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# Optimal Combustion Chamber for Yajna/Agnihotra

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*ABSTRACT:* **We have examined the structure of a combustion chamber used in combustion of ghee (clarified butter), scented materials, and herbs etc. (a traditional Indian process called Yajna for purifying the air in and around the residence). We have theoretically examined the shape and structure of the combustion chamber for the its efficiency and cost effectiveness and found that an inverted truncated pyramid with specific relation between height, opening, and base as explained in this paper is more efficient than a similar inverted truncated cone or hemisphere or a cuboid or a hemisphere.**

***KEY WORDS: Yajna, Agnihotra, Vedi***

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## I. INTRODUCTION

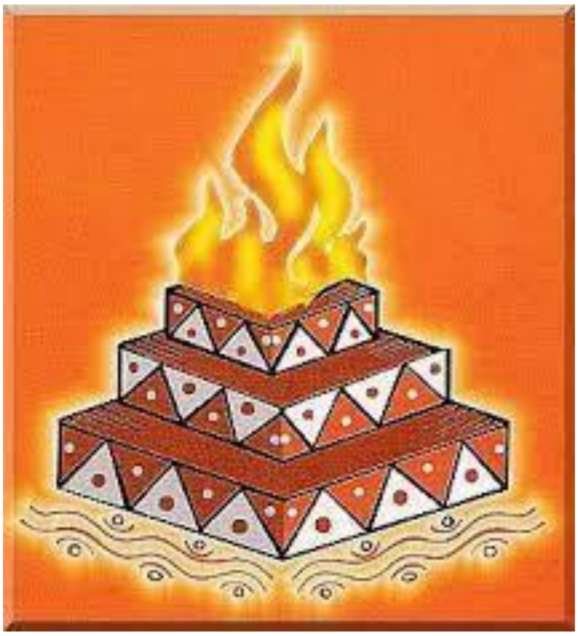

**Figure – 1**

***1.1 WHO and Air Pollution***

According to WHO (World Health Organization) [1] Air pollution kills an estimated seven million people worldwide every year. WHO data shows that 9 out of 10 people breathe air containing high levels of pollutants. From smog hanging over cities to smoke inside the home, air pollution poses a major threat to health and climate. More than 80% of people living in urban areas that monitor air pollution are exposed to air quality levels that exceed WHO guideline limits. With low- and middle-income countries suffering from the highest exposures, both indoors and outdoors.

***1.2 Experiments show reduction in Air Pollution***

When combustion of materials like butter, and herbs etc., that are offered in a combustion chamber, hot smoke and steam are produced. Due to heat these materials get dried by releasing the vapors from them. These vapors mixing with the air enters the atmosphere. These vapors and particles interact with the atmospheric particles and are found to reduce air pollution. Experimental [2] results showed that the pollutants like $SO_x$, $NO_x$, CO, and PM (particulate matter) could be reduced by combustion of ghee (clarified butter) and herbs etc. It was shown that $SO_x$ reduced by about 51% and $NO_x$ reduced by about 60% while RSPM and SPM were reduced by 9% and 65% respectively.

***1.3 What is Yajna and its benefits?***

The experimental set up and the process described in [2] is called as 'Yajna", "Agnihotra", and "Homa" etc., and with many other synonyms. The process generally is carried out in a combustion chamber made of metal and may be of inverted truncated pyramid, or inverted truncated cone, or some other shape. The fire in the combustion chamber generally ranges between 200 to 1000 degrees Celsius or above because sticks from various trees are used as fuel. At this temperature generally all materials (eatables, and herbs etc.) are vaporized and the molecules, atoms, ions that are produced rise high into the atmosphere. These molecules have high kinetic energy and travel long distances and climb great heights as the density of these vapors are lesser than the surrounding air. These molecules, atoms, ions have the capacity to interact with the atmospheric gases, and particles and can reduce the pollution. For example, Sulphur dioxide can be removed using Carbon (Sappok and Walker) [3]**.**

***1.4 What are Medicinal Smokes and its uses?***

Herbs and scented materials are used in medicinal smoke to cure illness [4] such as pulmonary, neurological and dermatological apart from being beneficial to health and include smoke for social use. The authors also demonstrate that medicinal smoke can be extended to use in modern medicine as a form of drug delivery and is a promising source of new active natural ingredients.

***1.5 Agnihotra/Yajna Ash and its uses. Does Yajna decrease microbial count?***

It is experimentally found [5] that the ash collected from the combustion chamber (pyramidal shape) after doing the "Agnihotra" may increase the extractable P in the soil. Priyadarshini et al [6], reported that at a specific distance from combustion chamber (called homa kunda in this paper) microbial count decreased between 72.6% and 93.39% after the homa (Agnihotra or Yajna) process".

***1.6 Yajna/Agnihotra reduces pollution and increases rainfall***

Eight years [7] of continuous experiments on Yajna/Agnihotra results were reported and the results show that Yajna can reduce Particulate Matter pollution for a period of up to 96 hours and up to a distance of 50 km. Also, the rainfall [8] in Atlanta (GA, USA) was estimated during the period of Yajna and compared with the period when there was no Yajna. The report indicates that during the Yajna period the rainfall is 23% more than the period when there was no Yajna.

***1.7 Problem statements***

In this paper we studied the shape and structure of the open combustion chamber used for Yajna for efficient combustion, for reducing the losses, and for a cost-effective combustion chamber design.

## II. MATERIAL AND METHODS

For an efficient process of the aforementioned combustion of materials, we studied the shape of the combustion chamber so that

(a) the fire in the pit attains higher temperatures and hence the materials offered in the fire quickly split into minute particles such as atoms, molecules, ions, and nanoparticles.
(b) the vapors that are produced can easily and quickly spread into the atmosphere leaving space for oxygen to enter into the combustion chamber for combusting other materials.
(c) the heat loss through the lateral surfaces is minimized.
(d) the metal used for the combustion chamber construction is minimized.

## III. RESULTS AND DISCUSSIONS

***III.1 Relation between the height of the combustion chamber and the side of the upper opening for having maximum temperature inside the combustion chamber.***

From the scientific findings of Adrian Bejan [9], "hottest pile of burning fuel occurs when the height of the pile is roughly same as its base diameter". This is for a pile of fuel where the base width is more than the top width. Since bonfires are shaped as cones and pyramids, the same result will hold true if consider it for the combustion chamber where the top width is greater than the bottom.

Therefore, for the fire to be hottest we conclude that the height 'h' of the combustion chamber must be equal to the side length 'a' or diameter 'a' of the opening of the chamber.

$$h = a \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

This causes the materials to quickly split into minute particles and become vapor.

***III.2 Finding the half angle of the combustion chamber for easily spreading the vapors into the atmosphere.***

Truncated pyramid or cone shaped combustion chambers are like nozzles for gas flow.

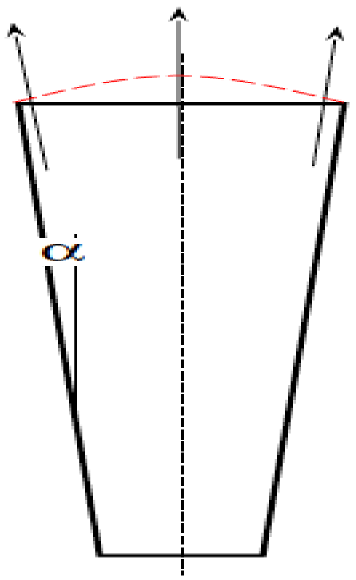


**Figure – 2**

From figure-2 the angle '∝' is called the half angle and that decides the relation between top side length of the nozzle, height of the nozzle, and the base side length.

The divergence factor for a convergent divergent nozzle [10] is given in terms of the half angle '∝'

$$\lambda = (1 + \cos(\propto))/2 \quad \ldots\ldots\ldots\ldots\ldots (2)$$

And the equation for the trust force is given by $F = \mu v \lambda$ ………………. (3)

Where 'μ' is the mass flow rate of the gases, 'v' is the axial flow velocity, and '$\lambda$' is the divergent factor. When the angle '∝' becomes greater than 20˚, the loss is quite heavy.

In our case where we want trust to be less on the combustion chamber, the trust force given by (3) will be least as '∝' increases. Since the height 'h' of the combustion chamber is related to the side 'a' or diameter of opening of the combustion chamber (refer to equation (1)) for obtaining high temperature inside the combustion chamber, we cannot increase '∝' as we like.

Considering lateral surface area of a truncated pyramid (including the bottom area),

$$S= 2(a + b) [((a - b)/2)^2 + h^2]^{1/2} + b^2 = 2(a + b) h/\cos(\propto) + b^2 \quad \ldots\ldots\ldots\ldots (4)$$

As '∝' increases the trust decreases but the surface area increases as given by equation (4).

$$\text{Where, } \cos(\propto) = h / (h^2 + ((a - b)^2/2)^{1/2} \quad \ldots\ldots\ldots\ldots (5)$$

From equation (4) we can see that as '∝' increases, the value of 'S' increases, and hence more surface area that results in more heat lose and more metal to be used. But if '∝' decreases trust increases on the base of the combustion chamber, and the spreading of the vapor decreases. Efficiency of the Yajna process increases if the vapors spread more and hence the angle should not decrease. Therefore, there must an optimal condition at which the trust is less, lateral surface area is less, and spreading of the vapor is more.

From the rocket nozzle condition, it is found that if the angle '∝' is more than 20˚, the loses are substantial and it does not appear meaningful to have such a nozzle. But from the point of view of the combustion chamber the angle '∝' must be greater than or equal to 20˚ so that the trust is least, and the height of the combustion chamber is less. Keeping the height equal to the side of the opening (as it is the necessity for a higher temperature inside the combustion chamber), we cannot keep increasing the angle '∝'. Because as the angle increases so does the upper side and hence the height. This makes us to limit the angle to around 20˚ and calculate the base side length or diameter. The length of the base of the combustion chamber is obtained from (5) by substituting h = a, and '∝' = 20˚,

$$b = 0.27\,a \approx a / 4 \quad \ldots\ldots\ldots\ldots\ldots\ldots (6)$$

***III.3 Combustion chamber geometry for least heat transfer to the surroundings.***

Let us consider different shapes of combustion chamber viz., (a) truncated pyramid, and (b) truncated cone, (c) cuboid, and (d) hemisphere. If the lateral surface area is minimum, then that combustion chamber will transfer least heat to the surroundings and the temperature will be maximum inside. This condition gives materials to combust properly and reduce production of carbon monoxide.

(a) Truncated pyramid (Fig-3): Let the opening be of side 'a', height of the truncated pyramid be 'h', and base be of side 'b'. Then the lateral surface area (only the sides and bottom but not the top) is given by

$$\text{Later Surface Area of the truncated pyramid} = 2(a + b)\,[((a - b)/2)^2 + h^2]^{1/2} + b^2 \ \ldots (7)$$

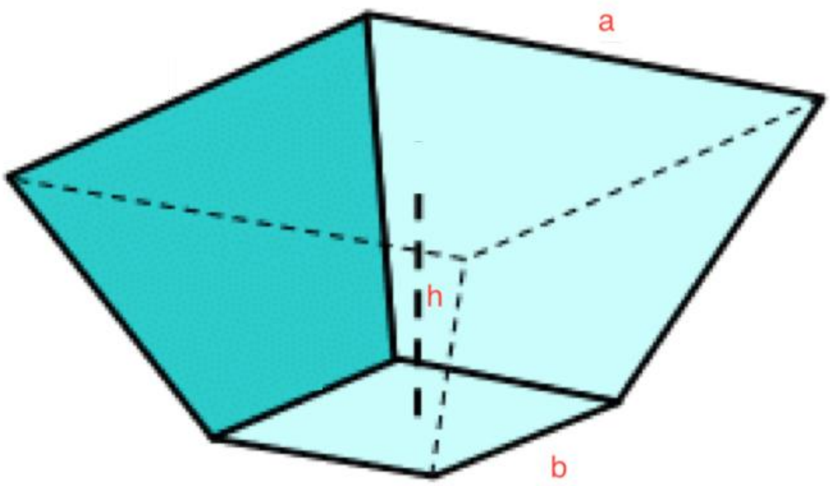


**Figure-3**

(b) Truncated cone (Fig-4): Let the opening have radius 'a', height 'h', and base have radius 'b'. Then the Lateral surface area (only the sides and not the bottom and top) is given by

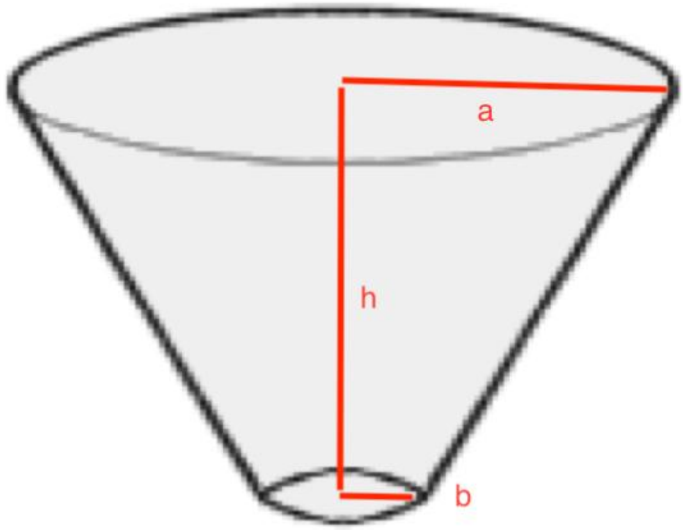


**Figure – 4**

Lateral Surface area of the truncated cone = $\pi$ (a + b) [((a – b)$^2$ + h$^2$]$^{1/2}$ + $\pi$ b$^2$ ……. (8)
Comparing (7), and (8), we find that the Lateral surface area of truncated pyramid is the least for any values of 'a', 'b', and 'h'.
Since we have h = a, and b = a / 4, for an efficient combustion chamber, on substituting these values in (7) and (8) to obtain lateral surface areas of each geometrical structure.
For the inverted truncated pyramid from (7),
Lateral Surface area of inverted truncated pyramid with larger square open = 2.73 a$^2$ …………. (9)
For the inverted truncated cone from (8),
Lateral Surface area of inverted truncated cone with larger circle open = 5.11 a$^2$ …………. (10)
For a cuboid with all sides equal to 'a',
Lateral Surface area of cuboid with one side open = 5 a$^2$ ………………… (11)
For a hemisphere with radius equal to 'a',
Lateral Surface area of hemisphere with open circular area = 2$\pi$ a$^2$ = 6.28 a$^2$ …………. (12)
From (9), (10), (11), and (12) we can clearly see that Lateral Surface area of the inverted truncated pyramid is the least. Therefore, the loss due to radiation and conduction is least in the inverted truncated pyramid.
Having lesser lateral surface area means, using lesser metal for construction of the fire pit. Therefore, truncated pyramid costs less as combustion chamber than the others (truncated cone etc.).

## IV. CONCLUSIONS AND RECOMMENDATIONS

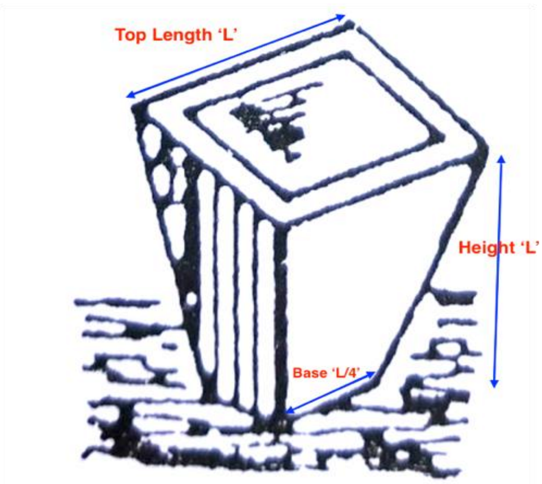


**Figure - 5**

(a) If the height of the combustion chamber is equal to one side of the opening, then the temperature in the combustion chamber will be high enough to split the materials offered in the fire, and the rate of formation of vapor containing atoms, molecules, ions, and nanoparticles will be higher.
(b) If the base side length is about one fourth the top side length, then these vapors containing atoms, molecules, ions, and nanoparticles are quickly spread into the atmosphere and does not cause greater trust.
(c) If the combustion chamber is an inverted truncated pyramid, then the heat losses from the lateral surface area will be least when compared to inverted truncated cone with similar dimensions because of lesser lateral surface area. Also, the cost and material used for construction of the combustion chamber will be least when compared to other structures.
(d) An efficient combustion chamber for the process of Yajna is an inverted truncated pyramid as shown in figure - 5.

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