United States Patent [19]

Soulier

[11] **3,784,777**

[45] **Jan. 8, 1974**

[54] **MICROWAVE FURNACE FOR THE TREATMENT OF SHEETS OR PLATES MADE OF A MATERIAL ABSORBING SAID WAVES**

[76] Inventor: **Joël Henri Auguste Soulier,** 66 Chaussee Jules Cesar, Eaubonne, France

[22] Filed: **Dec. 22, 1971**

[21] Appl. No.: **210,801**

[30] **Foreign Application Priority Data**

Dec. 31, 1970 France 7047567

[52] **U.S. Cl.** .... **219/10.55,** 333/81 B

[51] **Int. Cl.** **H05b 9/06**

[58] **Field of Search** .... 219/10.55; 333/81 R, 333/81 A, 81 B

[56] **References Cited**

UNITED STATES PATENTS

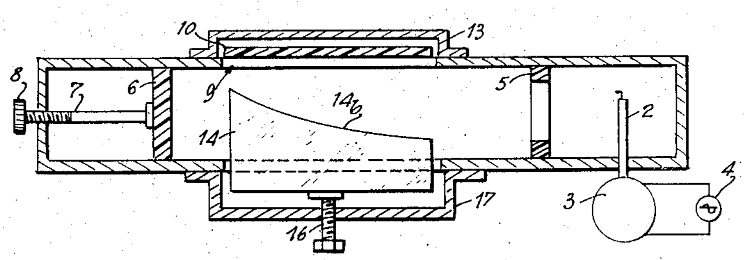
3,457,385	7/1969	Cumming	219/10.55
3,555,232	1/1971	Bleackley	219/10.55
3,218,583	11/1965	Pon et al.	333/81 A
2,869,085	1/1959	Pritchard et al.	333/81 B

Primary Examiner—C. L. Albritton
Assistant Examiner—Hugh D. Jaeger
Attorney—Saul Jecies

[57] **ABSTRACT**

A microwave furnace comprises a guide with a slot of a length corresponding to the width of a sheet which is to be treated by being continuously moved through the guide. A microwave generator is electrically connected to said guide and at least one metal plate is placed in front of said slot.

21 Claims, 6 Drawing Figures



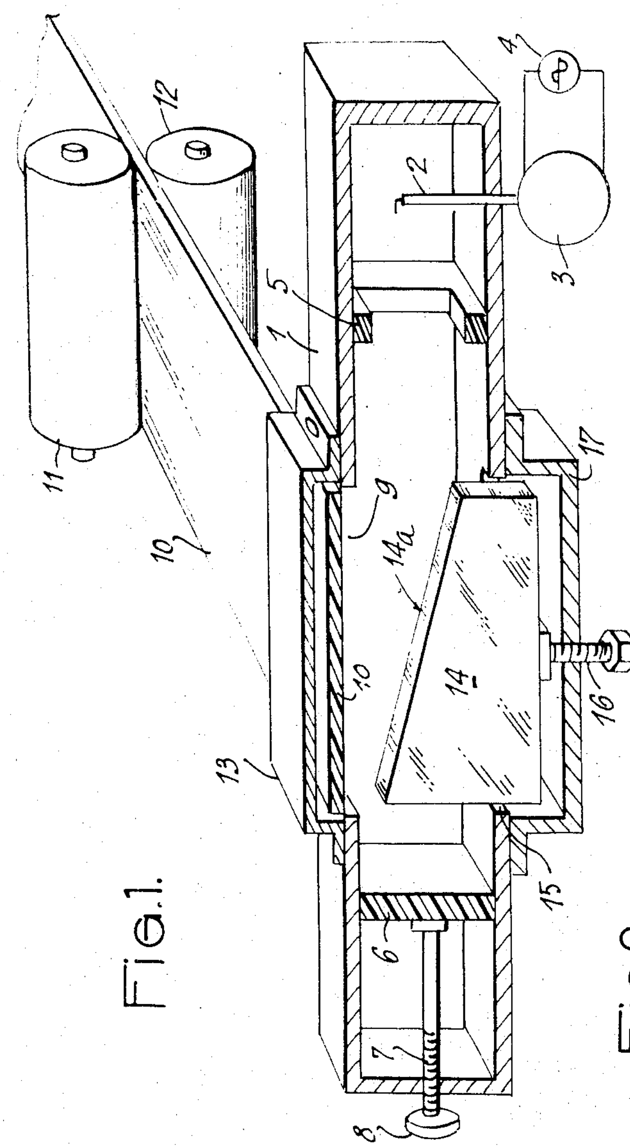


Fig.1.

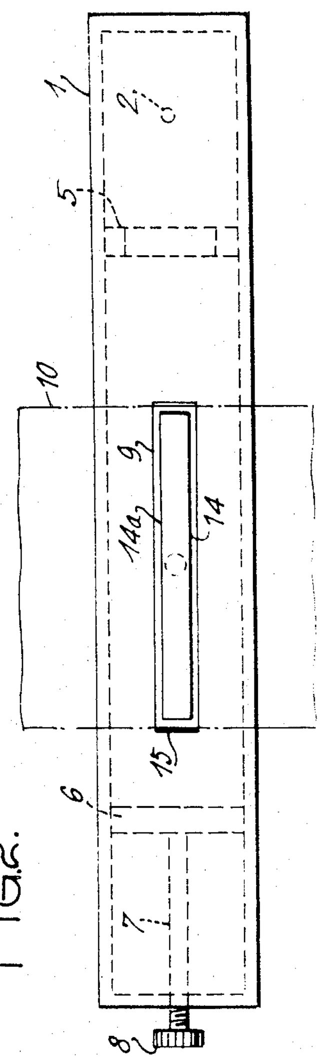


Fig.2.

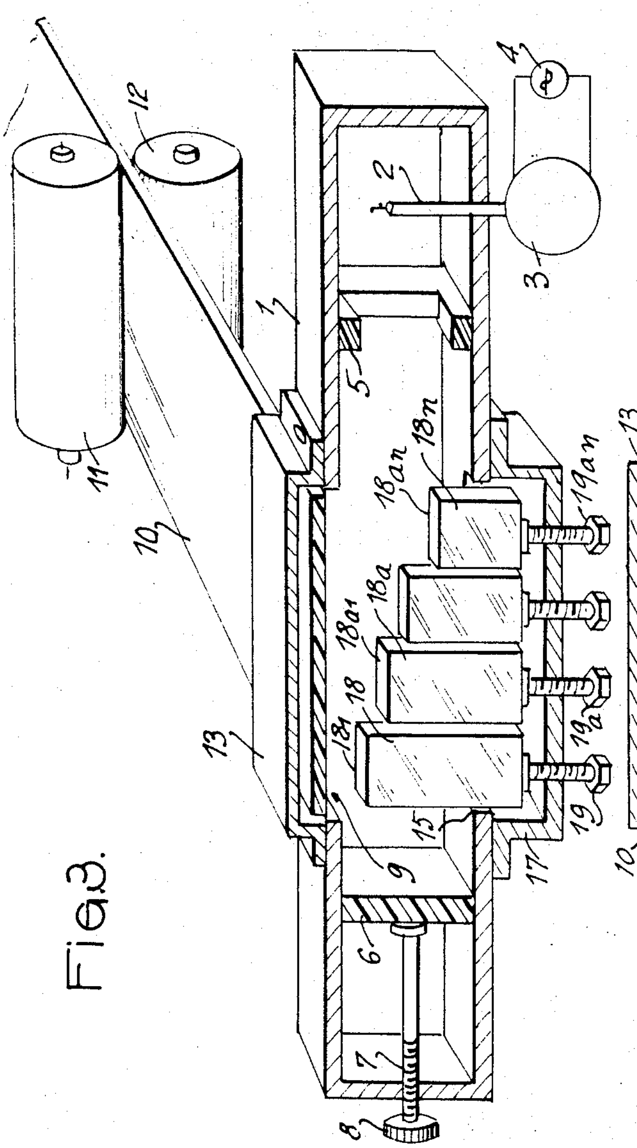

1
2
3
4
5
6
7
8
9
10
11
12
13
15
17
18
18a
18an
18n
19
19an

Fig.3.

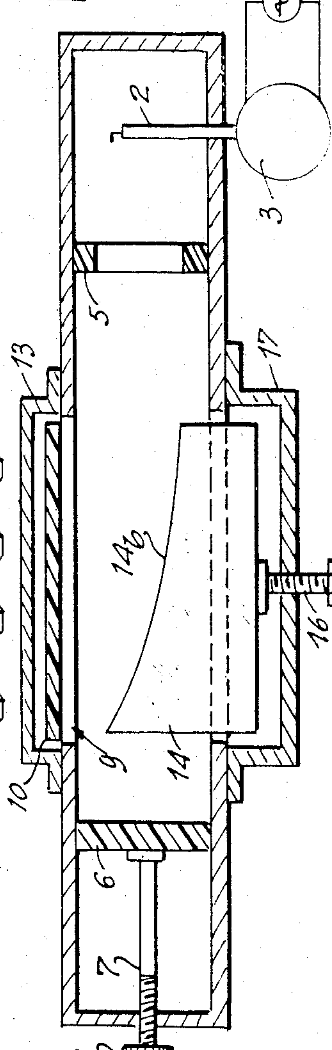

2
3
4
5
6
7
8
9
10
13
14
16
17

Fig.6.

Fig.5.

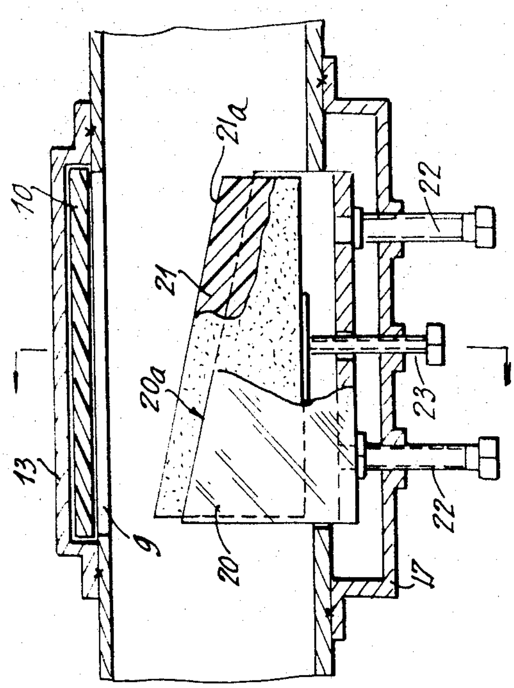
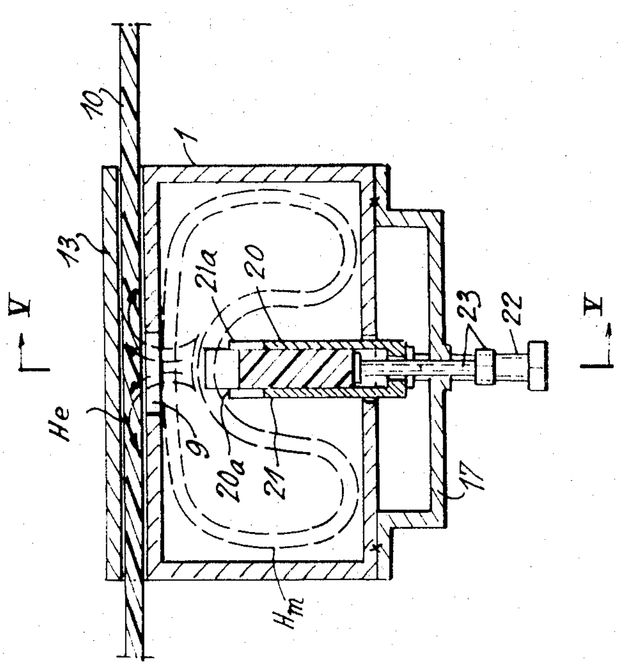

10
13
9
21a
21
20a
20
22
23
22
17

Fig.4.


V
V
10
1
13
He
21a
20
9
20a
21
23
22
17
Hm

MICROWAVE FURNACE FOR THE TREATMENT OF SHEETS OR PLATES MADE OF A MATERIAL ABSORBING SAID WAVES

The invention relates to a novel microwave furnace for the treatment of sheets or plates (i.e. workpieces) of great width and made of material absorbing said microwaves, said sheets or plates being made to travel through the furnace.

According to the invention, the novel furnace comprises a wave-guide, a slot provided in said wave-guide, and having a length corresponding to the width of said sheet or plate, conveying means for moving said sheet or plate transversely with respect to said slot, a microwave generator electrically connected to said guide, and at least one metal plate placed in front of said slot perpendicularly to the plane of and over the whole length of said slot. The plate has one side turned towards the slot and said side has an inclination decreasing in the direction of the microwave generator.

Other characteristics of the invention are shown in the following detailed description.

Embodiments of the invention are shown by way of the non-restrictive examples illustrated in the accompanying drawings in which:

FIG. 1 is a longitudinal diagrammatic perspective section of a furnace according to the invention;

FIG. 2 is a diagrammatic top plan view of the furnace of FIG. 1, with portions omitted for the sake of clarity;

FIG. 3 is a longitudinal perspective section, illustrating a variant embodiment of FIG. 1;

FIG. 4 is a cross-sectional view illustrating a further development of the invention;

FIG. 5 is an elevation sectional view taken on line V—V of FIG. 4; and

FIG. 6 is a diagrammatic view illustrating another development of the invention.

The furnace shown in the drawings comprises a wave-guide excited on the mode TE01; this waveguide is hereinafter called "resonant cavity." The resonant cavity **1** is of a parallelepipedal shape and into it protrudes the antenna **2** of a microwave generator **3** constituted, for example, of a magnetron and fed by a power source **4.**

As well-known in the art, the inside of the resonant cavity **1** in which ultra high frequency waves are dissipated includes matching elements **5,** for example constituted by rings or plates made of polytetrafluorethylene; in addition, the resonant cavity **1** is provided, at the end thereof opposite the end into which the antenna **2** protrudes, with an absorbing load **6** whose position can be modified by an adjusting device **7,** the control **8** of the latter being placed outside the cavity **1.**

The upper wall of cavity **1** is provided with a slot **9** whose length corresponds to the width of a sheet to be heated, and which is of a material absorbing the microwaves; the width of sheet **10** can be for example from 0.25 m to 2.50 m or more. Such materials are technically known as polar materials and are, for example, constituted by various thermoplastic and thermosetting rubbers and resins, which are, should the occasion arise, made polar by appropriate additives. Among numerous known materials capable of absorbing microwaves can be cited: butyl rubber, ethylenepropylene terpolymer, natural rubber, copolymers of ethylene and vinyl acetate, nitrile rubbers or blends thereof, chloroprene rubbers, and others.

Slot **9** may have various widths, but its width should preferably be in the range of about 5 to 10 mm.

The furnace being designed to treat or heat a sheet **10** which travels continuously, means are provided for advancing the sheet, such as, for example, sets of cylinders **11, 12,** bands or other suitable conveying devices.

To prevent any propagation of microwaves in the atmosphere, it is advantageous as shown on the drawings, that a protective cover **13** be provided above the slot **9** and preferably over the whole width of the cavity wall having said slot. This cover **13** is made of conductive metal and has its ends secured outside of the cavity.

The furnace is also provided in front of slot **9** with a plate **14** made of conductive metal, for example aluminum, whose length is preferably equal to the length of said slot **9.** The side **14*a*** of the plate **14** facing slot **9** is oblique to delimit a downwards inclination facing the antenna **2** of the magnetron **3.** The plate **14** can be permanently placed into the cavity **1** so as to be supported by that inner wall of the cavity, which is opposite to the wall provided with the slot **9.** However, as shown in the drawings, it is preferred that the plate **14** be located in an opening **15** and supported by one or several adjusting elements **16,** so that the position of the inclination **14*a*** in the cavity may be modified. An envelope like protective cover **17** is designed to prevent any propagation of the microwaves to the exterior of the cavity and is fixed, like the protective cover **13,** to the outside of the cavity **1.**

As is well-known, the absorption coefficient (designed by $tg\ \delta$) of the materials absorbing microwaves, increases with the temperature thereof. The microwaves, of course, have a tendency to be more absorbed by the portions of the materials which are closest to the microwave source, i.e., the antenna **2,** and consequently the sheet **10** would tend to be more heated near the edge thereof corresponding to that end portion of the slot **9** which is near from the antenna **2.** The microwave power transmitted from the antenna **2** then has a tendency to decrease along slot **9,** in an exponential manner from this end portion towards the other end portion of the slot.

Due to the provision of the plate **14** with the inclination **14*a*,** the magnetic field which is produced inside the resonant cavity **1** and which extends transversely with respect to said cavity, has to pass around plate **14** as represented by line Hm in FIG. **4.** Consequently it will be noticed that the magnetic field becomes more and more concentrated at the vicinity of the slot **9** as the distance from the antenna **2** increases so that the resulting electrical field He which is shown on FIG. **4** and absorbed by the material of sheet **10,** is made substantially constant over the whole width of said sheet. This prevents the edge of the sheet which is closet to the antenna **2** from being more heated than the rest and thus to tend to absorb more of the microwaves. As a result, the microwave energy applied to said sheet is more uniform over the whole lenght of the slot **9.**

Since the plate **14** is adjustable by means of screw **16,** it is possible to concentrate the magnetic field more or less the cavity **1,** thus enabling heating of sheets **10** of various thickness or having different absorption coefficients ($tg\ \delta$).

In the event that all the microwave power developed by magnetron should not be absorbed by the sheet **10,** then the auxiliary load constituted by the piston **6** which is made of absorbing material, prevents reflections which can cause return waves to be applied to the antenna **2** and consequently to the magnetron **3** with the resulting risks of destroying the same.

FIG. **3** illustrates a variant of the preceding embodiment wherein the plate **14** is replaced by several successive small plates **18, 18***a* . . . **18***n*, each of them having a separate control means **19, 19***a* . . . **19***n*. The height of plates **18** to **18***n* is decreases or the control means **19** to **19***n* are designed in order that the top $\mathbf{18}_1$, $\mathbf{18}a_1$ . . . $\mathbf{18}a_n$ of each plate be set off substantially in step shape, as shown. Thus it is possible, by moving the different plates upwards or downwards, to more or less concentrate the field in different areas of the slot **9** and thus to uniformly heat a sheet **10** having a non-constant thickness or having a heterogeneous structure with respect to the absorption of microwaves.

FIGS. **4** and **5** show a development of the invention wherein the plate **14** of FIG. **1** or the various plates **18** to **18***n* of FIG. **3** are replaced by a part **20** of U-shaped cross section, said part **20** containing — between the branches thereof — a plate **21** made of polytetrafluorethylene or similar material. The part **20** is, as above mentioned, preferably adjustable upwards and downwards by means of control devices **22** which are for example, constituted by screws as shown. In a similar way, the plate **21** is also adjustable upwards and downwards by means of a control component **23** which can be operated separately from those operating and lifting or lowering of the part **20**. It is advantageous that the top **20***a* of the part **20** and also the top **21***a* of the plate **21** be parallel to each other. Due to this additional means it becomes possible, by adjusting the position of the plate **21** to adapt or match the impedance of the resonant cavity and, consequently, to prevent the formation of standing waves which are prejudicial to good operation.

It is also possible, as shown in FIG. **6**, for the plate **14** to have a top **14***b* substantially shaped as an exponential curve. This is advantageous when the exponential function of absorbtion decrease of a material having to be heated is exactly known. Actually, then, by replacing said function in the configuration of the top **14***b* of plate **14** it becomes possible to compensate the absorption decrease very accurately and, consequently, to obtain strictly uniform heating over the whole width of the sheet **10**.

The invention is not restricted to the embodiments shown and described in detail, for various modifications can be employed without departing from the scope of the invention. Especially in the event when all the microwave power developed from the magnetron would not be absorbed by the wave-guide, then the energy could be returned into one or several similar wave-guides through appropriate bends.

I Claim:

1. A microwave furnace for the treatment of sheet-shaped or plate-shaped workpieces whose material is capable of absorbing microwaves, comprising

a wave-guide having a wall bounding an interior cavity and provided with a slot having a length corresponding to the width of the workpieces to be treated;

conveying means for conveying a workpiece to be treated exteriorly of said cavity across said slot transversely to the elongation thereof;

a microwave generator electrically connected with said wave-guide for producing in said cavity of the latter an electric field to which the successive increments of the advancing workpiece are to be exposed through said slot, and which tends to be non-uniformly absorbed over the surface area of said slot by the material of the workpiece; and

field-equalizing means in said cavity for equalizing said electric field over the entire area of said slot so that the material of the workpiece will uniformly absorb the field during advancement of the workpiece across said slot.

2. A microwave furnace as defined in claim **1**, wherein said field-equalizing means comprises at least one metal plate located in said wave-guide in front of the slot and extending normal to the plane and over the entire length of the same, said plate having a surface facing said slot and inclined in direction toward the same from the region of said microwave generator.

3. A microwave furnace as defined in claim **2**; and further comprising control means associated with said plate for moving the same toward and away from said slot normal to the plane of the latter.

4. A microwave furnace as defined in claim **2**; and further comprising a plurality of additional plates similar to the first-mentioned plate and all aligned in a common plane extending longitudinally of said slot; and control means associated with said plates and operative for individually moving each plate toward and away from said slot.

5. A microwave furnace as defined in claim **2**, wherein said surface of said plate has a rectilinear inclination.

6. A microwave furnace as defined in claim **2**, wherein said surface of said plate has a step-shaped inclination.

7. A microwave furnace as defined in claim **2**, wherein said surface of said plate has an exponentially shaped inclination.

8. A microwave furnace as defined in claim **2**, wherein said plate comprises one portion of substantially U-shaped cross-section having an open side facing said slot, and another portion of material sensitive to microwaves arranged in said one portion and having said surface which faces said slot at said open side; and further comprising control means associated with said other portions for moving the same toward and away from said slot normal to the plane of the same.

9. A microwave furnace as defined in claim **2**, said wave-guide having another wall opposite the first-mentioned wall and provided with an opening through which said plate in part extends to the exterior of said wave-guide; and further comprising a cupped cover fixed to the outer side of said other wall over said opening.

10. A microwave furnace as defined in claim **2**; and further comprising a cupped cover secured to said wall at the outer side thereof and overlying said slot, said cover defining with said wall a guide passage for travel of said workpiece across said slot.

11. A microwave furnace for treating a workpiece in the form of an elongated band, comprising

a substantially electrically continuous cavity having a longitudinal axis and being bounded by circumferential walls;

a source of microwave power to energize the cavity for propagating therein microwave energy along said longitudinal axis;

one longitudinally extending slot provided in one of said walls, said slot having a length substantially equal to the width of the elongated band;

travelling means for moving said elongated band along its own longitudinal plane and transversally to said longitudinal axis in front of said slot and exteriorly of said cavity; and

at least one metal plate inside the resonant cavity in front of said slot perpendicularly to a plane limited thereby and over all the length thereof, said metal plate having one side turned towards the slot and provided with a slope generally decreasing in direction of the source of microwave power.

12. A microwave furnace as defined in claim **11**, wherein an aperture is provided in the cavity in a wall thereof opposite the slot, control means being connected to at least one metal plate for supporting and adjusting it through said apreture.

13. A microwave furnace as defined in claim **11**, wherein said at least one metal plate is composed of a succession of plates, means being provided for supporting and adjusting each plate in position.

14. A microwave furnace as defined in claim **11**, wherein said at least one metal plate has a rectilinear top inclination.

15. A microwave furnace as defined in claim **11**, wherein said at least one metal plate has a step-shaped top inclination.

16. A microwave furnace as defined in claim **11**, wherein said at least one metal plate has an exponentially shaped top inclination.

17. A microwave furnace as defined in claim **11**,

wherein said at least one metal plate has a U-shaped cross-sectional shape and is supported by means for adjusting the position thereof with respect to the slot.

18. A microwave furnace as defined in claim **11**, wherein a first protective cover is fixed outside the cavity on the wall thereof which is provided with a slot, said protective cover forming a passage for the band to be treated.

19. A microwave furnace as defined in claim **12**, wherein a second protective cover is fixed outside the cavity on the wall thereof which is provided with an aperture, said protective cover enclosing said control means of at least one metal plate.

20. A method of treating elongated sheet-shaped or plate-shaped workpieces of material capable of absorbing microwaves, with the aid of a microwave furnace, comprising the steps of

producing a microwave field in a microwave furnace having a wall provided with a slot;

advancing a workpiece over said wall and transversely of said slot outside said microwave furnace for exposing successive increments of the workpiece through said slot to said microwave field;

and equalizing the microwave field over the entire surface area of each increment exposed in said slot whereby to assure uniform absorption of the microwave energy of the field by the material of said workpiece.

21. A method as defined in claim **20**, wherein the step of equalizing said field comprises varying the field over the surface area of the respective increment exposed in said slot as a function which is the inverse of the exponential function of absorption decrease of the material of the workpiece.

* * * * *