

Low resilience flame retardant polyurethane foam

Field of the invention

Technical field

This invention relates to a method of production of flexible graphite filled low resilience
5 polyurethane foams and to novel products obtained thereby.

Background of the invention

The physical and mechanical properties of polyurethane foams make them useful for a wide variety of applications, including upholstery and bedding. However, the inherent flammability of polyurethane materials leads to melting and the spread of burning debris
10 when exposed to fire conditions. Additionally the inherent properties of polyurethane materials leads to sustained combustion by progressive smouldering even after the flames have been extinguished.

Furthermore, cellular materials manufactured from flammable polymers are more flammable than the solid materials because the insulating effect of their cellular nature
15 allows a rapid build-up of heat at the surface. Consequently cellular polymeric materials have a higher rate of pyrolysis than solid materials. In order to make polyurethane foam behave more like a rigid material when exposed to flame, a particular type of graphite, ie. expandable graphite, is employed.

The method of achieving flame retardancy in flexible polyurethane foam by addition of
20 the graphite flakes is not new. A general method of introducing graphite into foam has been disclosed in US Patent 4,698,369 assigned to Dunlop Limited (UK). Furthermore US Patents 5,192,811 and 5,169,876 describe methods of preparing graphite filled polyurethane foam in combination with melamine and casein, respectively. The current invention expands upon the work presented in the above patents by producing graphite
25 filled low resilience polyurethane foam with long recovery times, good hand feel, long serviceability, and good flame retardant properties.

Recently a need was created for graphite filled low resilience flame retardant polyurethane foam with specific physical properties such as slow rate of recovery, high degree of flame retardancy and good level of support. This foam would provide increased comfort to the user as well as provide certain health benefits such as pressure point reduction. A high degree of flame retardancy would make this foam useful especially in aircraft seating applications where discomfort is not uncommon, especially for longer flights.

Reference to any prior art in the specification is not, and should not be taken as, an acknowledgment, or any form or suggestion, that this prior art forms part of the common general knowledge in Australia or any other jurisdiction or that this prior art could reasonably be expected to be ascertained, understood and regarded as relevant by a person skilled in the art.

Summary of the invention

The term "expandable graphite" is intended to cover graphite containing one or more exfoliating agents such that considerable expansion will occur at higher temperatures. The foaming reaction mixture usually contains graphite in an amount such that there will be at least 10% by weight, preferably at least 15% by weight and advantageously at least 25% by weight of graphite in the final foam. The amount of graphite in the final foam may vary according to the level of flame retardancy required but usually the amount of graphite will not exceed 90% (preferably 15-50% by weight) in the final product. The amount of graphite in the final foam, expressed in parts per hundred parts of polyol is anywhere between 10 and 90 parts, advantageously between 30 and 60ppw.

In one aspect, the invention provides a process of preparing a low resilience polyurethane foam the steps of:

mixing expandable graphite into a polyol component, and reacting in a single step

a reaction mixture comprising

an organic polyisocyanate, water, a reaction catalyst and the graphite containing polyol component, the reaction mixture initially being at a temperature of less than 40°C.

When mixing any powder, including graphite, to a low resilience foam mixture, the resultant foam tends to lose its low resilience properties and become resilient. Therefore, to ensure the low resilience properties are maintained, environmental conditions and mechanical factors need to be optimised. The most preferable method of incorporating graphite into the foam is via the In Line Blending process.

In Line Blending process is a process for homogenous blending of dry powder additives into liquid chemical constituents without the need for batch processing or batch blending tanks. This system accurately meters dry powder additives such as melamine into a metered stream of polyol, where it is homogenised, de-aerated, chilled and then the powder/polyol slurry is accurately metered to the foam head as another component stream.

The initial temperature is preferably in the range of 15°C to less than 40°C, more preferably 15-30°C and even more preferably 19-25°C.

The graphite may comprise the sole flame retardant in the reaction mixture. More commonly, however, graphite will be accompanied by other, usually liquid flame retardants from the family of, but not limited to, phosphorus-containing flame retardants, boron compounds or halogen-containing flame retardants.

It is preferable that the carbon particle size is in the range of 0.1-0.75 mm and the addition rates provide a foam comprising at least 25% by weight of expandable graphite.

In another aspect of the invention, there is provided a low resilience, flame retardant flexible polyurethane foam formed by the process of mixing graphite into a polyol component and reacting in a single step at a blend temperature greater than 15°C and less than 40°C, a reaction mixture comprising an organic polyisocyanate, water, a reaction catalyst and the graphite containing polyol component.

The conditions needed to produce flexible polyurethane foam will vary according to the reactants selected. A person of ordinary skill in the art will know whether to include additives and what additives should be incorporated into the formula (eg. catalyst or an auxiliary blowing agent), and what reaction conditions are required. The molecular weights of the polymeric polyols used in flexible low resilience graphite filled foam manufacture are usually from 200 to 5000, preferably from 500 to 3000, with a functionality (number of active hydroxyl groups per molecule) up to 7, preferably 2 to 5 and advantageously 2 to 3. Functionality of isocyanate is usually at least 2.

Usually the foams described in the present invention will pass the requirements of the test as described in FAR 25.853 Appendix F, (a)(1)(ii) - 1995.

Although the concept of low resilience foam is well known in the field of polyurethanes, test methods for evaluating recovery times have not been formalised. In the scope of the present invention, we also present a test method for evaluating recovery times of low resilience polyurethane foams.

In a further aspect of the invention, there is provided a polyurethane foam including:

at least 15 wt% graphite; and

having a recovery time of at least one second.

In the preferred form of this aspect, the foam comprises a reaction product of an organic poly isocyanate, water, a reaction catalysts, graphite and a polyol component wherein the reaction product comprises at least 20 wt % graphite.

The invention may further provide a graphite filled polyurethane foam having at least one of the following characteristics:

a) Recovery time of at least 1 second

b) Cell count of at least 24 cells/inch (as per AS2282.5 (1999))

c) Density range 20-100 kg/m³ (as per AS2282.3 (1999))

d) IF40 Hardness range 20-300 N (as per AS2282.8 (1999))

e) Flame retardancy (as per FAR25.853 Appendix F - (a)(1)(ii) - 1995)

f) Resilience of less than 15% (as per AS2282.11 (1999))

In a preferred form of the invention, the foam has all of the above characteristics.

5 The tests for examining each of the above characteristics are described later in the specification.

Detailed description of the embodiments

10 The general chemical components of a one-shot polyurethane foam system are polyfunctional isocyanate and polyfunctional alcohol, along with the catalysts necessary to control the rate and type of reaction and other additives to control the surface chemistry of the process. The general method of producing cellular polyurethane is to mix the polyfunctional isocyanate, polyfunctional alcohols, catalysts, blowing agents and other additives. Carbon dioxide generated *in situ* by the reaction of isocyanate with water acts as a blowing agent and the heat from the reaction causes evaporation of volatile-blowing agent resulting in the creation of foam. In a one-shot process all of the polyurethane foam ingredients are mixed and then discharged from the mixer to form the foam. The reactions begin immediately and proceed at such a rate that expansion starts quickly, usually in less than 10 seconds. The expansion generally takes a few minutes. Curing may continue for several days.

20 The present invention is also applicable to the prepolymer (two-shot) process. In the prepolymer (two-shot) process, the isocyanate, the polyol and the crosslinking agent are reacted and isolated as intermediates. The prepolymers are subsequently reacted with an additional component, or components, to yield the finished product. Most commonly the prepolymer is reacted with water to produce foam.

25 Suitable polyfunctional isocyanates are any that when utilised in the process of the present invention will yield the desired graphite filled flame retardant polyurethane foam. Examples of suitable organic polyisocyanates include toluene diisocyanate, such as the 80:20 mixture or the 65:35 mixture of the 2,4- and 2,6-isomers, ethylene diisocyanate, propylene diisocyanate, methylene-bis-4-phenyl isocyanate, 3,3'-bis-toluene-4,4'-diisocyanate, hexamethylene diisocyanate, naphthalene-1,5-diisocyanate polymethylene

polyphenylene diisocyanate, mixtures thereof and the like. The preferred organic polyisocyanate is Toluene Diisocyanate (TDI 80/20). The amount of polyisocyanate employed in the present invention is any amount suitable to obtain the desired low resilience graphite filled polyurethane foam. Generally, the amount of polyisocyanate employed in the process of this invention should be sufficient to provide at least about 0.5 NCO equivalent per hydroxyl group present in the reaction system (that is, isocyanate index of 50), which includes all the polyol reactants including water. It is preferable to employ sufficient isocyanate to provide an isocyanate index not greater than about 115, preferably in the range of about 50 and about 100. In broad terms, number of parts of isocyanate in reaction can vary between 20 to about 150. In the preferred form of the invention, amount of isocyanate used is between 30-70 parts per weight of polyol (ppw).

The term 'polyol' is an abbreviated name for poly-functional alcohols. There are two main types of polyols that are utilised in the polyurethane industry, namely polyether polyols and polyester polyols. Polyether polyols are of particular importance to the invention. A polyether polyol chemically is a polyfunctional alcohol having a polymeric chain with ether (C-O-C) linkages. Polyol is a source of hydroxyl and other isocyanate reactive groups. It is the reaction of polyol with isocyanate that forms one of the fundamental reactions (gelling) in foam making. In flexible foam formulations polyether polyols are used, and based on the starting polyol structure, different processing and foam properties can be achieved.

The polyols that may be employed in the present invention are generally of polyalkylene triol type, molecular weight ranging 300-3500, hydroxyl number ranging 100-600. However, polyols having higher and lower hydroxyl values higher are within the scope of the present invention, as are polyols having higher and lower molecular weights values. The polyols may be random, block or graft polyols and include mixtures of such. The polyols generally have at least three hydroxyl groups. It is to be noted that not all of the polyol content used in the process of the present invention need necessarily be polyols with ethylene oxide content of around 75%. It is only a requirement for a proportion of the polyol content. Typically, at least 20% of the polyol mixture should be of the polyalkylene triol type. More typically, from about 50 to 100% of all the polyol

mixture used will be of the polyalkylene triol type. The polyol content that is not of the polyalkylene triol type can be any polyol that is typically used for the manufacture of polyurethane foam, that may include conventional polyol, copolymer polyol and/or high resilience polyol or a combination of polyols or any other polyol typically used in the
5 manufacture of polyurethane foam. Generally speaking, formulation is based on weight of polyol in the formulation. Number of parts of polyol can vary between 100 –150 parts. In the preferred form of the invention, number of parts is between 100 – 120.

Foam density is determined by the amount of blowing agents present in the formulation, which is indicated by the blow index, that is the equivalent number of parts of water per
10 100 parts of polyol. Typically, the amount of water in formulation is anywhere from 1ppw to about 8ppw. In the preferred form of the invention, amount of water is between 2-5 ppw.

The most common types of blowing agents for urethane foams are water or volatile fluids such as halocarbons. Water generally will be utilised in the present invention in an
15 amount sufficient to produce the desired polyurethane foam, an auxiliary blowing agent such as, but not limited to methylene chloride, methyl chloroform, acetone or carbon dioxide may be used to fine tune physical properties of the foam. While water is called the blowing agent, in fact it is carbon dioxide that acts as the blowing agent, as it is generated *in situ* by the reaction of isocyanate with water. When liquid halocarbons are
20 utilised, they evaporate to produce a gas as the foaming mixture heats up. Water is generally employed in an amount in the range of about 1 to 25 parts per 100 parts by weight (pphp) of the total polyol components. Generally, water is utilised in the range of about 1 to about 15 parts water per 100 parts by weight of the di- and polyhydric components, preferably in range of 2 to 10 pphp and more preferably in range of 3 to 5
25 parts water per 100 parts by weight of the polyol.

In the preparation of the polyurethane foams of the invention, minor amounts of one or more surfactants may be utilised to further improve the cell structure of the polyurethane foam.

Typical of these are the silicone surfactants, eg., the silicone oils and soaps and the siloxane-oxyalkylene block copolymers. Generally up to 4 pphp of the surfactants are employed, preferably between about 1.0 and about 2.5 pphp.

Other surfactants may be utilised as emulsifiers in the present invention. These
5 emulsifiers include ethoxylated alkylphenols, aliphatic alcohols and sulfated aliphatic alcohols, with molecular weights in the range of about 60 to about 3000, preferably in the range of about 300 to about 2000. Generally in the range of about 0.5 to about 50 pphp, preferably between about 10 and about 30 pphp.

Of the many different types of catalysts available, tertiary amines and organometallics
10 have been found to be the most useful in the production of flexible foam. Catalysts are used to assist both the gelling (isocyanate/polyol reaction) and blowing (isocyanate/water reaction) reactions in foam production. Different combinations of these catalysts can be used to develop a balance between the two reactions. It is important this balance is correct to ensure the gas is entrapped sufficiently in the gelling
15 polymer and the cell walls develop sufficient strength to maintain their structure without collapse or shrinkage. Catalysts also ensure the completeness of the reaction or the 'cure'. Catalysts may include tertiary amines, which are the most commonly used amines and are mostly used in assisting the blowing reaction. Different types and concentrations of amines can be selected to satisfy processing requirements such as
20 cream time, rise time, gel times and cure.

The catalyst may also include stannous octoate, which is the most widely used organometallic in the conventional slabstock foam industry. Generally any suitable catalyst may be utilised in the present invention as long as the desired polyurethane foam is produced. The catalyst employed may be any of the catalysts or mixtures of
25 catalysts known to be useful for producing polyurethane foams by the one-step method. Such catalysts include for example, tertiary amines and metallic salts, particularly stannous salts. Typical tertiary amines include, but are not limited to, the following: N-methyl morpholine, Bis(2-dimethylaminoethyl)ether, N-hydroxyethyl morpholine, triethylene diamine, triethylamine and trimethylamine. Typical metallic salts include, for
30 example, the salts of antimony, tin and iron, eg., dibutyltin dilaurate, stannous octoate,

and the like. Preferably, a mixture comprised of a tertiary amine and a metallic salt is employed as a catalyst.

The amount of catalyst utilised in the present invention may be any amount that is suitable to yield the desired polyurethane foam. Generally, however, the polyurethane
5 foams of the invention are prepared in the presence of a certain amount of a reaction catalyst. The catalyst or catalyst mixture, as the case may be, is usually employed in an amount in the range of about 0.01 and about 2.0, and preferably between about 0.10 and about 1.0 parts by weight per every 100 pphp.

After production, the graphite filled flame retarded polyurethane foam will have density
10 range of about 20 to about 100 kg/m³. Preferably the density range will be in the range of 30 to 90 kg/m³ and most preferably in the range of about 40 - 60 kg/m³. Furthermore, polyurethane foam from the present invention will have the following characteristics as determined by the accompanying test methods.

a) **Recovery Time**

15 A sample of foam is cut to size 380(W) x 380(L) x 50(T) mm. The sample is crushed and conditioned for 24 hours.

Samples are conditioned as per AS2282-1-1999. Crushing is generally done by passing a sample between two rollers at least 15mm apart for two cycles (one cycle being two passes between rollers).

20 A 5 kg weight (diameter 150mm, thickness 50 mm) is applied to foam for 30 seconds. After 30 second period has elapsed, the weight is removed and recovery time is recorded. Recovery time is the time in seconds at which no traces of applied weight are observable and the foam has completely recovered.

Recovery of less than 1 second is considered to be unacceptable.

25 b) **Cell count per inch**

The cell count per inch is preferably at least 24 more preferably greater than 42; and even more preferably greater than 50.

This test is carried out on a sample greater than 25(w) x 25(L) x 25(t) mm where the thickness (t) of the sample is cut perpendicular to the direction of the rise of the foam.

- 5 The amount of cells along a 25mm length is counted using a thread counting glass or other suitable optical instrument. The cell count is linear, repeated in three different areas and the average is calculated.

The present invention will be further described in the following Examples, but the present invention should not be construed as being limited thereto. The Examples
10 illustrate the preparation of the foam according to an embodiment of the invention and the testing of foam.

Examples

Flexible slab foams were prepared from the ingredients (polyisocyanates, polyols, catalysts, foam stabilisers, etc.) set out below.

15 Polyol

a.) Trade name "Caradol MD30-45" (available from Shell Chemicals): Suspension of styrene-acrylonitrile particles in a propylene oxide/ethylene oxide based polyether polyol. OH no. 30

b.) Trade name "Voranol 2070" (available from Dow Chemical (Australia) Limited.
20 Polyether triol of molecular weight 800; OH no. 234.

c.) Trade name "Caradol SA36-02" (available from Shell Chemicals): Polyether polyol, polyalkylene triol. High EO content (approx 75%). OH No. 36.

d.) Trade name "Daltocel TA160" (available from Orica): Polyether polyol, PO triol with Molecular weight 1050, OH number 160.

Diol

a) Trade name "DPG" (available from Dow Chemical (Australia) Limited): Dipropylene glycol. OH no.: 837.

Polyisocyanate

- 5 a.) Trade name "VORANATE T-80 TYPE 1 TDI" (available from Dow Chemical (Australia) Limited): Toluene diisocyanate. 80% 2,3-toluene-diisocyanate , 20% 2,6-toluene-diisocyanate).

Catalyst

- 10 a) Trade name 'DABCO 33lv CATALYST" (available from Air Products Pty. Ltd.): Tertiary amines, mixture of 77% Dipropylene glycol and 33% Triethylenediamine. OH No. 561
- b) Trade name "KOSMOS 29" (available from TH. Golschmidt AG): Tin catalyst, Tin-(II)-isooctoate.
- 15 c) Trade name "Tegoamin BDE" (available from TH Goldschmidt AG). Mixture of 70% bis-(2-dimethylaminoethyl)ether and 30% dipropylene glycol. OH number 251.
- d) Trade name "Metatin Katalysator 712" (available from Rohm and Haas Australia Pty Ltd). Preparation mixture of stannous compounds.

Surfactant (Stabiliser)

- 20 a) Trade name "Tegostab B2370" (available from TH. Goldschmidt AG): Silicone surfactant, Polyethersiloxane.

Expandable graphite

Trade Name "Carbofoil PU200" (available from Cleanline Products, India): Expandable graphite (particle size 100-750µm).

Filler

a) Trade name "Omyacarb 10" (available from Omya Australia Pty. Ltd.). Calcium Carbonate.

Flame retardants

- 5 a) Trade Name: "Antiblaze 80" (available from Albright & Wilson). Chlorinated phosphate ester (Tris(2-chloropropyl)phosphate).
b) Trade name Antiblaze V66 (available from Albright & Wilson). Proprietary high molecular weight phosphate ester.

Flexible slabstock foams were prepared using the following methods. In these methods
10 batches of flexible polyurethane foams based on polyether polyols and on diisocyanates of the TDI80/20 type were prepared. The formulations were based on 100 parts by weight of total polyol, the necessary additives and total water. The amount of TDI used in the formulations was calculated using the OH numbers (given by supplier) and TDI requirement factor equal to $0.00155 \times \text{OH No.}$ The following formula was used when
15 calculating the amount of TDI required in pbw per 100 parts of polyol.

$$\text{TDI} = (\text{index}/100) \times 0.00155 \times (\text{sum of polyol OH No's} \times \text{p.b.w.} + 6239 \times \text{total water pbw} + \text{sum of additives OH no's} \times \text{pbw}).$$

All chemicals were weighed to an accuracy of $\pm 1\%$. The mixing speed was 2575 ± 100 rpm.

20 **General Method of foam preparation applicable to Example A, Example B, Example C and Example D**

An open top metal box, (38cm x 38cm x 53cm high) was lined with paper to prevent sticking of the material to the walls. The polyol was weighed into a 2.2lt-mixing container. Graphite and flame retardants (if applicable) were then added gradually with
25 constant mixing with a spatula with gentle agitation for about 5 minutes Water, silicone, amines were weighed in this sequence into a mixing container and stirred with a spatula until it appeared homogeneous (about 10 seconds). The temperature was checked and

checked and adjusted to $21 \pm 1^\circ\text{C}$. TDI 80/20 was weighed in a 1-litre jug. Tin catalyst was added to the polyol blend and stirred with an electric stirrer for 10 seconds. Whilst stirring, pre-weighed TDI 80/20 was added. A timing device was started immediately after the TDI 80/20 was added to the polyol/water/catalyst mixture. The resultant mixture was mixed for 10 seconds and poured into the paper lined metal box. The time for the mixture to start to produce gas, losing clarity and become creamy was recorded as the cream time. The time at which the expansion finished was recorded as the rise time. After 10 minutes the foam was removed from the box and placed in an oven at 90°C for 20 minutes to cure the surface. The foam was cut perpendicular to the direction of rise through the centre and a sample for testing was prepared.

Chemical	Example A		Example B
Polyol (a)	10		10
Polyol (b)	45		45
Polyol (c)	3		3
Polyol (d)	45		45
Water	3.00/2.95		2.75/2.70
Surfactant/Stabiliser (a)	1.25		1.0
Catalyst (a)	0.065		0.065
Catalyst(b)	0.043		0.08
Catalyst (c)	0.117		0.117
Catalyst (d)	0.057		-
Flame retardant (a)	2.5		3.5
Flame retardant (b)	2.5		3.5
Diol (a)	0.117		0.117
Expandable graphite (a)	50.0		50.0
Filler (a)			4.0
Polyisocyanate (a)	45.0		55.49
PROPERTIES	RT	50°C	
Dry foam density (kg/m^3)	50	50.5	49.6

IF40 (N)	82	68	146
Cell count (cells/in)	50	50	50
Recovery Time (sec)	9.7	9.7	11.9
Gas loss (pphp)	7.3		6.7
F.A.R. 25.853/App.F/Part1 (Vertical burn)	Pass		Pass
F.A.R. 25.853/App.F/Part1 (Kerosene burner)	Pass		Pass
%wt graphite in final product	22.5		20.9

Laboratory work has shown that foam of acceptable physical properties is produced at blend temperature 18-30°C. Splits are produced at elevated temperatures when the blend temperature is above 40°C and the foam is softer by 17%. Therefore, the initial
5 blend temperature should be generally less than 40°C, preferably 19-25°C, most preferably 20-23°C to maintain physical properties claimed for this grade.

Conditions are of essential importance for this grade. Temperature has the greatest impact on cream time and end of rise. Foam can be made in the laboratory at 50°C. However, this foam has splits and is softer than expected. Therefore, based on previous
10 knowledge and experience, it is not expected this grade can be made in a production environment at temperatures above 40°C. From our experience, producing this grade at a blend temperature of 20-23°C provides the best operating window. It will be expected that elevated blend temperatures have negative impact on the LR foam reaction profile.

While the invention has been described in regard to a one shot polyurethane foam
15 system, the method of the invention could be used in a two shot polyurethane foam system.

Since modifications within the spirit and scope of the invention may be readily affected by persons skilled in the art, it is to be understood that the invention is not limited to the particular embodiment described, by way of example, hereinabove.

CLAIMS

1. A process for preparing a low resilience polyurethane foam the steps of:

mixing a polyol component and an expandable graphite component;

forming a reaction mixture including;

5 the polyol and expandable graphite admixture, an organic polyisocyanate, a blowing agent and a reaction catalyst; the reaction mixture initially being at a temperature of less than 40°C.
2. The process of claim 1, further including the step of reacting the reaction mixture in a single step.
- 10 3. The process of claim 1, wherein the initial temperature is in the range of 15 to less than 40°C.
4. The process of claim 3, wherein the initial temperature is in the range of 15 to less than 30°C.
5. The process of claim 1, wherein the amount of expandable graphite is in the
15 range of 10 to 90 parts by weight per 100 parts by weight of the total polyol components.
6. The process of claim 5, wherein the amount of expandable graphite in the reaction mixture is in the range of 10 to 90 parts by weight per 100 parts by weight of the total polyol components.
- 20 7. The process of claim 1, wherein the blowing agent is water.
8. The process of claim 7, wherein the amount of water in the reaction mixture is in the range of 2 to 10 parts by weight per 100 parts by weight of the total polyol components.

9. The process of claim 7, wherein the amount of water in the reaction mixture is in the range of 3 to 5 parts by weight per 100 parts by weight of the total polyol components.

10. The process of claim 1 wherein the expandable graphite is the sole flame
5 retardant of the reaction mixture.

11. The process of claim 1, further including a liquid flame retardant selected from a group consisting of phosphorus-containing flame retardants, boron compounds or halogen-containing flame retardants.

12. The process of claim 1, wherein the expandable graphite particle size is in the
10 range of 0,1 to 0.75 mm.

13. The process of claim 1, wherein the reaction mixture further includes a silicone surfactant in an amount up to 6 parts by weight per 100 parts by weight of the total polyol components.

14. A low resilience, flame retardant flexible polyurethane foam formed by the
15 process including the step of mixing an expandable graphite component to a polyol component;

forming a reaction mixture including;

the polyol and expandable graphite admixture, an organic polyisocyanate, water and a reaction catalyst; the reaction mixture initially being at a temperature of less than 40°C;
20 and greater than 15°C.

15. A polyurethane foam of claim 14, wherein the foam includes at least 15% by weight of expandable graphite.

16. A polyurethane foam of claim 14, wherein the foam includes at least 20% by weight of expandable graphite.

17. A polyurethane foam of claim 14, wherein the polyol has a molecular weight from 200 to 5000.
18. A polyurethane foam of claim 14, wherein the polyol has a molecular weight from 500 to 3000.
- 5 19. The polyurethane foam of claim 14, wherein the functionality of the polyol is up to 7.
20. The polyurethane foam of claim 19, wherein the functionality of the polyol, is 2 to 3.
21. The polyurethane foam of claim 13, wherein the functionality of the isocyanate is
10 at least 2
22. A low resilience, flame retardant flexible polyurethane foam including:

at least 15 wt% expandable graphite; and

having a recovery time of at least one second.
23. The polyurethane foam of claim 22, wherein the foam includes at least 20%
15 expandable graphite.
24. The polyurethane foam of claim 22, wherein the foam includes a reaction product of an organic polyisocyanate, water, a reaction catalyst, expandable graphite and a polyol component.
25. The polyurethane foam of claim 22, wherein the foam includes a recovery time
20 of at least 5 seconds.
26. The polyurethane foam of claim 22, wherein the foam includes a cell count of at least 24 cells/inch.

27. The polyurethane foam of claim 22, wherein the foam includes a cell count of at least 42 cells/inch

28. The polyurethane foam of claim 22, wherein the foam includes a density range 20-100 kg/m³.

5 29. The polyurethane foam of claim 28, wherein the foam includes a density range 40-60 kg/m³

30. The polyurethane foam of claim 22, wherein the foam includes a IF40 Hardness range of 20-300 N.

10 31. The polyurethane foam of claim 22, wherein the foam includes is flame retardant.

32. The polyurethane foam of claim 22, wherein the foam includes a resilience of less than 15%.

15 33. The polyurethane foam of claim 22 wherein the foam has at least one characteristic selected from a group of: a recovery time of at least 5 seconds; a cell count of at least 24 cells/inch; a density range in the range of 20-100 kg/m³; a IF40 Hardness in the range of 20-300 N and having a resilience of less than 15%.