

⑫ **EUROPEAN PATENT APPLICATION**

⑰ Application number: **84870148.8**

⑤① Int. Cl.⁴: **E 01 C 13/00**

⑱ Date of filing: **29.10.84**

③① Priority: **31.10.83 US 546803**

⑦① Applicant: **MONSANTO COMPANY**, Patent
Department 800 North Lindbergh Boulevard, St. Louis,
Missouri 63166 (US)

④③ Date of publication of application: **08.05.85**
Bulletin 85/19

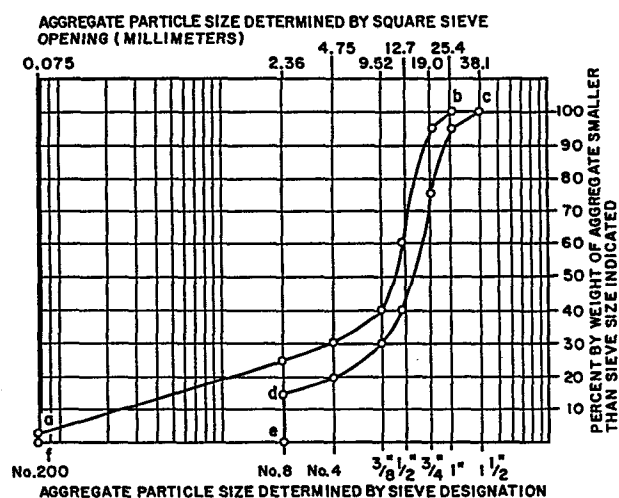
⑦② Inventor: **Jaber, Khalil Nicola**, 1458 Johns Road N.E.,
Dalton Georgia 30720 (US)
Inventor: **Orofino, Rhamas Allan**, 145 Rock Hill Road,
Rocky Face Georgia 30740 (US)

⑧④ Designated Contracting States: **DE FR GB IT NL**

⑦④ Representative: **McLean, Peter et al**, Monsanto Europe
S.A. Patent Department Avenue de
Tervuren 270-272 Letter Box No 1, B-1150 Brussels (BE)

⑤④ **Artificial turf playing fields.**

⑤⑦ A layer of water-conducting asphaltic concrete comprising a skip-graded mixture of aggregate rock which is applied over a non-permeable base allows horizontal drainage under artificial turf playing surfaces.



ARTIFICIAL TURF PLAYING FIELDS

This invention pertains to artificial turf playing fields installed over a layer of water-conducting asphaltic concrete which is capable of allowing horizontal drainage of rainfall. This invention also permits conversion of non-permeable artificial turf playing fields to fields with a sub-surface layer capable of accumulating and draining rain water under a substantially dry artificial turf playing surface.

A variety of designs for playing fields have been proposed to extend recreation time into periods of rain and to provide a quality playing surface after periods of rain. Among basic field designs are the sloped impermeable playing field which allows rain water to run off and the permeable playing field which allows rain water to drain through.

Sloped playing fields may be provided with interceptors as disclosed in U.S. Patent 3,611,729 which discloses vertical slots extending through the top layer of a natural field and U.S. Patent 3,625,011 which discloses covered trenches for installation in an artificial turf field. In many cases fields of artificial turf comprise an impervious layer requiring slopes, for instance of a 1-1½ percent grade on American football fields, to provide water run off. In other cases where a flat field is required, for instance in baseball outfields, water can be removed mechanically by blowers or vacuum cleaners.

To assist in water removal from flat playing surfaces permeable fields have been proposed in a wide variety of constructions. U.S. Patent 2,837,984 discloses a quick drying tennis court comprising layers of granular limestone over a clay base. U.S. Patent 1,763,782 discloses a playing field of fibrous mats inserted in a drained cement basin. U.S. Patent

1,906,494 discloses a playing surface comprising a layer of felt, a layer of pervious concrete and a bedding of coarse stone or broken stone.

Grass-like artificial turf systems have been
5 proposed as an alternative to high maintenance
surfaces such as golf putting greens which, although
not necessarily flat, have been required to be highly
permeable. See, for instance, U.S. Patents 2,515,847;
3,740,303; and 4,007,307; and Canadian Patent 886,152
10 which disclose artificial turf over permeable layers
of sand, gravel, stone, rubber, plastic chips and the
like. While such playing fields appear to provide
some degree of permeability they do not appear to have
a base with sufficient stability to maintain a smooth
15 playing surface even with only occasional traffic of
maintenance vehicles.

In recent years flat playing fields have
been designed with both advantageous permeability and
a strong, stable base by overlying artificial turf on
20 a base of permeable concrete. Permeable concrete
bases were proposed as early as 1930 in U.S. Patent
1,906,494 which relates to playing surfaces comprising
a layer of felt, a layer of pervious concrete and a
bedding of coarse stone or broken stone. In one
25 embodiment the porous concrete is said to be
compounded of a mixture containing about eight parts
by volume of coarse crushed stone having a mean
diameter of three-quarters of an inch (about 19
millimeters) and a shape factor of about 1.5, one part
30 by volume of Portland cement and water. Permeable
concrete which may be usefully for supporting
artificial turf is also disclosed in U.S. Patents
4,333,765 and 4,376,595.

Peremable asphaltic concrete has been
35 utilized in the construction of special air strips,
parking lots, road surfaces and other areas where

vertical draining for removal of rain water to prevent ice formation and to prevent hydroplaning of vehicle tires was desired. Critical to the performance of permeable asphaltic concrete is the requirement for an open-graded aggregate mix to provide void space to facilitate vertical drainage of water. Other critical factors include resistance to stripping of asphaltic cement from the aggregate, and temperature control of the mix to prevent the asphaltic mix from flowing down off of the aggregate.

At least three automobile parking lots have been constructed from permeable asphaltic concrete at the University of Delaware during the period 1972 through 1974. As of 1983 these parking lots appear to be in excellent condition with the permeable asphaltic concrete exhibiting acceptable load-bearing properties. A parking lot has also been installed in 1981 in Tallahassee, Florida utilizing a 4 inch (10 centimeters) layer of permeable asphaltic concrete over a 36 inch (about 90 centimeters) deep rock base.

Permeable asphaltic concrete has been applied with some success to highways to provide a friction course to minimize the possibility of hydroplaning on accumulated rain water. See, for instance, U.S. Patent 3,690,227 which discloses a frictional, self-draining paving surface useful for runways and roadways comprising a porous layer of aggregate particles of greater size than 1/16 inch (about 1.6 millimeters) mesh bonded with a resinous binder.

Permeable asphaltic concrete has also been utilized as a base layer for highways. Within the last several years a 56-mile (about 90 kilometers) section of highway was constructed near Sao Paulo, Brazil where permeable asphaltic concrete was covered with a dense graded impervious asphalt. The permeable

asphaltic concrete was used to carry away surface water which might otherwise have undermined the road base.

5 Permeable asphaltic concrete has also been
utilized in the construction of athletic fields of
artificial turf. Within the last five years at least
16 athletic fields have been installed in Europe and
Australia with artificial turf overlaid on a base of
permeable asphaltic concrete. Athletic fields in
10 Europe comprising artificial turf installed over
permeable asphaltic concrete often comply with
Deutsche Normen (DIN) 18 035, Part 6 on Permeable
Asphalt, April 1978, which specifies that the
permeable concrete is installed in two lifts (a lift
15 being a separate layer of concrete). The aggregate
for the separate upper and lower lifts is specified
according to gradation diagrams from which the
gradation data listed in Table 1 has been extracted.

TABLE 1
Aggregate Gradation For Two Lifts of Permeable Concrete
Extracted From Gradation Diagrams in
Deutsche Normen (DIN) 18 035 (April, 1978)

	Aggregate Sieve Size (Millimeters)	Weight Percent of Aggregate Passing The Sieve	
		Lower Lift	Upper Lift
5	13	90-100	
	11	44-100	
10	9.5	35-75	
	8	30-62	90-100
	5	21-41	41-100
	4		30-80
	3		20-55
15	2	10-25	15-30
	1.2	6-19	9-22
	0.25	5-14	5-16
	0.09	3-6	4-7

20 A disadvantage of such specification for permeable asphaltic concrete is of course that the asphaltic concrete be applied in two lifts, that is two separate layers. A more significant disadvantage is that the upper lift comprises aggregate of a substantially smaller particle size than an aggregate of a lower lift.

25 A preferred method of installing artificial turf is to glue the artificial turf assembly to the upper layer of asphaltic concrete to avoid migration of line markers on a playing field. However, in such installations it is almost always required that the artificial turf be laid loosely on top of the upper lift of permeable asphaltic concrete. Gluing of artificial turf to the upper surface of the asphaltic concrete is generally precluded because the adhesive tends to occlude the smaller-size pores in the upper

surface of such asphaltic concrete which comprises aggregate of smaller particle sizes.

5 This same deficiency is inherent in most specifications for permeable asphaltic concrete. For instance permeable asphaltic concrete designed for use in paving surfaces such as parking lots and highways generally comprise an aggregate of a small particle size to provide the necessary strength to support vehicle traffic. This requirement to provide
10 structural strength requires significant sacrifice in the permeability qualities of the permeable asphaltic concrete.

It would be desirable to convert existing non-permeable artificial turf playing fields to
15 permeable artificial turf playing fields. A considerable number of such non-permeable artificial turf playing fields are installed with the layer of artificial turf playing surface and optional polymeric foam cushion over a substantial non-permeable base, for instance, of asphaltic concrete or Portland cement
20 concrete. However the cost of removing such a non-permeable concrete base to install a permeable base and water-conduit piping may be excessive and economically prohibitive.

25 Accordingly when resurfacing with new artificial turf is required on existing non-permeable playing fields, a conversion to a permeable artificial turf playing field often cannot be justified.

SUMMARY OF THE INVENTION

30 This invention provides an artificial turf playing field having an interlayer of water-conducting

asphaltic concrete composition having a porosity sufficient to accumulate a moderately high level of rainfall and allow horizontal drainage of accumulated water. The interlayer of water-conducting asphaltic concrete comprises a gradated mixture of aggregate rock of particle sizes much larger than those previously used in asphaltic concrete designs.

BRIEF DESCRIPTION OF THE DRAWING

Figure 1 is a gradation diagram which illustrates the particle size ranges for a gradated mixture of aggregate rock useful in the asphaltic concrete composition of this invention.

DESCRIPTION OF PREFERRED EMBODIMENTS

By this invention applicants have provided an artificial turf playing field which can be advantageously and economically incorporated into the design of existing non-permeable artificial turf playing fields to convert such existing fields to an artificial turf playing field capable of accommodating moderate rainfall while retaining a substantially dry artificial turf playing surface.

The artificial turf playing field of this invention comprises a layer of artificial turf, an optional shock-absorbing cushion, an interlayer of water-conducting asphaltic concrete and a substantially impervious base. In a preferred aspect of this invention the interlayer of water-conducting asphaltic concrete comprises a gradated mixture of aggregate rock having a size distribution such that the percent by weight of aggregate rock passing a sieve with square openings is within the limits expressed in Table 2.

TABLE 2
Aggregate Gradation For Permeable Asphaltic
Concrete According To This Invention

5	Aggregate	Square Sieve Opening		Weight Percent of
	Sieve	Designation		Aggregate Passing
		(Millimeters)	(Inches)	the Sieve
	1½	38.1	1.5	100
	1	25.4	1.0	95-100
	¾	19.0	0.75	75-95
10	½	12.7	0.5	40-60
	⅜	9.52	0.375	30-40
	No. 4	4.75	0.187	20-30
	No. 8	2.36	0.094	15-25
	No. 200	0.075	0.003	0-3

15 The gradation of the aggregate rock can also be determined by reference to Figure 1 which graphically illustrates the gradation specified in Table 2. Figure 1 provides a gradation diagram which is a semi-logarithmic plot of the percent by weight of aggregate smaller than the size indicated (that is, the percent by weight passing a designated sieve) versus the particle size of the aggregate rock as determined by sieve designation. With reference to Figure 1 a gradated mixture of aggregate rock useful in the layer of water-conducting permeable asphaltic concrete of the artificial turf playing field of this invention is required to have a size distribution substantially within the area identified as a-b-c-d-e-f-a.

30 This gradated mixture comprises a very high percent by weight of aggregate rock above the ¾ sieve size. About 60 to 70 percent by weight of the aggregate rock is above ⅜ sieve size. A minor amount by weight, for instance in the range of about 15 percent by weight, of the aggregate rock is in the range of No. 8 to ⅜ sieve size. A somewhat larger

but still minor amount by weight of the aggregate rock is in the range of No. 200 to No. 8 sieve size. Essentially none of the aggregate rock is of a size smaller than No. 200 sieve size. Because of the
5 specification the gradation profile is bimodal with points of inflection near the ends of the particle size distribution bracket by the No. 8 and the 3/8 sieve size. Such a gradation profile is referred to as "skip-graded" or "gap-graded". In this regard the
10 large percentage of aggregate rock above 3/8 sieve size provides exceptional porosity, enhanced permeability, to the asphaltic concrete. The minor amount by weight of aggregate rock in the No. 8 to 3/8 sieve bracket provides considerable stability to the
15 aggregate within the concrete without unduly impairing permeability.

The shape of the aggregate rock is also critical in the permeable asphaltic concrete of this invention. The three dimensions of the individual
20 particles of the aggregate rock should be of the same order of magnitude. Such particles are described as being bulky in shape. Many of these bulky particles of aggregate rock are approximately spherical. In this regard it is undesirable that anything but a
25 minor amount by weight of the aggregate rock be of plate-like shape or rod-like shape.

The aggregate rock may comprise any of a variety of compositions, for instance crushed quarry stone of granite or washed gravel or any other stable
30 mineral composition which can be graded to the required specifications.

In preparing the water-conducting asphaltic concrete it is desirable that the aggregate rock be substantially free of moisture to promote the adhesion
35 of the asphaltic cement to the aggregate. In this regard it is often desirable that an anti-stripping

agent be added to the dry mix of the aggregate rock prior to the introduction of asphaltic cement. Such anti-stripping agents are intended to remove residual moisture, provide better contact and promote adhesion between the asphaltic cement and the aggregate rock. A useful anti-stripping agent comprises hydrated lime which can be added at a rate of about 1 percent by weight based on the dry weight of the aggregate rock. The anti-stripping agent such as hydrated lime should be adequately mixed with the aggregate rock to sufficiently coat the dry aggregate rock at a point in the mixing process so as not to become unduly air entrained in the exhaust air system of the mixing plant.

Alternatively, promotion of adhesion of asphaltic cement to aggregate is sometimes achieved by adding surface active agents to asphaltic cement. Preferred surface active agents include those derived from lignin. Such surface active agents should be used in minor amounts, say at a level of about 0.5 percent by weight of the liquid asphaltic cement. At high levels of surface active agent the viscosity of the asphaltic cement can be significantly reduced which may promote separation of the cement from the aggregate and puddling of cement at the bottom of the layer of concrete. Moreover at high levels of surface active agent the concrete may tend to be susceptible to stripping by water.

The layer of water-conducting asphaltic concrete useful in this invention also comprises an asphaltic cement which is present at a level of about 4.5 percent by weight of the asphaltic concrete. Suitable asphaltic concretes include those designated as AC-5, AC-10, AC-20 or AC-30, or their equivalents, the selection of which depends on geographical

considerations, such as weather and climate, and material availability.

The Mix Design Methods For Asphalt Concrete published by the Asphalt Institute as Manual Series
5 No. 2 (MS-2), Fourth Edition, March 1974, is particularly useful in defining terms and methods relating to this invention, especially in Chapter III, incorporated herein by reference, which relates to the Marshall Method of Mix Design.

10 The Marshall Method of Mix Design provides procedures useful in specifying certain parameters for preparing the hot mix of the asphaltic concrete of this invention. Among the more critical criteria of the Marshall Method are what is known as "flow",
15 "stability" and "voids". The Marshall Method of Mix Design test procedures have been standardized by the American Society for Testing and Materials (ASTM) as Test Method D-1559, entitled a Standard Test Method for "RESISTANCE TO PLASTIC FLOW OF BITUMINOUS MIXTURES
20 USING MARSHALL APPARATUS", incorporated herein by reference.

The Marshall Method of Mix Design is generally applicable only to hot-mix asphalt paving mixtures containing aggregates with maximum sizes of 1
25 inch (25.4 millimeters) or less. However, for purposes of defining and practicing this invention the Marshall Method of Mix Design will be modified where necessary. For instance, the method will be extended to apply to mixtures containing aggregate up to a
30 maximum size of 1½ inch (38 millimeters).

This Marshall Method of Mix Design is generally modified in conducting stability and flow tests of water-conducting asphaltic concrete such that these tests are conducted at room temperature, that
35 is, at 25°C, rather than at the generally specified test temperature of 140°F (60°C). This is necessary

because water-conducting asphaltic concretes are generally intrinsically extremely weak and often degrade at the generally specified test temperature of 140°F (60°C). At best previously known

5 water-conducting asphaltic concrete compositions have disintegrated at loads of about 200 lb_f (890 newtons) when tested at 140°F (60°C).

Surprisingly the water-conducting asphaltic concrete of this invention is remarkably stable at the

10 specified test temperature of 140°F (60°C) and have exhibited "stability" at loads in the range of 700 to 900 lb_f (3100 to 4000 newtons). In this regard the water-conducting asphaltic concrete compositions of this invention will preferably exhibit stability of at

15 least about 400 lb_f (1780 newtons) and more preferably at least about 500 lb_f (2225 newtons) at the specified test temperature of 140°F (60°C).

In this regard the constituents of the water-conducting asphaltic concrete should be

20 proportioned to produce water-conducting asphaltic concrete having a "Marshall" flow at 25°C in the range of about 8 to 20 x 10⁻² inches (2 to 5 millimeters), "Marshall" a stability at 60°C of at least 400 lb_f (2780 newtons). Moreover it is generally desirable

25 that the water-conducting asphaltic concrete be compacted to have voids at a level of at least 10 percent by volume and preferably in the range of 12 to 22 percent by volume.

In preparing the hot mix of the

30 water-conducting asphaltic concrete of this invention care should also be taken to control the temperature of the asphaltic concrete hot mix so as to minimize asphaltic concrete separation from the aggregate rock. When using asphaltic cement having a viscosity

35 designation AC-10 satisfactory results have been

obtained by maintaining hot mix in the temperature range of from 116°C to 127°C.

5 The water-conducting asphaltic concrete is particularly useful as an interlayer between artificial turf and a supporting base, for instance of impervious asphaltic concrete.

10 In this regard athletic fields are often prepared with a sub base of stable fill material, for instance gravel or rock. The sub base supports an impervious slab of concrete, such as asphaltic concrete. The impervious slab of concrete may be 6 inches (about 15 centimeters) or more in thickness. In the construction of sloped playing fields a practice has been to install the artificial turf, including the optimal resilient polymeric foam cushion, over a sloped surface of an impervious slab of concrete. For instance an American football field may have surfaces sloping from a crowned center of the field at a grade of 1½ percent say in the range of about 1 to 2 percent. Baseball outfields are generally constructed with slopes of 1 percent.

25 Such sloped playing fields of artificial turf can be improved by this invention by providing an interlayer of water-conducting asphaltic concrete over the impervious concrete slab. The interlayer comprises the gradated mixture of aggregate rock described above and has a minimum thickness of 1.5 times the sieve size of the largest aggregate rock present in the gradated mixture. The interlayer may have larger thickness, for instance up to about 6 inches (15 centimeters) or more to accommodate higher quantities of rainfall. Asphaltic concrete is not generally applied in layers thicker than about 1 inch (2.5 centimeters) or so in a single lift because of compaction instability in installing such a layer.

However, interlayers of water-conducting asphaltic concrete of larger thickness are achievable with a gradated mixture of aggregate rock of large particle size as specified above because of the inherent stability of such a gradated mixture. The interlayer should be of uniform thickness with an upper surface generally conforming to the upper surface of the slab of impervious concrete. In some cases however it may be desirable to provide the interlayer with a substantially horizontal upper surface to provide a flat playing field.

To provide superior adhesion of the interlayer to the impervious slab it is often desirable to apply a tack coat to the upper surface of the impervious slab. The tack coat can comprise low viscosity asphaltic cement or a water emulsion of asphaltic cement and can be applied at a rate of about 0.15 gallons per square yard (0.68 liters per square meter).

An interlayer prepared according to this invention is substantially porous and will accumulate rainfall quickly, however because of the underlying impervious slab the accumulated rainfall is required to drain laterally across the field.

In this regard a 2 inch thick (5 centimeters) interlayer of water-conducting asphaltic concrete was prepared according to this invention with a 13 percent void volume and applied over an impervious concrete slab having a 1.5 percent grade. Such interlayer of water-conducting concrete has an initial capacity to store about 0.3 inches (7.6 millimeters) of rainfall which of course must drain laterally down the slope. When such an interlayer is applied over a large field, say a field of 200 foot x 300 foot (60 meters x 90 meters) with a 1.5 percent

slope, it could take about 30 days for complete drainage, neglecting evaporation.

5 The drainage is so relatively slow, because of the long distances for drainage, for instance about 100 feet (30 meters). Moreover such an interlayer exhibits a steady-state rainfall-handling capacity of about 0.0025 inches per hour (0.064 millimeters per hour).

10 It is often desirable to improve the rainfall-handling capacity of such an interlayer of water-conducting asphaltic concrete. This can be accomplished by providing water-conducting channels intermediate the periphery and center of the sloped playing field. Such water-conducting channels can be
15 cut into the impervious slab of concrete for instance with a trenching saw. The channels can be run at various angles to the slope of the field to optimize water drainage. The channels should not be
20 excessively wide such that the interlayer of water-conducting asphaltic concrete can collapse and occlude the channel. In this regard channels of about 1-inch wide may be satisfactory.

The interlayer is overlaid with an artificial turf which may optionally comprise a layer
25 of resilient polymeric foam cushion. It is generally desirable that the artificial turf be glued to the optional cushion layer and that the artificial turf or cushion layer be glued to the interlayer. For instance a suitable adhesive is used to glue the
30 artificial turf to the underlying layer of resilient polymeric foam cushion. Similarly, the artificial turf is desirably glued to the interlayer of water-conducting asphaltic concrete. Sufficient
35 adhesive is required to provide a good bond between the layers. However, the adhesive should not be applied in such excessive amounts as to occlude pores

in the top surface of the interlayer of water-conducting asphaltic concrete. In this regard the interlayer of water-conducting asphaltic concrete of this invention is advantageous in that it utilizes
5 aggregate rock of a sufficiently large size that the possibility of pore occlusion by the adhesive is minimized.

In order to provide an athletic field comprising artificial turf which is
10 vertically-draining to the water-conducting interlayer it is necessary that the layer or layers of artificial turf be permeable. Artificial turf can generally be provided in a permeable configuration. For instance, artificial turf of knitted or woven construction is
15 generally permeable. Artificial turf of tufted construction is generally not permeable unless holes or perforations are provided after the turf is fabricated. The optional resilient polymeric foam cushion can be made permeable by either utilizing an
20 open-celled polymeric foam or, when a close-celled polymeric foam is utilized a cushion can be made permeable by punching or drilling a sufficient number of holes in the polymeric foam cushion. Sufficient holes should be provided so as to provide suitable
25 permeability without adversely affecting the resilient properties of the cushion.

While specific embodiments of the invention have been described, it should be apparent to those skilled in the art that various modifications thereof
30 may be made without departing from the true spirit and scope of the invention. Accordingly it is intended that the scope of the following claims cover all such modifications which fall within the full inventive concept.

CLAIMS:

1. An artificial turf playing field comprising a layer of artificial turf, a resilient shock-absorbing cushion, an interlayer of water-conducting asphaltic concrete and a substantially impervious base, wherein said interlayer of water-conducting asphaltic concrete comprises a gradated mixture of aggregate rock having a size distribution such that the percent by weight of aggregate rock passing a sieve with square openings of
- (a) 38.1 millimeters is 100 percent,
 - (b) 25.4 millimeters is 95-100 percent,
 - (c) 19.0 millimeters is 75-95 percent,
 - (d) 12.7 millimeters is 40-60 percent,
 - (e) 9.52 millimeters is 30-40 percent,
 - (f) 4.75 millimeters is 20-30 percent,
 - (g) 2.36 millimeters is 15-25 percent,
 - and
 - (h) 0.075 millimeters is 0-3 percent; and
- wherein said interlayer of water-conducting asphaltic concrete has a minimum thickness of $1\frac{1}{2}$ to 2 times the largest sieve size of said aggregate rock.
2. The field of claim 1 wherein the surface of the base is at a 1 percent grade.
3. The field of claim 2 wherein said interlayer of water-conducting asphaltic concrete has a thickness of less than about 7.6 cm.
4. An artificial turf playing field comprising a layer of artificial turf, a resilient shock-absorbing cushion, an interlayer of water-conducting asphaltic concrete and a substantially impervious base, having a plurality of water-conducting channels in its upper surface.

