

## **SUSPENDED BOX SOLAR OVEN**

**An improved solar oven design with high performance**

*The cooking ability of typical box type solar cooker is not satisfactory in comparison to the cost involved. Focusing type cooker needs frequent adjustment to track the motion of the sun. So, a highly efficient solar oven is designed and fabricated to ease the solar cooking for an extended period from morning to afternoon.*

***Designed and Fabricated by:***

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*Conventional box type solar cookers can not able to follow the sun properly except during solar noon. Moreover, use of single reflector is not so suitable to boost up the energy collection. Box type cookers with multiple reflectors generally known as solar ovens are equipped with adjustable leg at back for changing the inclination with respect to the ground. But these ovens also can not able to follow the sun in morning and afternoon (during summer intensity of solar radiation is still high during these times in most part of our country) as adjustment of these ovens with the ground is limited. It is due to the fact that after certain degrees of inclination the oven will be turned over in front for the weight of reflectors and also for the rotation of line of action of oven box weight towards front. Another problem with existing solar ovens with the typical adjustable back stand is that, when oven inclination is to be changed then at first oven is to be lifted against its weight before readjustment in its stand. By the use of fiberglass body and aluminium reflectors this handling problem however partly solved but material cost is thus increased.*

*Focusing type solar cookers however not suffered by the aforesaid problems but need frequent adjustment to track the motion of sun. Also, High wind velocity reduces the efficiency of such cookers. Besides, these cookers are costlier.*

## **CONSTRUCTIONAL DETAILS**

Presently proposed suspended box type solar oven consists of two boxes, a black painted aluminum inner box kept inside of an outer box. The outer box is made of G.I. sheet. The space between the two boxes is filled up with loose packed glass wool insulation. Length, width and depth of the oven box are 44 cm, 44 cm and 36 cm respectively. The upside of the oven box has double transparent glass covers keeping a gap of 20 mm in between. Neoprene rubber is used for cover gasket to seal the closed cover and inner box. The supporting frame of the glass cover is hinged with oven box and cooking pot can be withdrawn or handled by opening the glass cover.

The oven box is suspended from inverted "T" shape main frame and can be easily adjusted from 5 degree to even up to 80 degree with respect to the ground by simply swing the oven box and thereafter positioning of rectangular support frame in desired slot. Slots are formed by series of long studs provided in the mainframe base. Location of pivot points from those the oven is suspended is just few centimeters above the C.G. (Centre of gravity) point of the oven box so that the tusk of changing of inclination of oven box required a light force. (Approximate C.G. point is detected by trial keeping oven box sidewall parallel to the ground with open reflectors). The sketch of proposed oven is shown in Figure – 1.

In this oven, only one cooking pot is used mainly for rice cooking because generally in most localities of these sub-continent peoples are not habituated to take boiled food except rice. During rice cooking, lintel soup (Dal) can also be easily cooked at the same time by placing another small pot inside of large main pot containing rice. However, the oven can be easily designed also even for four numbers of cooking pots without alternation of basic design but in that case size and weight of the oven will be larger. The tilting cooking tray is square in shape and ends of the tray are folded upwards. The cooking pot is kept on this cooking tray. The holding arrangement of the tray is shown in Figure-2. In this new oven, cooking tray along with cooking pot is suspended through M.S. strips from pivots fixed in the sidewalls of the inner box and these pivots are aligned with the horizontal axis of the cooking pot. For the stability of the pot a counter weight of about one and a half kilogram is attached at the bottom of cooking tray During changing of oven inclination, the tray along with pot rotates at its horizontal axis and maintains constant horizontal position to avoid spilling over of food items. Cooking pot and interior of the oven are painted black by automobile muffler paint to increase absorption of solar radiation.

The oven has four foldable mirror reflectors. Size of the reflectors is equal to the glass cover and these are hinged with oven box at four sides of the glass cover. The reflectors when open are held fixed at an angle of 115 degree with the oven face by the help of reflector supports and holding clips provided at the backside of the reflectors. Reflectors can be folded for keeping on the top of the oven box cover when not in use.

During reorientation of the oven, apart from changing of inclination of the oven box, the whole oven can be rotated at the ground at desired position with the help of caster wheels attached at the bottom of the supporting frame, but the position of reflectors remain unchanged throughout the working period. To get best performance, reorientation in every 30 minutes interval is suggested.

## **ORIGINALITY / NOVELTY OF THE INVENTION**

1. Invented solar oven can be able to follow the sun at right angle almost throughout the day which is especially beneficial in summer for solar cooking as during summer, intensity of solar radiation is still sufficient to solar cook when sun is low in the sky. The new oven allows the user to cook more meals per year as the oven still works when the sun is low in the sky.

2. Little effort is required during its reorientation. Adjustment is possible just by swing the suspended oven box without direct oven weight handling.

3. Ingenious cooking pot holding arrangement permits the cooking pot to rotate around its horizontal axis and thus always remains in central position of oven interior for which proper utilization of upper and bottom reflectors at every inclination of the oven are possible. Moreover, rotation of the pot around its horizontal axis takes minimum space for rotation and so, depth of the oven box is reduced. During solar noon, distance of pot from glass cover is remained less in this design for which it is possible to set reflectors at wider inclination.

## **SPECIFICATIONS OF DIFERENT COMPONENTS OF THE OVEN:**

### **Cover Plate:**

Number of Glazing-Two

Material-: Plain glass (But better to use tempered glass for lower glazing)

Size- Length- 38 cm. Width- 38 cm

Spacing between two glazing – 2 cm

Glass thickness- 0.3 cm

Width of supporting frame in all sides- 1.8 cm

Additional Design Feature--Provision or keeping cover plate in inclined position (opened position) with respect to its closing position for handling of cooking pot.

### **Inner Box:**

Material- Aluminum Sheet

Thickness of Sheet- 24 Gauge.

Size- Length- 34cm, Width- 34cm, depth- 28cm

Paint on Inner Surface - Mat black finish by automobile muffler paint.

### **Oven Box**

Material- G.I. Sheet

Thickness- 24 Gauge.

Size- Length- 44 cm, Width- 44 cm, Height- 36 cm.

### **Cooking Tray**

Material- Frame made of 1.8 cm M.S angle (standard 3/4<sup>th</sup> inch. M.S angle)

Size- 24 cm x 24 cm

Depth of pivots of sidewalls (from which tray is suspended through M.S strips) from glass cover (or, inner box top) - 14 cm

Distance of tray from pivots- 5.7 cm

Counter weight – 1.50 kg. - made of automobile spring strip of length 20.5 cm welded at the bottom of tray at mid position

Paint on Inner Surface- Mat black finish by automobile muffler paint

### **Cooking Pot with Lid**

Number of pot – One

Material- Aluminium

Diameter- 23 cm

Depth- 11 cm

## **Gasket and Insulation**

Gasket Material- Neoprene rubber

Thickness- 0.2 cm

Insulation Material- Glass Wool

Pad (insulation) thickness- In all sides and bottom – 5 cm

## **Reflecting Mirror**

Number of reflectors - Four

Mirror thickness- 3 mm

Size: Length - 38cm, Width – 38 cm

Additional design Feature: Provision for keeping the mirror at an inclination of 115 degree (working position) with respect to its folding position (when not in use)

## **Caster Wheel**

Number- Four

Construction- Nylon Ball

## **COST OF FABRICATION OF PROTOTYPE OVEN**

1. Aluminium sheet (24 Gauge) - 4 feet x 2.5 feet @Rs.160 per running feet of width 4 feet -	Rs.400
2. G.I sheet (24 Gauge) - Total 6 feet x 3 feet For making both oven box and back support of reflector frame, 6 feet x 3 feet piece -	Rs.360
3. 3/4 <sup>th</sup> inch square pipe (16 Gauge) for support, 10 feet long piece -	Rs.100
4. 3/4 <sup>th</sup> inch round pipe for support - 5 feet long piece -	Rs.60
5. 3 mm thick plain window glass - 15 inch x 15 inch, two pieces @ Rs.25 per sq feet, but 2 pcs, 15 inch x 15 inch glass considered as total 2 sq. feet during purchase from the market -	Rs.50
6. 3 mm thick mirror- 1ft x 1 ft, 4 pieces, @Rs.55 per sq. feet	Rs.336
7. MS angle and automobile leaf spring strip for cooking tray making -	Rs.50
8. Dull black paint (DUCO paint): 200 ml. @ Rs.220 per litre-	Rs.44
9. Paint for support frame: 150ml @ Rs.120 per litre	Rs.18
10. Glass wool- 2 kg. @ Rs.35 per kg -	Rs.70
11. Gasket material and adhesive -	Rs.150
12. Strips and clips for mirror holding, fiber sheet for mirror back etc. -	Rs.150
13. Bolt and nut, rivet, screws etc. -	Rs.50

14. Welding rod, soft solder –	Rs.80
15. Aluminium pot of 3 litre capacity -	Rs.100
16. Caster wheel - 4 Nos. -	Rs.60
17. Fabrication charge	Rs.400
	Rs.2412

TOTAL: Rs.2412, say, Rs.2450. It is expected that the cost will come down to an appreciable amount if a number of ovens are made at a time and materials are purchased in bulk.

### **TOOLS AND EQUIPMENTS REQUIRED FOR FABRICATION**

1. Light Duty Bending Machine  
(For metal sheet folding to form the inner and outer box).
2. Potable Drilling Machine (To drill holes of size 1/16<sup>th</sup> and 1/8<sup>th</sup>).
3. Welding Machine (For making support stand).
4. Shear Cutting Machine-Light duty (For sheet metal cutting).
5. Light duty Grinding Machine.
6. Spray Painting Machine (For painting inner box, outer box support stand etc).
7. Soldering Iron Set (For soldering the joints of outer box, glass cover channel, reflector frame).
8. Hand Shear (For misc. small cuttings).
9. Standard Hammer.
10. Rubber Mallet, and Wooden Mallet.
11. Standard Pliers.
12. Wrench Set.
13. Screw Driver Set.
14. Working Table with Bench Vice.
15. Some Gigs and Fixtures for convenient working.
16. Measuring Tape, Steel Scale, Calipers, Marking Gauge.

## TENTATIVE MAN POWER REQUIREMENT

### For each Oven:

Sheet metal worker for box making- 1 head for whole one day.

Fitter for cutting, drilling, riveting, painting supporting stand pipe bending etc and for final assembly work - 1 head for whole one day.

Welder for support stand welding, making of cooking tray- 1 head for three hours.

Tin smith for soft soldering of joints at top corners of the oven box at the location of glass cover seating and also in glass cover frame - 1 head for one hour.

## TEST RESULTS

*All tests are carried out by the innovator himself. Formal test in any authorized School of Energy Studies not yet performed. During tests, Dr. Soupayan Mitra, Asstant Professor of local Govt. Engineering College kindly cooperated by measuring solar radiation through radiation pyrometer available in the college.*

At first after construction of the solar oven, some routine tests such as inner box leakage test, leakage test of upper and lower sides of cover plate, cover gasket leakage test etc are carried out in line with IS code [1].

Other performance tests as stated below are carried out. Reorientation is done in every 30 minute interval.

**i) Test date, time and location- between 6th April'2006 to 15th April'2006, from 9-30am to 12-30pm, Jalpaiguri (26.32 ° N latitude, 88.46 ° E longitude), West Bengal.**

Average Ambient temperature - 27 degree Celsius.

Average intensity of solar radiation during test period - 0.53 kW per square metre

Peak temperature of empty cooking pot - 170 degree Celsius.

**ii) Test date, time and location – 16th April'2006 to 25<sup>th</sup> April'2006, from 10-30am to 12-50pm, Jalpaiguri, W.B.**

Average ambient temperature – 28 degree Celsius.

Initial temperature of water - 26 degree Celsius.

Average intensity of solar radiation during test period- 0.55 kw. per square metre

Time taken for boiling of 2 kg. of water- 110 minutes.

### **iii). Cooking Performance:**

Average time taken for cooking 1.5 kg (after preparation) of rice - 100 minutes.

## ESTIMATED APPROXIMATE PROJECT COST FOR MASS PRODUCTION

### Land and Building

**Total Rs.200000.**

(Considering price of 1200sq.ft land outside of town area = Rs.100000 and 30ft x 30ft workshop building built of 5inch brick wall with 3ft Ht. plinth level and with tin shed = Rs.100000)

### Machineries and Equipments

1. Light Duty Bending Machine:	1 No	Rs.18500
2. Potable Drilling Machine:	1No	Rs.6000
3. Welding Machine:	1 No	Rs.8500
4. Shear Cutting Machine-Light duty:	1 No	Rs.4000
5. Light duty Grinding Machine:	1 No	Rs.5000
6. Spray Painting Machine:	1 No	Rs.3000
7. Soldering Iron:	2 Set	Rs.350
8. Hand Shear:	2Nos. Rs.200 x 2-	Rs.400
9. Standard Hammer:	2Nos. Rs.200 x 2-	Rs.400
10. Rubber Mallet and Wooden Mallet:	2 Set	Rs.600
11. Standard Pliers:	2 Nos.	Rs.160
12. Wrench Set:	2 Set	Rs.800
13. Screw Driver:	2 Set	Rs.150
14. Work Table with Bench Vice:	1 NO:	Rs.2500
15. Gigs and Fixtures:		Rs.3000
16. Measuring Tape, Steel Scale, Calipers, Marking Gauge etc:		Rs.600

**Total Rs.53960,  
Considered as Rs.54000**

### Expanses for Staff (per month)

Salary of 4Nos Sheet Metal Workers, 2Nos Fitters,  
1No Welder, 1No Painter and 2Nos unskilled workers:

@ (4 x Rs.6000) + (2 x Rs.6000) + 6000 + 6000 + (2 x Rs.4000): **Total Rs.56000**

**Raw Material (per month)**

For 100 ovens per month  
@Rs.1800 material cost per oven: **Total Rs.180000**  
(in case of mass production)  
[Considering 25 working days in a month]

**Utility and other Expenses** **Total Rs.20000**  
(Power, Consumables, Packaging,  
Freight etc)

**Working Capital (per months):** **Total Rs.256000**  
(Raw Material, Staff, Utilities)

**Total Capital Investment** **Total Rs.1022000**  
(Land and Building, Machinery and Equipments  
and Working capital for 3months)

**Cost of Production per month** **Total Rs.267522**  
(Considering bank interest @ 13%  
and depreciation on Machinery  
@ 10% per annum + cost of Raw Material,  
Staff, Utilities)  
[Repayment of principle  
amount of loan part by part is not considered  
while calculating Bank interest]

**Total Sales (per annum)**

100 ovens per month x 12month **Total Rs.3480000**  
@ Rs.2900 as ex-factory price for each oven

*[Maximum retail price in market is considered  
as Rs.3500. In fact, cost will be lowered down to  
Rs.3400 in actual as incentive of Rs.100 is arranged  
by MNRE, Govt. of India for Box Type Solar Cooker]*

**Profitability (per annum)**

Total sales – Production cost **Total Rs.269736**

**Break-even analysis:**

$(\text{Annual fixed cost} \times 100) / (\text{Annual fixed cost} + \text{Profit per annum})$

Where:

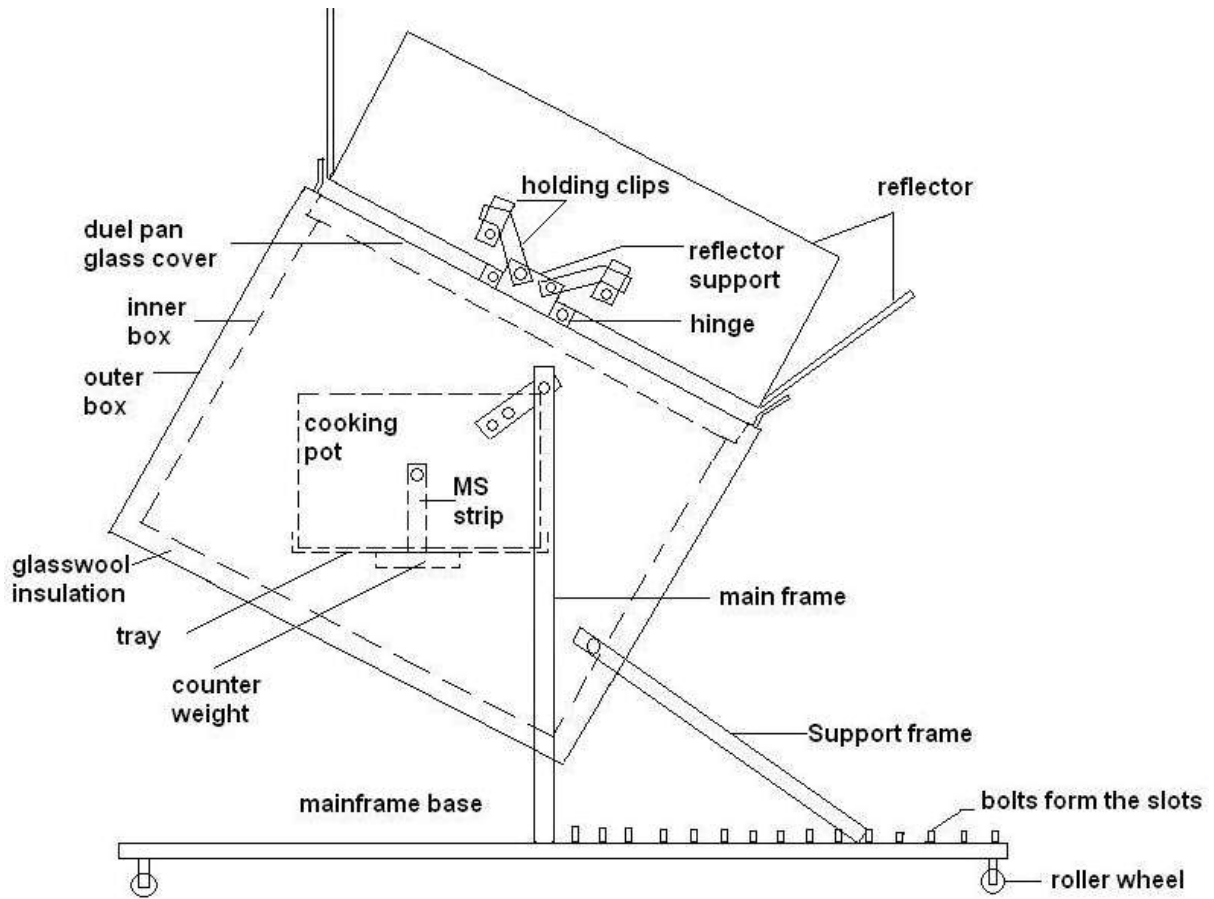
Profit per annum: Rs.269736

Annual fixed cost: Rs.407060  
(12% Bank interest  
+10% depreciation on Machinerics  
+ 40% on Salaries)

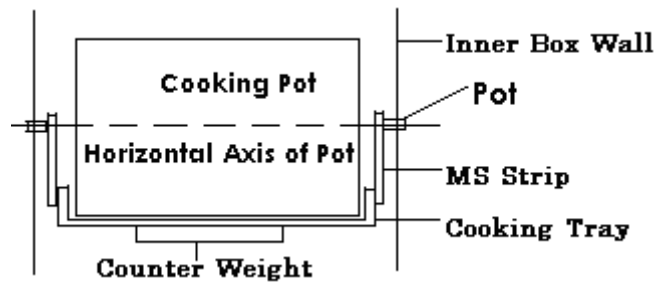
**B.E.P: 60%**



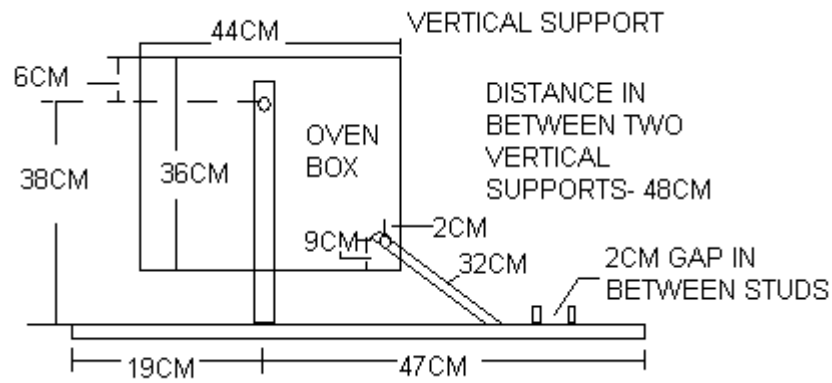
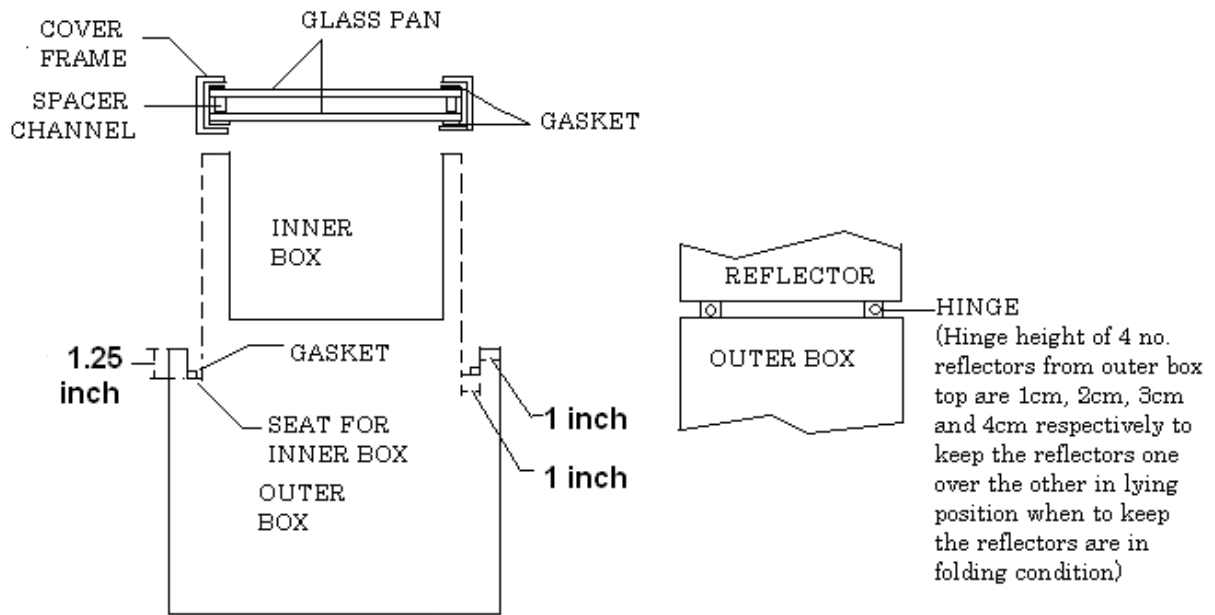
## SKETCHES: SUSPENDED BOX SOLAR OVEN



**FIG.1- Shows the schematic view of suspended box oven**



**Fig.2- Schematic drawing of tilting cooking tray arrangement with pot**



**FIG.3- Sketches of the oven box components and support system**



**PHOTOGRAPH.1- Shows a view of solar oven**



**PHOTOGRAPH.2- Shows the cooking pot inside of oven**



**PHOTOGRAPH.3- Shows the tilting tray inside of oven**



**PHOTOGRAPH.4- Shows the close-up view of reflector holding system**



**PHOTOGRAPH.5- Shows the reflectors in folding position**

#### **CONCEPT OF SUSPENDED SOLAR OVEN WITH FOUR NUMBER COOKONG POTS**

As shown in Fig-1, the oven box is suspended from inverted “T” shape main frame made of hollow square MS pipes and can be easily adjusted from 5 degree to even up to 80 degree with respect to the ground by simply swing the oven box and thereafter positioning of rectangular support frame in desired slot. Slots are formed by series of long studs provided in the mainframe base. Location of pivot points from those the oven is suspended is just few centimeters above the C.G. (Centre of gravity) point of the oven box so that the tusk of changing of inclination of oven box required a light force. Sketch of proposed oven is shown in Figure-1.

The constructional feature of the oven is shown in Fig-2. The oven consists of two boxes, a black painted aluminum inner box kept inside of an outer box. The outer box is made of G.I. sheet. The space between the two boxes is filled up with loose packed glass wool insulation. The upside of the oven box has double transparent glass covers. Silicon rubber is used as cover gasket to seal the closed cover and inner box. The supporting frame of the glass cover is hinged with oven box and cooking pots can be withdrawn or handled by opening the glass cover.

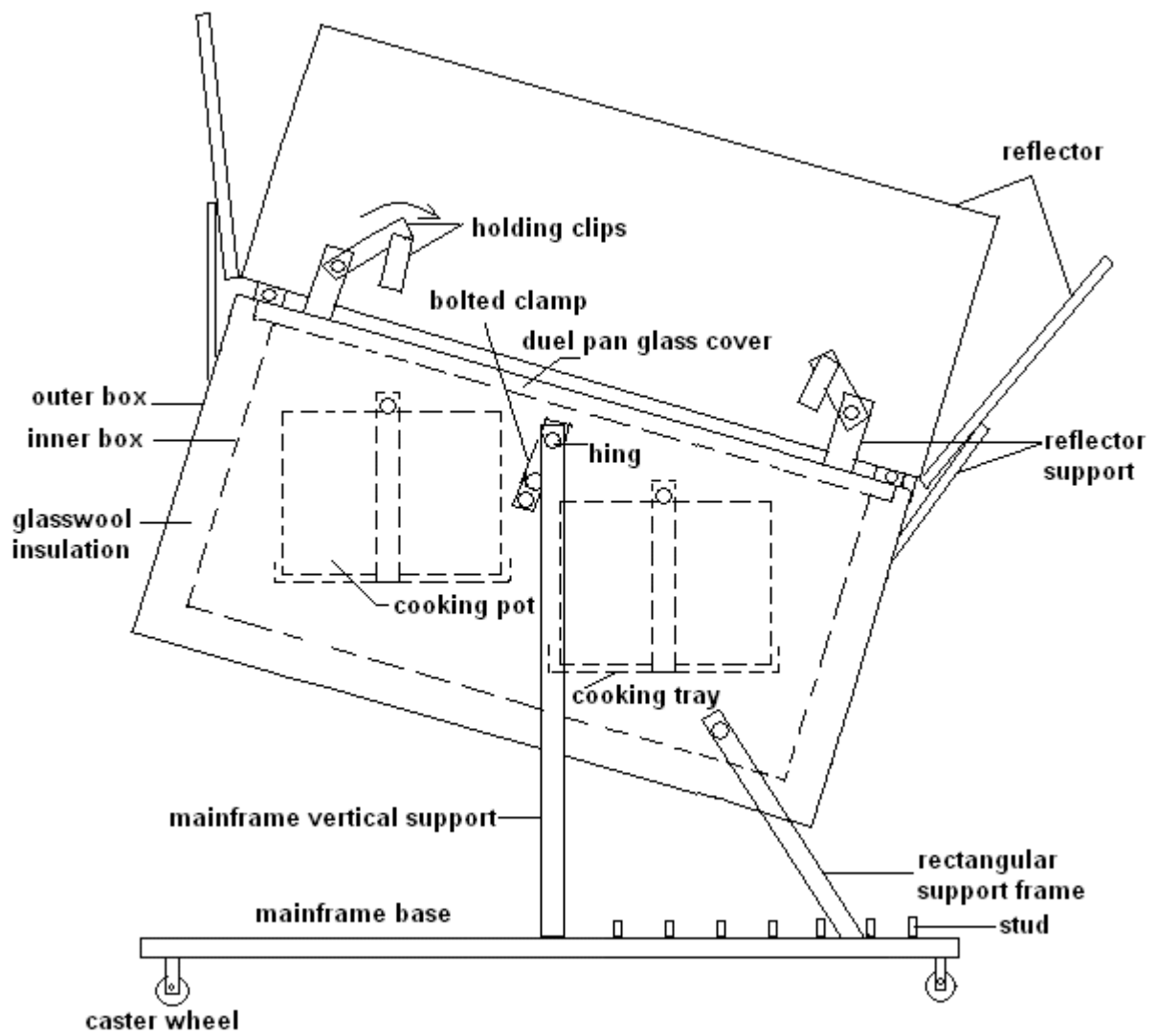
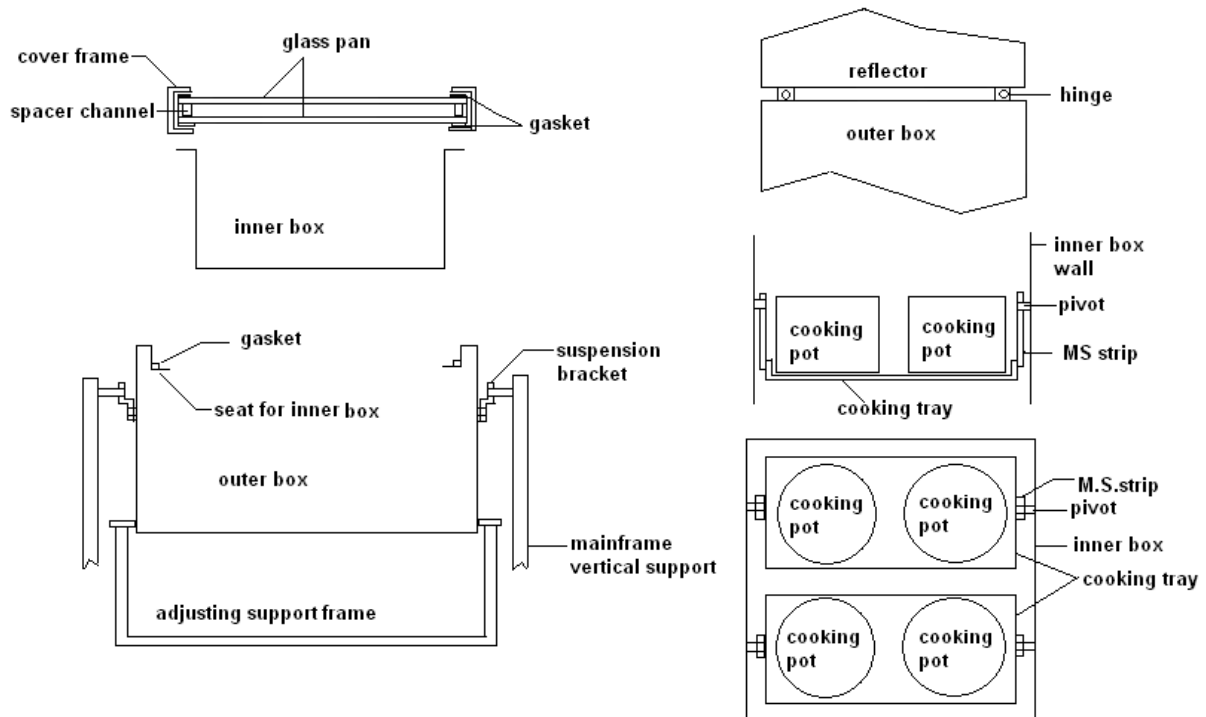


FIG- 1



**FIG- 2**

Four number of black painted aluminium cooking pots are used in this oven. There are two tilting cooking trays and two cooking pots are placed on each cooking tray. For each cooking tray, two bolts acted as hinge are fixed at right and left sidewalls of the oven inner box. The cooking tray is suspended from the end of the bolts through M.S strips. Length of these strips should be more than the cooking pot radius (actually taken nearly equal to the pot height in for these particular pots which is much more than pot radius to get more stability) and these strips are fixed with width side ends of the tray aligned with horizontal axis (longer side) of the tray as shown in Fig-2. When the oven box inclination is changed the cooking tray along with cooking pots, for its own weight, rotated around the bolts and always remained in horizontal position. To avoid the chance of tilting of pots, width of the trays is kept slightly more than the diameter of pots and ends of the trays are folded upward.

The oven has four foldable mirror reflectors. These are hinged with oven box at four sides of the glass cover. The reflectors when open are held fixed at an angle of 115 degree with the oven face by the help of reflector supports and holding clips provided at the backside of the reflectors. Reflectors can be folded for keeping on the top of the oven box cover when not in use.

During reorientation of the oven, apart from changing of inclination of the oven box, the whole oven can be rotated at the ground at desired position with the help of caster wheels attached at the bottom of the supporting frame, but the position of reflectors remain unchanged throughout the working period. To get best performance, reorientation in every 30 minutes interval is suggested.

### **SPECIFICATIONS:**

For proper selection of dimensions of the cooker, an original cooking pot is collected and accordingly a hard paper board model of the proposed cooker box is made suitable to provide four such cooking pots. Thereafter, all the necessary dimensions are brought out by measuring dimensions from the model.

### Cover Plate

Number of glazing-Two

Material- plain glass (if available, tempered glass is better to use for bottom glass pan)

Size- Length- 49cm. Width- 49cm

Spacing between two glazing– 2cm

Glass thickness- 0.3cm

Width of supporting channel frame in all sides- 1.8 cm

Additional Design Feature- Provision or keeping cover plate in inclined position (opened position) with respect to its closing position for handling of cooking pots.

### Inner Box

Material- Aluminium sheet

Thickness of sheet- 24Gauge.

Size- Length- 44cm, Width- 44cm, Depth- 20cm

Paint on inner surface -Mat black finish by automobile muffler paint (DUCO dull black paint).

### Outer Box

Material- G.I. sheet

Thickness- 24 Gauge.

Size- Length- 54cm, Width- 54cm, Height- 27.5cm.

### Suspended Cooking Tray

Material: Aluminium

Thickness of sheet: 24Gauge

Size: 35cm x 15cm

Length of M.S strips (for suspension of the trays) - 9cm (including bolt hole and margin)

Depth of hinge (for suspension of trays) from inner box top- 8cm.

Paint on inner surface: Mat black finish by dull black automobile muffler paint.

### Cooking Pot with Lid

Material- Aluminium

Number-Four

Diameter-14.5cm

Depth:-10cm

Paint on outer surfaces: Mat black finish by dull black automobile muffler paint.

### Gasket and Insulation

Gasket Material- Silicon rubber

Thickness- 0.3cm.

Insulation Material- Glass wool

Pad (insulation) thickness- In all sides and bottom- 5cm

### Reflecting Mirror (Mirror glass used, anodized aluminium reflector preferable)

Number of reflectors- Two

Mirror thickness- 0.3cm

Size- Length- 54cm, Width= 54cm



Additional design Feature- Provision for keeping the mirror at an inclination of 115 degree (working position) with respect to its folding position (When not in use)

#### Caster Wheel

Number- Four

Construction- Nylon Ball

#### Supporting Frame

To select the dimensions, at first original cooker is to be fabricated. By trial method approximate C.G point of the cooker box then can be fixed up keeping oven box sidewall parallel to the ground with open reflectors.