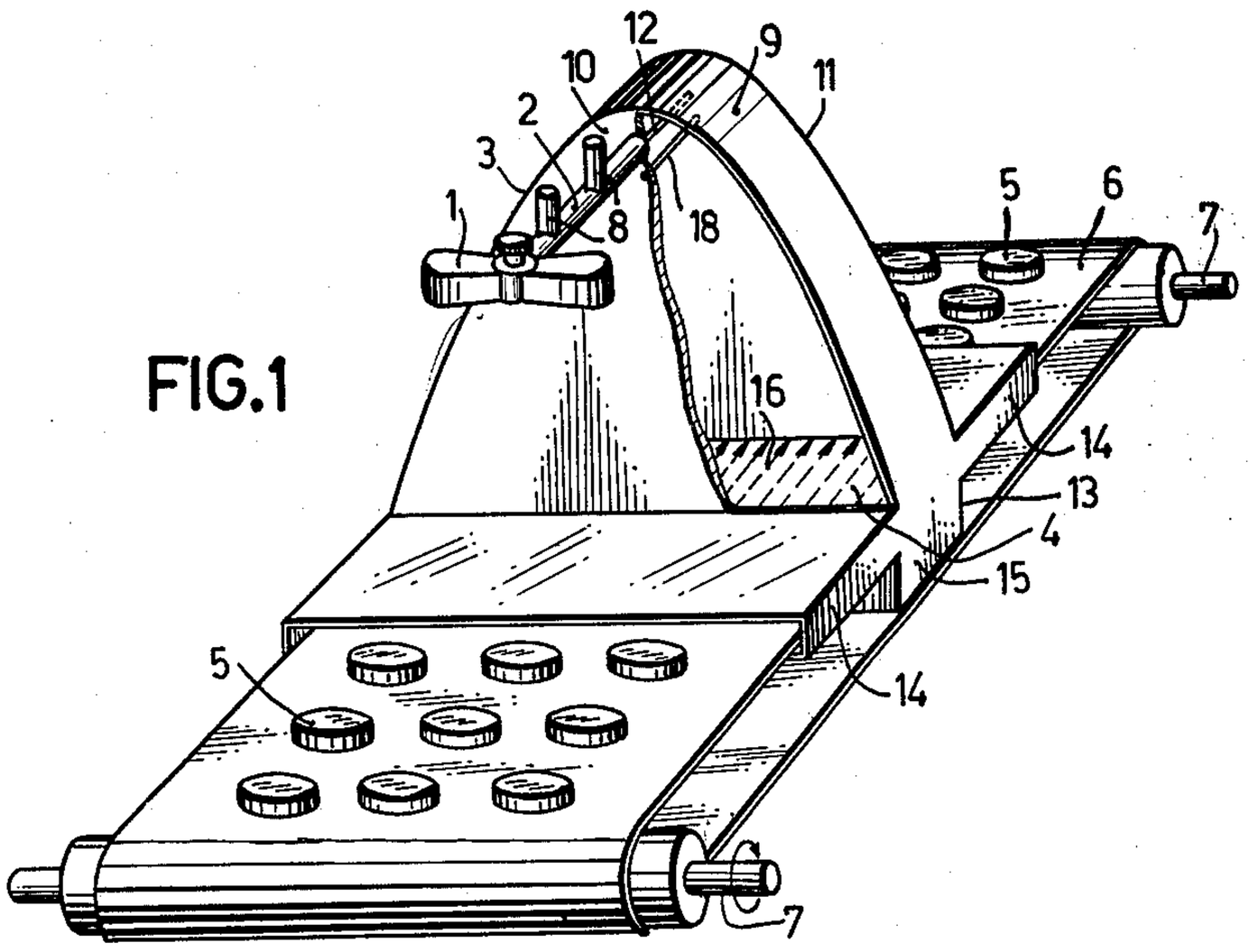
Aug. 27, 1963 J. VERSTRATEN 3,102,181

HIGH-FREQUENCY HEATING FURNACES OPERATING WITH VERY HIGH FREQUENCIES

Filed May 2. 1960 2 Sheets-Sheet 1

FIG.1



INVENTOR

JAN VERSTRATEN

BY

AGENT

Aug. 27, 1963 J. VERSTRATEN 3,102,181

HIGH-FREQUENCY HEATING FURNACES OPERATING WITH VERY HIGH FREQUENCIES

Filed May 2. 1960 2 Sheets-Sheet 2

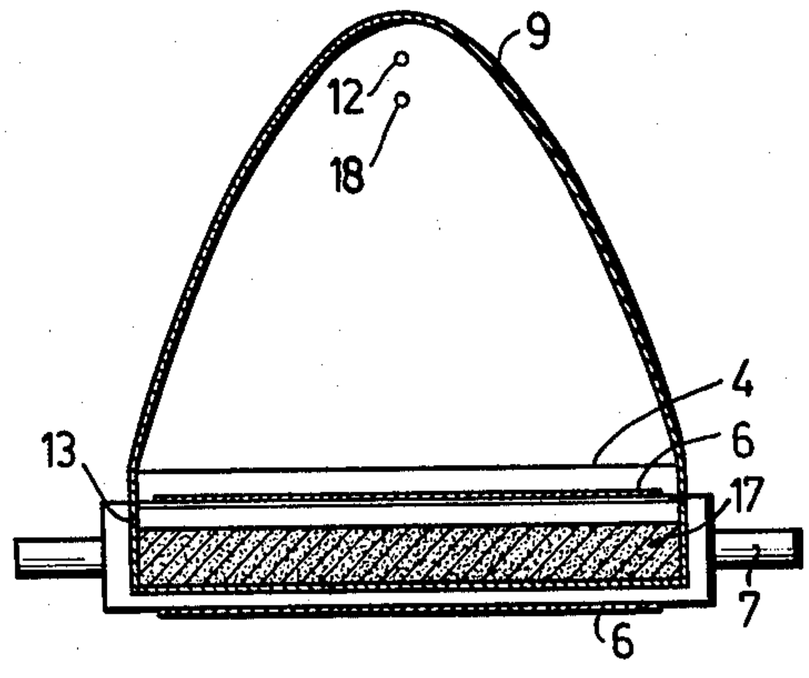


FIG.2

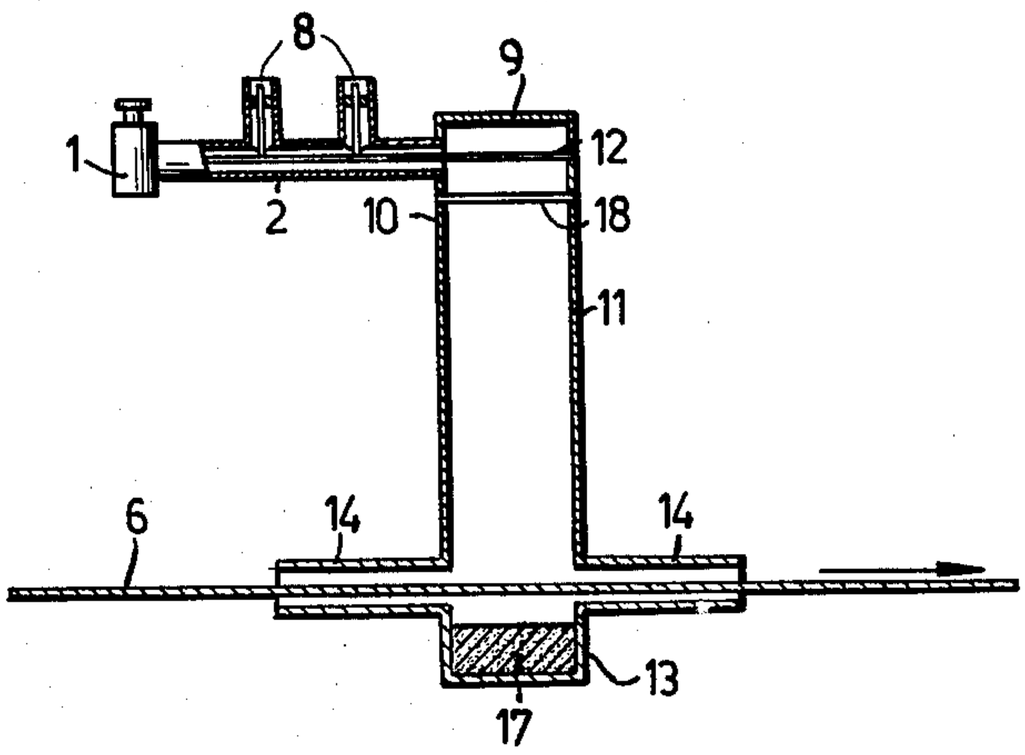


FIG.3

INVENTOR

JAN VERSTRATEN

BY Frank R. Trifari

AGENT

United States Patent Office

3,102,181

Patented Aug. 27, 1963

3,102,181

HIGH-FREQUENCY HEATING FURNACES OPERATING WITH VERY HIGH FREQUENCIES

Jan Verstraten, Eindhoven, Netherlands, assignor to North American Philips Company, Inc., New York, N.Y., a corporation of Delaware

Filed May 2, 1960, Ser. No. 26,235
Claims priority, application Netherlands May 1, 1959
12 Claims. (Cl. 219—10.55)

The invention relates to devices for heating by means of electromagnetic waves of very high frequencies. More particularly, the invention relates to furnaces for heating with waves of the decimeter or centimeter range. Furnaces of this type may comprise a very high-frequency generator, such as a magnetron generator, and a waveguide system, the output of the very high-frequency generator being connected to the waveguide system to conduct the oscillations of ultra high frequency to the outlet port of the waveguide system. The objects to be heated are moved by means of a conveyor belt arranged at the outlet port of the waveguide.

In order to insure uniform heating of the objects to be heated, the construction of the waveguide system has to fulfill particular requirements, particularly when the conveyor belt has a width of the order of a multiple of the wavelength of the heating oscillations. Under this condition heating the objects uniformly demands special precautions, particularly in the construction of the high-frequency furnace.

The invention has for its object to provide a high-frequency furnace of simple construction, which is particularly suited for heating objects by means of high frequency electromagnetic waves and utilizes a conveyor belt having a width a multiple of the wavelength of the heating energy. In addition, there is provided a furnace construction which is well shielded so that substantially no radiation of the heating energy takes place.

The high-frequency furnace according to the invention is characterized in that the waveguide system comprises a component having a parabolic cylinder surface and two parallel boundary surfaces at right angles to the former. On the focal line of the parabolic cylinder surface there is arranged, a linear radiator which is coupled with the output circuit of the high-frequency generator. A reflector is arranged between the linear radiator and the outlet opening of the waveguide system remote from the parabolic surface and serves to reflect toward the parabolic surface the energy normally directly radiating from the linear radiator in the direction of the outlet opening. In addition, the conveyor belt is guided in a direction which is substantially at right angles to the parallel boundary surfaces of the parabolic component.

The invention will be described more fully with reference to the appended drawing forming part of the specification and in which;

FIG. 1 is a perspective view of one embodiment of a high-frequency furnace according to the invention, and

FIGS. 2 and 3 are a cross sectional view and a longitudinal sectional view, respectively, of the high-frequency furnace according to the invention.

The high-frequency furnace shown in a perspective view in FIG. 1, having a power of, for example, two kilowatts, comprises a magnetron or other suitable generator 1, which is adapted to produce oscillations of a wavelength of, for example, 12 cms. The output circuit of the generator 1 is connected via a coaxial conductor 2 to a waveguide system 3, to guide the ultra high-frequency oscillations towards the output opening 4 of the waveguide system 3. The front wall of the system 3 has been partly broken away to illustrate the construction

of the interior. The objects 5 to be heated, for example, individually baked biscuits, are conveyed on a conveyor belt 6, and passed along the output opening of the waveguide system 3. Belt 6 may be driven in any suitable manner, such as by driving rollers 7. For adjusting the generator 1 to the load being processed tuning means 8 of well known construction are provided as part of the coaxial conductor system 2.

The conveyor belt 6 may have a width, for example, of over 120 cms. and in order to produce uniform heating of the objects throughout the width of the conveyor belt, the waveguide system 3 is dimensioned to surround the conveyor belt. In the form shown, the system 3 comprises a parabolic cylinder surface 9 and two parallel boundary surfaces 10, 11, at right angles to the former. A linear radiator 12 is arranged at the focal line of the parabolic cylinder surface 9. Interposed between the radiator 12 and the outlet opening 4 of the waveguide system remote from the parabola top there is positioned a reflector 18. Reflector 18 reflects the direct rays emanating from the linear radiator in the direction of the output opening 4 back towards the parabolic cylinder surface 9. In the embodiment shown the reflector 18 consists of a reflector rod arranged parallel to the linear radiator 12. The conveyor belt 6 is guided in a direction substantially at right angles to the parallel boundary surfaces 10, 11 of the waveguide system 3.

In order to obtain a closed structure the waveguide system 3 is closed by a closing wall 13, which extends beyond the output opening 4 along the conveyor belt 6 to form entrance and exit passages 14 for the conveyor belt 6. At the region of the output opening 4 of the waveguide system 3 the closing wall 13 is extended away from the conveyor belt 6 to form a rectangular trough 15. Trough 15 is filled partially with absorbing material 17 to absorb the radiation of the linear radiator 12 which passes along the conveyor belt 6 (cf. FIGS. 2 and 3), so that the magnetron generator 1, even in the absence of objects to be heated, is adequately loaded. A suitable material for this purpose may be, for example, carbon.

In the device described the rays emanating from the linear radiator 12 are reflected in the direction of the output opening 4 of the waveguide system 3 by the parabolic surface 9 and the reflector 18. As a result, a radiation characteristic of the cardioid type is obtained in planes at right angles to the linear radiator 12. This radiation characteristic is obtained by a suitable choice of the dimensions of the system, for example by the adjustment of the linear radiator 12 and the reflector rod 18 and of their relative spacing, which in the embodiments shown, is about 0.2 times the wavelength. Substantially the whole radiation from the linear radiator 12, emanating therefrom in accordance with the characteristic described above, is reflected from the parabolic cylinder surface 9 of the waveguide system 3 in the direction of the parabola axis towards the output opening 4 of the waveguide system 3. At the output opening 4, in directions parallel to the boundary surfaces 10, 11, a uniform electro-magnetic field of substantially constant intensity is obtained, so that the objects 5 to be heated are substantially uniformly heated in their passage along the output opening 4.

The simplified construction shown in FIG. 1 adequately provides a uniformity of the electro-magnetic field at the output opening 4 of the waveguide system 3, which is sufficient for many puposes such as the heating of individually baked biscuits. In those instances where a greater uniformity of magnetic field at the output opening 4 is desired, for example, for drying tissues, a plurality of reflector rods or a reflection screen may be used parallel to the linear radiator 12. By means of this ar-

rangement, a radiation characteristic is achieved in which substantially no direct radiation occurs in the direction of the output opening, and only beamed energy of uniform distribution appears at the opening.

Apart from the simple construction and the uniform heating obtained for the objects **5** to be heated, the device described above has the practically important advantage that the rays emanating from the high-frequency furnace are minimized, since the linear radiator **12** irradiates a linearly polarized field, of which the direction of the electric field vector E is parallel to the direction of the linear radiator **12**, so that the rays extend parallel to the output **4** of the waveguide system in the direction indicated in the figure by the dot-and-dash arrows **16**. The energy vector (Poynting vector) is at right angles to the electric field vector E and hence has no component in the direction of movement of the conveyor belt **6**, so that only stray rays can emanate from the waveguide system **3**. These rays are, moreover, attenuated in the inlet and outlet passages **14** of the conveyor belt **6**, for example, the emanating radiation is attenuated by a factor of about 25 db.

In a typical form of construction the height of the waveguide system **3** from the conveyor belt, may be, for example, 48 cms. and the width of the output opening **4** is 120 cms. The distance between the linear radiator **12** and the reflector rod **18** is about 25 cms.

The distance between the two boundary surfaces **10**, **11** is 24 cms. and the length of the passages **14** is 30 cms. and the height thereof is 5 cms.

While I have described by invention by means of specific examples and in a specific embodiment, I do not wish to be limited thereto for obvious modifications will occur to those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. A high frequency furnace comprising a high frequency generator and a wave guide system, said wave guide system comprising first, second and third wall portions defining an enclosure having an open end, said first wall portion having a parabolic shape and said second and third wall portions forming two parallel boundary surfaces at right angles to said wall of parabolic shape and extending beyond the focal line of said parabolic wall portion, wave energy radiating means arranged at the focal line of said parabolic wall, wave energy reflecting means interposed between said radiating means and said open end, means for coupling said generator to said radiating means, and means for supporting objects to be heated at said open end of said enclosure.

2. A high frequency furnace comprising a high frequency generator and a wave guide system, said wave guide system comprising first, second and third wall portions defining an enclosure having an open end, said first wall portion having a parabolic shape and said second and third wall portions forming two parallel boundary surfaces at right angles to said wall of parabolic shape and extending beyond the focal line of said parabolic wall portion, wave energy radiating means arranged at the focal line of said parabolic wall, wave energy reflecting means interposed between said radiating means and said open end, means for coupling said generator to said radiating means, and means for supporting objects to be heated at said open end of said enclosure, said latter means comprising a conveyor belt member and means for moving said belt member across said open end in a direction substantially at right angles to said second and third wall portions.

3. A high frequency furnace comprising a high frequency generator for producing energy of given wavelength and a wave guide system, said wave guide system comprising first, second and third wall portions defining an enclosure having an open end, said first wall portion having a parabolic shape and said second and third wall portions forming two parallel boundary surfaces at right angles to said wall of parabolic shape, wave energy radiating means in the form of a linear element arranged at the focal line of said parabolic wall, wave energy reflecting means interposed between said radiating means and said open end, means for coupling said generator to said radiating means, said reflecting means comprising a reflector rod spaced about 0.2 of said given wave-length from said radiating means, and means for supporting objects to be heated at said open end of said enclosure.

4. A high frequency furnace comprising a high frequency generator and a wave guide system, said wave guide system comprising first, second and third wall portions defining an enclosure having an open end, said first wall portion having a parabolic shape and said second and third wall portions forming two parallel boundary surfaces at right angles to said wall of parabolic shape, wave energy radiating means arranged at the focal line of said parabolic wall, wave energy reflecting means interposed between said radiating means and said open end, means for coupling said generator to said radiating means, means enclosing said open end and providing aligned openings in said second and third wall portions, a conveyor belt member extending through said aligned openings for supporting objects to be heated at said open end, and shield means enclosing said conveyor belt at portions thereof adjacent said aligned openings.

5. A high frequency furnace comprising a high frequency generator and a wave guide system, said wave guide system comprising first, second and third wall portions defining an enclosure having an open end, said first wall portion having a parabolic shape and said second and third wall portions forming two parallel boundary surfaces at right angles to said wall of parabolic shape, wave energy radiating means arranged at the focal line of said parabolic wall, wave energy reflecting means interposed between said radiating means and said open end, means for coupling said generator to said radiating means, means enclosing said open end and providing aligned openings in said second and third wall portions, a radiation absorbing body in said enclosing means, a conveyor belt member extending through said aligned openings for supporting objects to be heated at said open end and between said radiation means and said absorbing body, and means for moving said belt member in a direction at right angles to said second and third wall portions.

6. A high frequency furnace comprising a high frequency generator and a wave guide system, said wave guide system comprising first, second and third wall portions defining an enclosure having an open end, said first wall portion having a parabolic shape and said second and third wall portions forming two parallel boundary surfaces at right angles to said wall of parabolic shape, wave energy radiating means arranged at the focal line of said parabolic wall, means for coupling said generator to said radiating means, means for supporting objects to be heated at said open end of said enclosure, and shield means enclosing said support means adjacent the open end of said waveguide system.

7. A high frequency furnace comprising a high frequency generator and a wave guide system, said wave guide system comprising first, second and third wall portions defining an enclosure having an open end, said first wall portion having a parabolic shape and said second and third wall portions forming two parallel boundary surfaces at right angles to said wall of parabolic shape and extending beyond the focal line of said parabolic wall portion wave energy radiating means positioned at the focal line of said parabolic wall and arranged to radiate a linearly polarized field in which the direction of the electric field vector is substantially perpendicular to said second and third wall portions, means for coupling said generator to said radiating means, and means for supporting objects to be heated at said open end of said enclosure, said latter means comprising a conveyor belt member and

means for moving said belt member across said open end in a direction substantially at right angles to said second and third wall portions.

8. A high frequency furnace comprising a high frequency generator and a wave guide system, said wave guide system comprising first, second and third wall portions defining an enclosure having an open end, said first wall portion having a parabolic shape and said second and third wall portions forming two parallel boundary surfaces at right angles to said wall of parabolic shape, wave energy radiating means arranged at the focal line of said parabolic wall, means for coupling said generator to said radiating means, means enclosing said open end and providing aligned openings in said second and third wall portions, a conveyor belt member extending through said aligned openings for supporting objects to be heated at said open end, and shield means enclosing said conveyor belt at portions thereof adjacent said aligned openings.

9. A high frequency furnace comprising a high frequency generator and a wave guide system, said wave guide system comprising first, second and third wall portions defining an enclosure having an open end, said first wall portion having a parabolic shape and said second and third wall portions forming two parallel boundary surfaces at right angles to said wall of parabolic shape, wave energy radiating means arranged at the focal line of said parabolic wall, means for coupling said generator to said radiating means, means enclosing said open end and providing aligned openings in said second and third wall portions, a radiation absorbing body in said enclosing means, a conveyor belt member extending through said aligned openings for supporting objects to be heated at said open end and located between said radiation means and said absorbing body, and means for moving said belt member in a direction at right angles to said second and third wall portions.

10. High frequency heating apparatus comprising a high frequency generator and a waveguide system, said waveguide system comprising first, second and third wall portions defining an enclosure having an open end, said first wall portion having a parabolic shape and said second and third wall portions forming two parallel boundary surfaces substantially at right angles to said wall of parabolic shape and extending beyond the focal line of said parabolic wall portion, wave energy radiating means comprising a linear radiating element arranged at the focal line of said parabolic wall, wave energy reflecting means mounted between said radiating means and said open end, said radiating and reflecting means coacting with said wave guide system to produce at said open end a linearly polarized field in which the direction of the electric field vector is substantially perpendicular to said second and third wall portions, means for coupling said generator to said radiating means, and conveyor means for carrying objects to be heated past the open end of said enclosure in a direction substantially at right angles to said second and third wall portions.

11. A high frequency furnace comprising a high frequency generator for supplying electromagnetic energy having a predetermined wave length and a waveguide system, said waveguide system comprising first, second and third wall portions defining an enclosure having an open end, said first wall portion having a parabolic shape and said second and third wall portions forming two parallel boundary surfaces at right angles to said wall of parabolic shape, wave energy radiating means arranged at the focal line of said parabolic wall and including means to focus substantially all of the radiated energy at said parabolic wall, said parabolic wall portion being arranged to reflect substantially all of the energy emitted from said radiating means towards said open end so that at said open end in directions parallel to said second and third wall portions a substantially uniform electromagnetic field of substantially constant intensity is produced, said focal line lying within said waveguide enclosure, means for coupling said generator to said radiating means, and conveyor means having a width dimension greater than the wave length of said electromagnetic energy for carrying objects to be heated past the open end of said enclosure.

12. High frequency heating apparatus comprising a high frequency generator and a waveguide system, said waveguide system comprising first, second, third and fourth wall portions defining an enclosure, said first wall portion having a parabolic shape, said second and third wall portions forming two parallel boundary surfaces substantially at right angles to said first wall, and said fourth wall forming a closing surface substantially at right angles to said second and third wall portions, said second and third wall portions including substantially aligned inlet and outlet apertures for receiving objects to be heated, wave energy radiating means arranged at the focal line of said parabolic wall, means for coupling said generator to said radiating means, and conveyor means extending through said inlet and outlet apertures for carrying objects to be heated through said waveguide enclosure.

References Cited in the file of this patent

UNITED STATES PATENTS

2,259,318	Mouromtseff	Oct. 14, 1941
2,478,241	Chu	Aug. 9, 1949
2,500,752	Hanson et al.	Mar. 14, 1950
2,539,511	Hansen et al.	Jan. 30, 1951
2,560,218	Dunlap	July 10, 1951
2,627,571	Hiehle et al.	Feb. 3, 1953
3,027,442	Verstraten	Mar. 27, 1962

OTHER REFERENCES

Karl-August Heyne, German application, Serial No. B34,942, printed December 13, 1956 (Klasse 21h Gruppe 36).