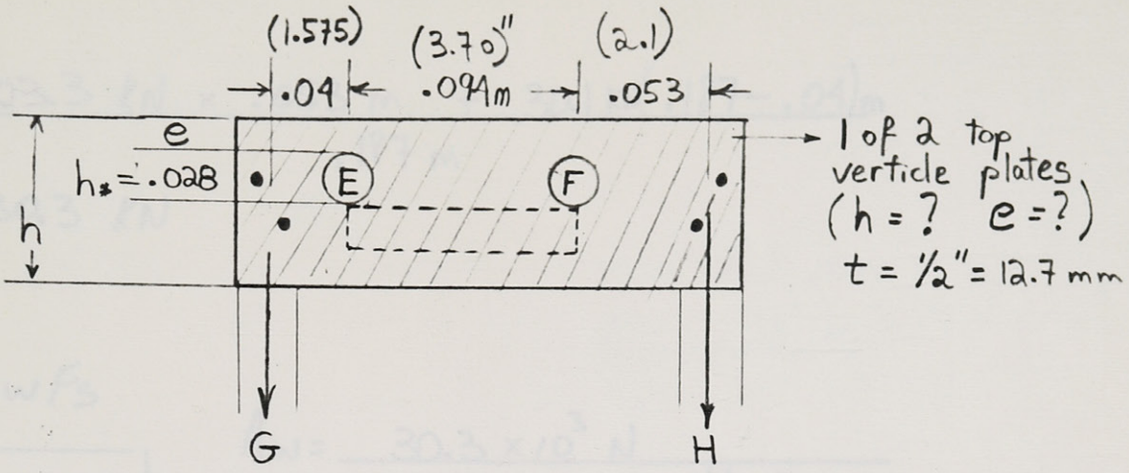
$$r = .48 \text{ in}$$

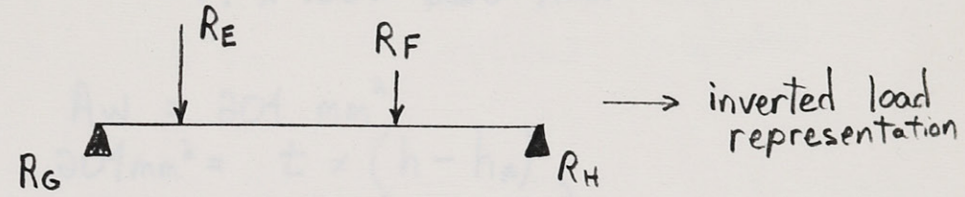
~~the rod should have~~

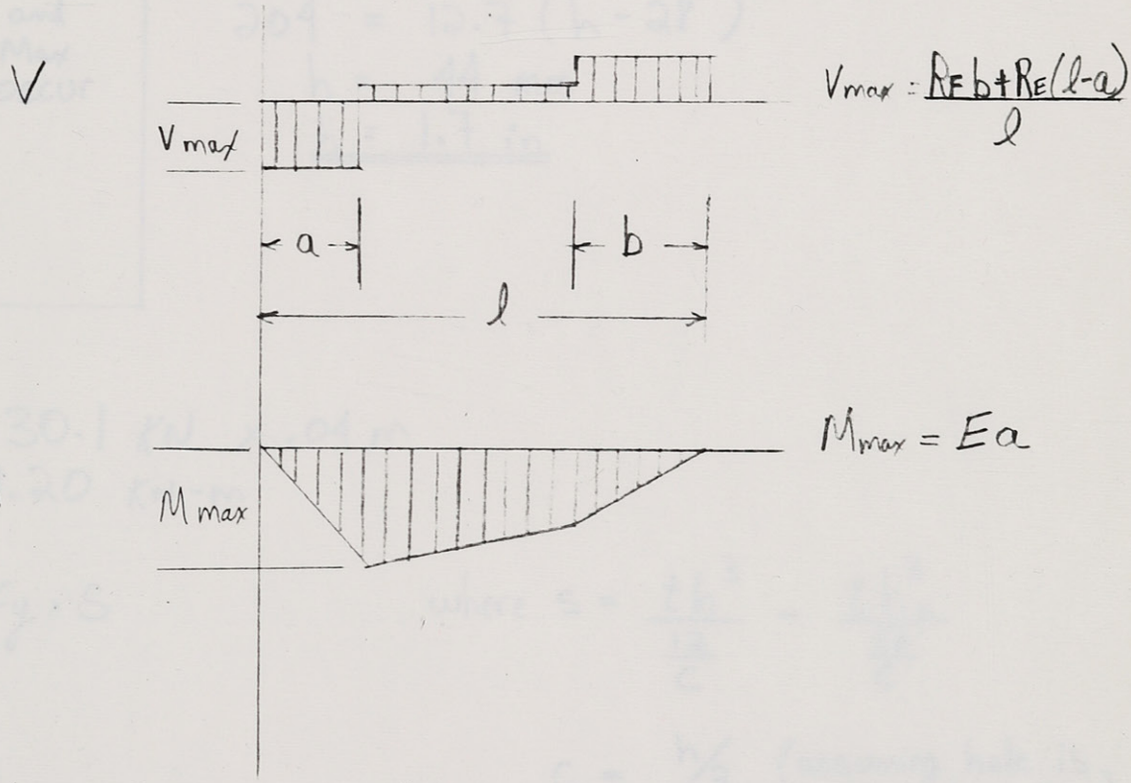
$$\text{Diameter} = .96''$$

reaction iii)

ref: Front view







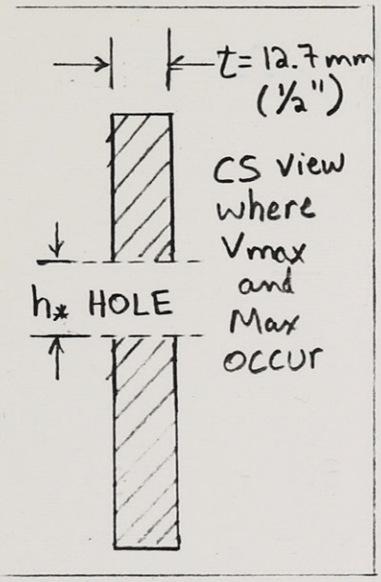
$$R_E = \frac{R_A}{2} \qquad R_F = \frac{R_B}{2}$$

$R_E = 30.1$ KN $\qquad R_F = 23.3$ KN

$$V_{max} = \frac{23.3\ KN \times .053\ m + 30.1\ KN (.187 - .04)m}{.187\ m}$$

$$= 30.3\ KN$$

$$V_r = \phi A_w F_s$$



$$A_w = \frac{30.3 \times 10^3\ N}{.9 \times .66 \times 250\ N/mm^2}$$

$$A_w = 204\ mm^2$$

$$204\ mm^2 = t \times (h - h_*)$$

$$204 = 12.7\,(h - 28)$$

$$h = 44\ mm$$

$$\underline{h = 1.7\ in}$$

$$M_{max} = 30.1\ KN \times .04\ m$$

$$= 1.20\ KN\text{-}m$$

$$M_r = \phi F_y \times S \qquad \text{where } S = \frac{th^3}{\frac{12}{c}} - \frac{th_*^3}{\frac{12}{c}}$$

$$c = h/2 \quad \text{(assuming hole is in center)}$$

$$\frac{1.2 \times 10^6\ N\text{-}mm}{.9 \times 250\ N/mm^2} = S \qquad \therefore S = \frac{th^2}{6} - \frac{t(h_*)^3}{6(h)}$$

$$5{,}333\ mm^3 = 2.117\ h^2 - \frac{46{,}167}{h}$$

$$2.117\ h^3 - 5{,}333\ h - 46{,}167 = 0$$

$$h = 54.1$$

$$\underline{h = 2.13\ in}$$

$$t_r = \phi\, t\, n\, e\, F_u$$

$$\frac{30.1 \times 10^3\ N}{.67 \times 12.7 \times 400\ N/mm^2} = e$$

$e = 8.8\ mm$

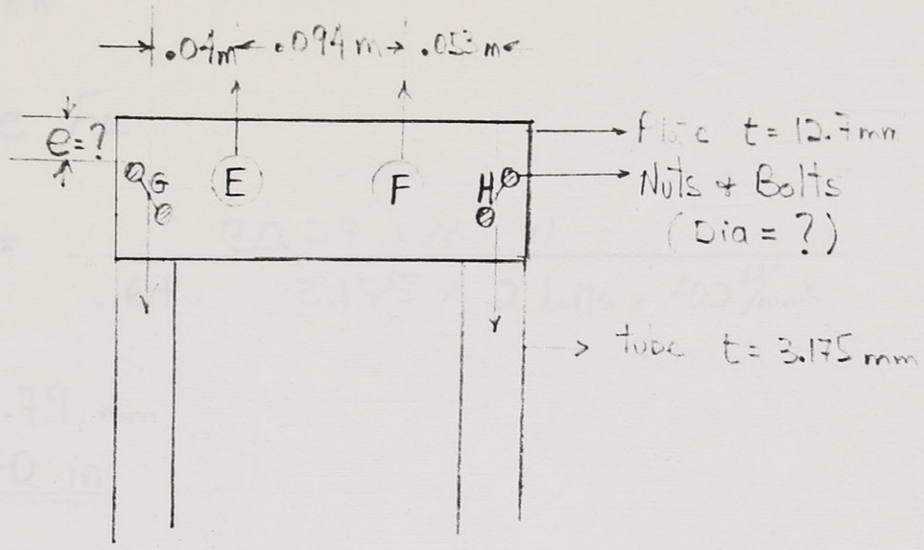
$\underline{e = .35\ in}$

$\therefore$ $h = 2.13$ in
$e = .35$ in

For each Top Vertical cross plate

Reaction iv)

Ref: front view



$$R_E + R_F = R_G + R_H = 53.4 \text{ kN} \quad (12{,}000 \text{ lb})$$

$$R_E(.04) + R_F(.134) = R_H(.17)$$

$$30.1(.04) + 23.3(.134) = R_H(.17)$$

$$R_H = 23.3 \text{ kN}$$

$$R_G = 30.27 \text{ kN}$$

$V_f = .6\,\phi\, n\, m\, A_b\, F_U$

$$\frac{30.27 \times 10^3 \text{ N}}{.6 \times .67 \times 2 \text{ bolts} \times 1 \text{ shear plane} \times 150 \frac{\text{N}}{\text{mm}^2}} = \text{Area bolt (mm}^2\text{)}$$

$$A_b = \frac{\pi d^2}{4} = 85.665$$

$$d = 10.32 \text{ mm}$$

$$\underline{\underline{d = .41 \text{ in}}}$$

use $\frac{7}{16}" = .438$ in

$R_G = 30.27\ kN$

$Er = \phi\ t\ n\ e\ Fu$

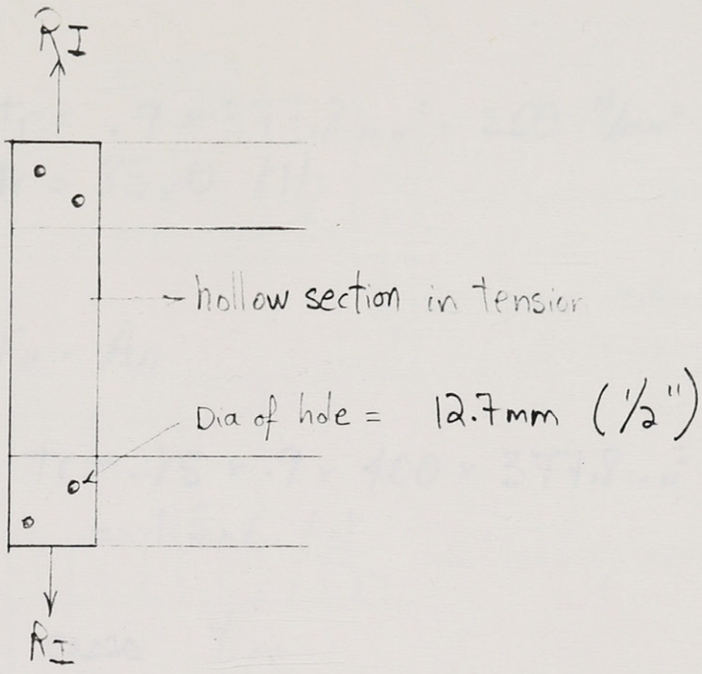
$$e_{mm} = \frac{30.27 \times 10^3\ N}{.67 \times 3.175 \times 2\ bolts \times 400\ N/mm^2}$$

$e = 17.79\ mm$

$\underline{e = .70\ in}$

Reaction V)

ref: front view



ref: top view



Try 2

2" x 1" x ⅛" (50.8 x 25.4 x 3.175)mm

A_g = ⅛" (2+2+1+1)" = .75 in²

= 483.87 mm²

A_n = 3.175 (50.8 + 50.8 + 25.4 - 12.7 - 1) mm

= 377.8 mm²

$\frac{A_n}{A_g} = \frac{377.8}{483.87} = .781 > .625 = \frac{250}{400} = \frac{F_y}{F_u}$

∴ i) $R_I = 2R_G$ (because 2 top & 2 bottom horizontal plates)

$R_I = 2 \times 30.27$

$R_I = 60.54$ kN

$T_r = \phi A_n f_y$

$T_r = .9 \times 377.8\ mm^2 \times 250\ N/mm^2$

$T_r = 85.0\ kN$

ii) $T_r = .85 \cdot \phi \cdot f_u \cdot A_n$

$T_r = .85 \times .9 \times 400 \times 377.8\ mm^2$

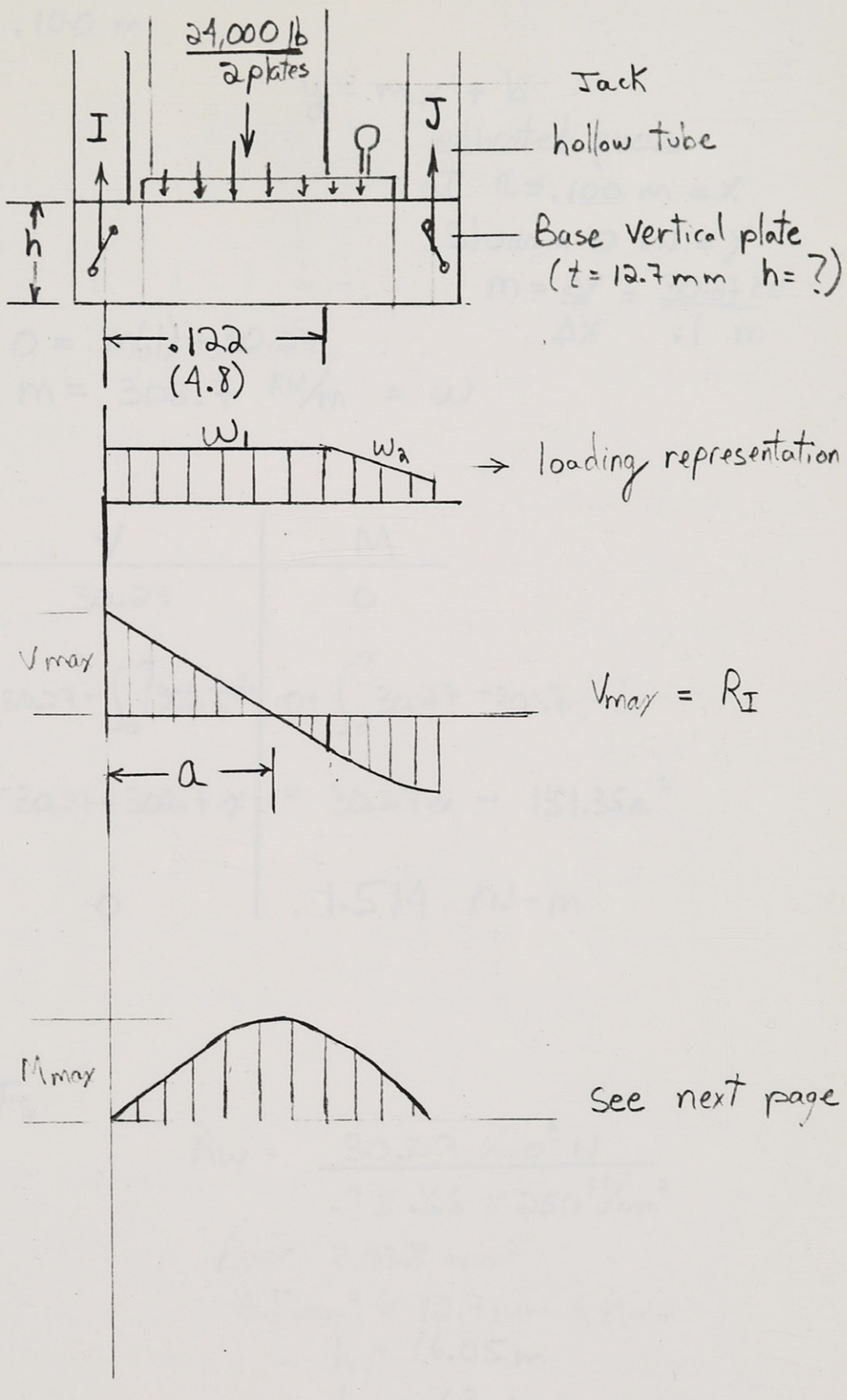
$= 116.6\ kN$

in both cases the

1" x 3" x 1/4" is acceptable.

Reaction vii)

ref: front view



Since we are only considering 1 of the 2 horizontal bottom plates.

$R_I = 60.54 \div 2 = 30.27$ KN

→ $V_{max} = 30.27$ KN

→ $a \approx .100$ m

$y = mx + b$

educated guess

at $a = .100$ m $= x$

Shear $= 0$ KN $= y$

$m = \frac{\Delta y}{\Delta x} = \frac{30.27 \text{ KN}}{.1 \text{ m}}$

$\therefore \quad 0 = m(.1) + 30.27$

$m = 302.7 \text{ KN/m} = w$

X	V	M
0	30.27	0
$0^+ < x < .122$	$30.27 - \int_0^x (302.7)\,dx$	$0 + \int_0^x 30.27 - 302.7x\,dx$
	$= 30.27 - 302.7x$	$= 30.27x - 151.35x^2$
at $x = .100$	0	1.514 KN-m

$V_r = \phi A_w F_s$

$A_w = \frac{30.27 \times 10^3 \text{ N}}{.9 \times .66 \times 250 \text{ N/mm}^2}$

$A_w = 203.5 \text{ mm}^2$

$203.5 \text{ mm}^2 = 12.7 \text{ mm} \times h \text{ mm}$

$h = 16.05$ m

$h = .63$ in

$Mr = \phi Fy S$ where $S = \frac{t h^2}{6}$

$$h^2 = \frac{1.5 \times 10^6 \text{ N-mm} \times 6}{.9 \times 250 \text{ N/mm}^2 \times 12.7}$$

$h = 56.1$ mm

$h = 2.2$ in

DESIGN IMPROVEMENTS

As previously mentioned, the calculations for the prototype and the actual dimensions of the prototype (or blueprint) do not always correspond. Before the hydraulic jack was made available, certain assumptions were made regarding the jack and the structure of the briquetting unit itself. These assumptions were incorporated in the primary calculations. When construction took place it became evident that the design was to be somewhat altered from the original. The unavailability of certain dimensions of steel also proved to cause some inconveniences and hence alterations in the design. Despite a combination of faulty assumptions and the unavailability of certain steel dimensions, a successful yet mostly over designed briquetting unit was born. The secondary calculations, which are those presented in this paper, plus the minimum edge distance for bolts, add up to give a much better representation of what the prototype should have looked like. From these secondary calculations and other arguements, the improvements will now be presented.

The most overdesigned component of the unit are the two vertical cross plates. A more logical way of finding the dimensions of the plate will be displayed.

The minimum edge distance for the rod hole (1.1" dia) according to the code is 51 mm or 2". This minimum distance is with respect to any edge; the distance is taken from the centre of the hole. Therefore, the height of the plate must be 4" with the centre of the hole half way up.

From calculation in reaction iii)

$$S = 5{,}333\ mm^3 = \frac{t h^2}{6} - \frac{t (h_*)^3}{6h} \qquad (4" = 101.6\ mm)$$

$$5{,}333 = \frac{t(101.6)^2}{6} - \frac{t(28)^3}{6(101.6)}$$

$$5{,}333 = t\ 1{,}720.4\ mm^2 - t\ 36\ mm$$

$$t = 3.166\ mm$$

Plate thickness; $t = .125$ inches ($1/8"$)

Checking shear:

$$204\ mm^2 = t(h - h_*)$$

$$204 = t(101.6 - 28)$$

$$t = 2.77\ mm \rightarrow OK$$

Check bearing resistance of this new arrangement:

$$\frac{30.1 \times 10^3}{.67 \times 3.175 \times 400} = 35.4\ mm \quad (1.39")$$

($1/8"$)

∴ our distance from the top of the hole is:

$$2" - \frac{1.1"}{2} = 1.45" \rightarrow OK$$

∴ plate should be no more than $1/8"$ thick

The hollow section used is 2"x 2"x1/8", yet our calculations proved that 1"x 2"x1/8" was adequate. If the latter is used however, the minimum edge distance of the bolts will not comply with the code. The minimum edge distance for a hole $\frac{1}{2}$" in diameter was extrapolated from the table to be 1" in every direction from the centre of the hole. If 1"x 2"x1/8" were used, the distance to the edge would only be $\frac{1}{2}$".

This raises the next improvement; the positioning of the bolts is incorrect on the prototype. Actually, the first thing that would fail in the prototype would probably be the bolts ripping through the top of the hollow section. The center of the top bolt holes should be situated in the center (horizontally) of the hollow section at least 1" from the top of the section. The second hole should be at least 1" below the first hole and at least 1" above the bottom of the vertical cross plate. These bolts are situated in the center of the hollow section so that the minimum edge distance is respected on each side. This of course, applies to the bolts in all four corners of the design.

The prototype has 4 bolts per corner. Using longer bolts will allow us to use only 2 bolts per corner. Calculations however should be conducted to ensure that the bolts do not bend in the center of the hollow section.

It was suggested that only one bolt (a bigger one of course) be used in each corner. This could be arranged however, the minimum edge distance restriction will not allow this unless the hollow section is wider than the present 2".

It is important that all regulations be respected because an unfortunate failure of the structure could possibly injure the operator who would be standing directly over the structure.

The horizontal cover plate should be increased in thickness from 1"

to 1.2". It is surprising that such a small piece of steel be restricted by its bending moment. This is due to a poor section modulus (S) of the material subject to such high forces. In other words, the quantity of steel present was plentiful to resist shearing failure, but the way the plate is layed out, it becomes most inefficient to resist bending. Beams often operate in a reverse fashion for short lengths. The beams' high section modulus usually makes bending less restrictive than the shear resistance for short lenghts.

The bottom vertical plates should be as thick as possible to help balance the unit. With the new straight bolt arrangement, a minimum of 3" in height is required. Calculations for the plate width can be derived similarly to the calculations for the top vertical cross plates presented above.

The jack is welded to the bottom vertical plates. A simple spot torch weld would have been adequate. The arc welding that was done on the prototype proved to be very inconvenient. The heat melted the seals inside the jack, so the seals had to be replaced.

CONCLUSION

The original goals of the project were met. The briquetting unit is less than 2'x 1'x $\frac{1}{2}$' and weighs about 47 lb. The unit compresses biomass with up to nearly 7,000 psi using only the strength of a human arm. The price of the unit is about $50, and its materials are accessible just about anywhere in the world. The unit makes use of available resources to convert waste into useable energy. This unit is an example of appropriate technology in the hopes of advancing one step closer to the solution of the energy crisis in the rural areas of developing countries.

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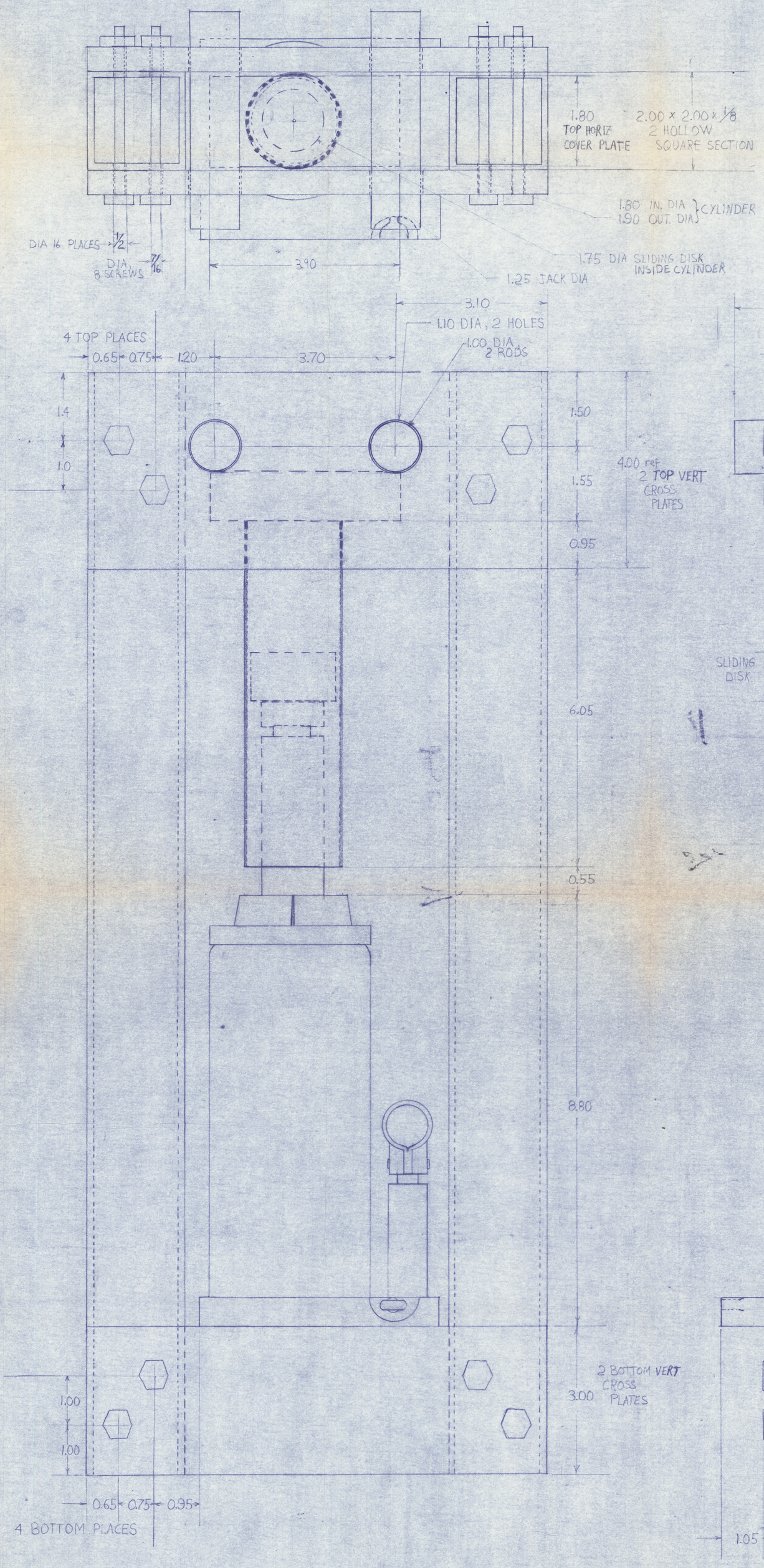
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REVISION	DATE	DESCRIPTION: BRIQUETTING UNIT

AGRICULTURAL ENGINEERING DEPARTMENT
McGILL UNIVERSITY

BOX 400, MACDONALD COLLEGE, QUE. H0A-1C0

ROBERT BERGERON (7919172)
SENIOR PROJECT; DEC 1982

All measurements in inches

SCALE				DWG. NO.
1:1	DRAWN	R Bergeron		1 of 1
	CHECKED			
	REVISED			