

PATENT SPECIFICATION

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(54) POLYMER/POLYOLS AND POLYURETHANE DERIVATIVES THEREOF

We, UNION CARBIDE CORPORATION, a Corporation organised and existing under the laws of the State of New York, United States of America, of 270 Park Avenue, New York, State of New York 10017, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to polyols and polymer/polyols which are useful in the production of polyurethane foams, and to polyurethane foams prepared therefrom.

Within the past few years, seat cushions fabricated from high-resiliency polyurethane foams have gained increasingly wide acceptance. The polyurethane foams in such cushions are usually made by reacting a polymer/polyol composition and another polyol with organic polyisocyanate in the presence of catalyst, a blowing agent and a silicone surfactant. The polymer/polyol compositions most widely used in producing such polyurethanes consist essentially of a major amount of a polyol and a minor amount of a polymer. The polyols in these polymer/polyol compositions are typically polyoxypropylene-polyoxyethylene polyols wherein the polyoxyethylene blocks endblock at least 35 mole percent of the polyoxypropylene blocks and are terminated with primary hydroxyl groups. These polyols usually have about 85 weight percent polyoxypropylene blocks and about 15 weight percent polyoxyethylene blocks and have hydroxyl numbers of about 34, about 2.6 hydroxyl groups per molecule and about 70 mole percent primary hydroxyl groups. Seat cushions fabricated from polyurethane foams made from formulations containing such polymer/polyol compositions have outstanding properties, particularly excellent load-bearing properties.

Although the above-described polyurethane foams have outstanding properties, there is still some room for improvement in their properties, particularly when intended for use in seat cushions that may be subjected to certain conditions. By way of illustration, seat cushions fabricated from such polyurethane foams tend to exhibit a phenomenon known as "static fatigue". Thus, when an individual is seated on the cushion for a prolonged period of time, the cushion tends to become deformed and to retain the deformation to some extent after the load imposed by the individual is removed. As a further illustration, seat cushions fabricated from such polyurethane foams tend to lose their desirable load-bearing properties to some extent when exposed to conditions of high humidity for prolonged periods of time.

In accordance with the present invention, there is provided a normally liquid polyoxyalkylene-polyoxyethylene polyol consisting essentially of: (1) polyoxyalkylene blocks that consist of oxalkylene groups containing at least 3 carbon atoms, (2) polyoxyethylene blocks that consist of oxyethylene groups, that endblock at least 35 mole percent of the said polyoxyalkylene blocks and that are terminated with primary hydroxyl groups and (3) the residue of at least one starter (as hereinafter defined), the said polyol comprising from 90 to 97 weight percent of

the said polyoxyalkylene blocks and from 10 to 3 weight percent of the said polyoxyethylene blocks, based on the total weight of blocks in the polyol, and having (a) an average of at least 3.2 hydroxyl groups per molecule, (b) a hydroxyl number no greater than 45 and (c) at least 35 mole percent of primary hydroxyl groups, based on the total number of moles of hydroxyl groups in the polyol.

This invention also provides polymer/polyol compositions consisting essentially of:

(A) a major amount of a normally liquid polyoxyalkylene-polyoxyethylene polyol consisting essentially of: (1) polyoxyalkylene blocks that consist of oxyalkylene groups containing at least 3 carbon atoms, (2) polyoxyethylene blocks that consist of oxyethylene groups, that endblock at least 35 mole percent of the polyoxyalkylene blocks and that are terminated with primary hydroxyl groups and (3) the residue of at least one starter (as hereinafter defined), the said polyol comprising from 90 to 97 (preferably from 93 to 97) weight percent of the said polyoxyalkylene blocks and from 10 to 3 (preferably from 7 to 3) weight percent of the said polyoxyethylene blocks, based on the total weight of blocks in the polyol, and having (a) an average of at least 3.2 (preferably at least 3.4) hydroxyl groups per molecule, (b) a hydroxyl number no greater than 45 (preferably from 25 to 35) and (c) at least 35 (preferably at least 50) mole percent of primary hydroxyl groups, based on the total number of moles of hydroxyl groups in the polyol; and (B) a minor amount of a polymer formed by polymerizing at least one ethylenically unsaturated monomer in the said polyol by free radical polymerization, the polymer being in the form of particles that are stably dispersed in the polyol.

This invention further provides elastomeric polyurethanes produced by reacting: (I) a polyol or a polymer/polyol composition as described above and (II) an organic polyisocyanate in the presence of (III) a catalyst for the reaction of (I) and (II) to produce the polyurethane.

Figure 1 shows a plot of the 50 percent Indentation Load Deflection (ILD) of a high resiliency polyurethane foam versus time.

Figure 2 shows a plot of the fraction of load retained (Δ ILD) by a high resiliency polyurethane foam versus logarithmic time.

Figure 3 shows plots of the fraction of load retained (Δ ILD) by a "hot cure" polyurethane foam, a high resiliency (HR) polyurethane foam of this invention and a prior art high resiliency polyurethane foam versus logarithmic time.

The polyols employed in producing the polymer/polyol compositions of this invention contain from 90 to 97 weight percent polyoxyalkylene blocks and from 10 to 3 weight percent of polyoxyethylene blocks. The polyoxyalkylene blocks consist of oxyalkylene groups containing at least 3 carbon atoms (e.g., oxypropylene, oxybutylene and/or oxypentylene groups). The polyoxyethylene blocks endblock at least 35 mole percent of the polyoxyalkylene blocks and are terminated with the primary hydroxyl groups. Polyols with smaller than this minimum amount of these polyoxyethylene blocks are difficult to convert to polyurethane foams using formulations conventionally employed to produce high resiliency polyurethane foams, apparently because these polyols contain an insufficiency of primary hydroxyl groups. Terminal oxyethylene groups provide essentially only primary hydroxyl groups whereas terminal oxypropylene groups provide secondary and primary hydroxyl groups in a ratio of about 97 to 3. Apparently an insufficiency of primary hydroxyl groups, due to an insufficiency of terminal oxyethylene groups, results in a polyol of insufficient reactivity to permit adequate viscosity buildup in the polyurethane-forming formulation. Consequently, the reaction mixture is of insufficient viscosity to trap the gas used by the blowing agent. On the other hand, polyols having a polyoxyethylene content higher than the maximum polyoxyethylene content of the polyols employed in the present invention tend to result in polyurethane foams whose properties deteriorate to an excessive extent during humid aging.

The polyols employed in producing the polymer/polyol compositions of this invention have an average of at least 3.2 hydroxyl groups per molecule. Polyols having fewer hydroxyl groups tend to have the same disadvantageous properties as polyols having an insufficiency of terminal oxyethylene groups pointed out above (i.e., insufficient reactivity). In this case, the insufficient reactivity is due to the relatively small number of hydroxyl groups. Moreover, polyols having fewer than 3.2 hydroxyl groups per molecule tend to result in polyurethane foams which suffer from static fatigue to an undesirable degree. More preferably, the polyols employed in this invention contain an average from 3.8 to 4.8 hydroxyl groups per molecule.

The polyols employed in the present invention are produced by reacting a "starter" or mixture of "starters" with propylene oxide to form a polyol intermediate and then reacting ("capping") the polyol intermediate with ethylene oxide. Preferably, a basic material such as potassium or potassium hydroxide is employed as a catalyst in the reactions.

By the term "starter" as used herein is meant a compound which contains at least one active hydrogen atom.

The minimum average number of hydroxyl groups per molecule in the polyols employed in this invention is achieved by control of the functionality of the starter or mixture of starters used in producing the polyol. Examples of suitable starters are organic compounds having at least 4 active hydrogen atoms and up to 20 carbon atoms such as polyhydric alcohols (e.g., erythritol, sorbitol, sucrose, pentaerythritol and methylglycoside) and primary and secondary amines (e.g., ethylene diamine and diethylene triamine). Water is a starter for polyols produced from alkylene oxides and may be present as an impurity in the above-mentioned starters. Moreover, when potassium hydroxide is used as a catalyst in the production of the polyol, it reacts with the starter to produce an alkoxide and water. Water reacts with alkylene oxide to produce polyoxyalkylene diols. Moreover, propylene oxide can isomerize to form allyl alcohol which is a starter and results in the formation of mono-ols. These mono-ols and diols lower the average functionality of the final polyol product and so the presence of starters leading to mono-ol and diols must be taken into account in order to produce a polyol of the desired average number of hydroxyl groups ("functionality").

The polyols employed in the present invention have hydroxyl numbers no greater than 45. Polyols having hydroxyl numbers above 45 are undesirable because no improvement is noted in the static fatigue and humidity sensitivity of polyurethane foams made from polymer/polyol compositions derived from these polyols.

As noted above, the polyols employed in the present invention are produced by reacting a starter with propylene oxide to form a polyol intermediate and then reacting ("capping") the polyol intermediate with ethylene oxide. Due to the volume limitations of the reactor employed, it may be necessary to produce the polyol intermediate in a series of steps in order to produce a final polyol intermediate of the desired relatively low hydroxyl number (i.e., relatively high combining weight). In order to ensure that a relatively high proportion of the endblocking groups in the final polyol product are primary hydroxyl groups, it is desirable to heat the polyol intermediate at reduced pressure so as to volatilize any unreacted propylene oxide. As noted above, the propylene oxide tends to produce almost exclusively secondary hydroxyl groups and hence at most only a small amount of propylene oxide should be present during the final step in the production of the polyol. After the polyol intermediate has been capped with ethylene oxide to produce the final polyol product, magnesium silicate may be added and the product filtered so as to remove potassium catalyst.

The polymer/polyol compositions of the present invention are produced by polymerizing a minor amount of at least one ethylenically unsaturated monomer in a major amount of the above-described polyols by free radical polymerization.

Ethylenically unsaturated monomers suitable for use in producing the polymer/polyol compositions of the present invention include the hydrocarbon monomers such as butadiene, isoprene, 1,4-pentadiene, 1,6-hexadiene, 1,7-octadiene, styrene, alpha-methylstyrene, methylstyrene, 2,4-dimethylstyrene, ethylstyrene, isopropylstyrene, butylstyrene, phenylstyrene, cyclohexylstyrene and benzylstyrene; substituted styrenes such as chlorostyrene, 2,5-dichlorostyrene, bromostyrene, fluorostyrene, trifluoromethylstyrene, iodostyrene, cyanostyrene, nitrostyrene, N,N-dimethylaminostyrene, acetoxystyrene, methyl 4-vinylbenzoate, phenoxystyrene, *p*-vinyl diphenyl sulfide and *p*-vinylphenyl phenyl oxide; and acrylic and substituted acrylic monomers such as acrylic acid, methacrylic acid, methylacrylate, 2-hydroxyethyl acrylate, 2-hydroxyethyl methacrylate, methyl methacrylate, cyclohexyl methacrylate, benzyl methacrylate, isopropyl methacrylate, octyl methacrylate, methacrylonitrile, methyl alpha-chloroacrylate, ethyl alpha-ethoxyacrylate, methyl alpha-acetaminoacrylate, butyl acrylate, 2-ethylhexyl acrylate, phenyl acrylate, phenyl methacrylate, methacrylonitrile, acrylonitrile, N,N-dimethylacrylamide, N,N-dibenzylacrylamide, N-butylacrylamide and methacrylyl formamide; the vinyl esters, vinyl ethers and vinyl ketones, such as vinyl acetate, vinyl chloroacetate, vinyl alcohol, vinyl butyrate, isopropenyl acetate, vinyl formate, vinyl acrylate, vinyl methacrylate, vinyl

methoxy acetate, vinyl benzoate, vinyl iodide, vinyl toluene, vinyl naphthalene, vinyl bromide, vinyl fluoride, vinylidene bromide, 1-chloro-1-fluoroethylene, vinylidene fluoride, vinyl methyl ether, vinyl ethyl ether, vinyl propyl ethers, vinyl butyl ethers, vinyl 2-ethylhexyl ether, vinyl phenyl ether, vinyl 2-methoxyethyl ether, methoxybutadiene, vinyl 2-butoxyethyl ether, 3,4-dihydro-1,2-pyran, 2-butoxy-2'-vinylloxy diethyl ether, vinyl 2-ethylmercaptoethyl ether, vinyl methyl ketone, vinyl ethyl ketone, vinyl phenyl ketone, vinyl ethyl sulfide, vinyl ethyl sulfone, N-methyl-N-vinyl acetamide, N-vinyl-pyrrolidone, vinyl imidazole, divinyl sulfide, divinyl sulfoxide, divinyl sulfone, sodium vinyl sulfonate, methyl vinyl sulfonate and N-vinyl pyrrole; dimethyl fumarate, dimethyl maleate, maleic acid, crotonic acid, fumaric acid, itaconic acid, monomethyl itaconate, *t*-butylaminoethyl methacrylate, dimethylaminoethyl methacrylate, glycidyl acrylate, allyl alcohol, glycol monoesters of itaconic acid, dichlorobutadiene and vinyl pyridine. Mixtures of these monomers can be used.

Preferably a mixture of from 40 to 85 weight percent acrylonitrile and from 60 to 15 weight percent styrene, based on the weight of the acrylonitrile and styrene, is polymerized in the polyol to produce the polymer.

The free radical polymerization catalyst that can be employed in producing the polymer/polyols of this invention include peroxides, persulfates, perborates, percarbonates and azo compounds, including hydrogen peroxide, dibenzoyl peroxide, acetyl peroxide, benzoyl hydroperoxide, *t*-butyl hydroperoxide, di-*t*-butyl peroxide, lauroyl peroxide, butyryl peroxide, diisopropylbenzene hydroperoxide, cumene hydroperoxide, paramenthane hydroperoxide, diacetyl peroxide, di- α -cumyl peroxide, dipropyl peroxide, diisopropylene peroxide, isopropyl-*t*-butyl peroxide, butyl-*t*-butyl peroxide, dilauroyl peroxide, difuroyl peroxide, ditriphenylmethyl peroxide, bis(*p*-methoxybenzoyl)peroxide, *p*-monomethoxybenzoyl peroxide, rubrene peroxide, ascaridol, *t*-butyl peroxybenzoate, diethyl peroxyterephthalate, propyl hydroperoxide, isopropyl hydroperoxide, *n*-butyl hydroperoxide, *i*-butyl hydroperoxide, cyclohexyl hydroperoxide, trans-Decalin hydroperoxide, α -methylbenzyl hydroperoxide, α -methyl- α -ethyl benzyl hydroperoxide, Tetralin hydroperoxide, triphenylmethyl hydroperoxide, diphenylmethyl hydroperoxide, α , α' -azo-2-methyl butyronitrile, α , α' -2-methyl heptonitrile, 1,1'-azo-1-cyclohexane carbonitrile, dimethyl α , α' -azo-isobutyronitrile, persuccinic acid and diisopropyl peroxy dicarbonate. A mixture of catalyst may also be used.

The polymer/polyol compositions of this invention consist essentially of a major amount of the polyol and a minor amount of the polymer preferably the compositions consist essentially of from 3 to 35 weight percent of the polymer and from 97 to 65 weight percent of the polyol based on the weight of the polyol and the polymer.

The process used in producing the polymer/polyol compositions of this invention involves polymerizing the monomers in the polyol while maintaining a low monomer to polyol ratio throughout the reaction mixture during the polymerization. These low ratios are achieved by employing process conditions that provide rapid conversion of monomer to polymer. In practice, a low monomer to polyol ratio is maintained, in the case of semi-batch and continuous operation, by control of the temperature and mixing conditions and, in the case of semi-batch operation, also by slowly adding the monomers to the polyol. The temperature employed is any temperature at which the half life of the catalyst is no longer than six minutes. The mixing conditions employed are those attained using a back-mixed reactor (e.g., a stirred flask or stirred autoclave). These reactors keep the reaction mixture relatively homogeneous and so prevent localized high monomer to polyol ratios such as occur in certain tubular reactors (e.g., in the first stages of "Marco" reactors when these reactors are operated conventionally with all the monomer added to the first stage). However, tubular reactors (e.g., Marco reactors) can be employed if modified so that increments of the monomer are added to various stages.

When using a semi-batch process, the feed times can be varied (as well as the proportion of polyol in the reactor at the start versus polyol fed with the monomer) to effect changes in the product viscosity. Generally, longer feed times result in higher product viscosities and may allow use of slightly broader acrylonitrile to styrene ranges for a given polyol and polymer content.

The crude polymer/polyol compositions usually contain small amounts of unreacted monomers. These residual monomers can be converted to additional polymer by employing a two-stage operation in which the product of the first stage

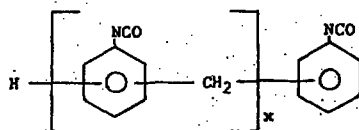
(the back-mixed reactor) is passed into a second stage which can be a Marco reactor operated conventionally or an unstirred tank reactor.

The temperature used in producing polymer/polyol compositions in accordance with this invention is any temperature at which the half life of the catalyst is no longer than six minutes (preferably no longer than from 1.5 to 2 minutes). The half lives of the catalysts become shorter as the temperature is raised. The maximum temperature used is not narrowly critical but should be lower than the temperature at which significant decomposition of the reactants or product occurs. By way of illustrations, azo-bisisobutyronitrile has a half life of six minutes at 100°C.

In the process used to produce the polymer/polyols of this invention, the monomers are polymerized in the polyol. Usually, the monomers are soluble in the polyol. It has been found that first dissolving the monomers in a minor portion of the polyol and adding the solution so formed to the remainder of the polyol at reaction temperature facilitates mixing the monomers and the polyol and can reduce or eliminate reactor fouling. When the monomers are not soluble in the polyols, known techniques (e.g., dissolution of the insoluble monomers in another solvent) can be used to disperse the monomers in the polyol prior to polymerization. The conversion of the monomers to polymers achieved by this process is remarkably high, (e.g., conversions of from 72% to 95% of the monomers are generally achieved).

The present invention also provides elastomeric polyurethanes produced by reacting: (I) a polymer/polyol composition of this invention as described above and (II) an organic polyisocyanate in the presence of (III) a catalyst for the reaction of (I) and (II) to produce the polyurethane. Preferably, the polyurethane is a foam and the reaction to produce the polyurethane is conducted in the presence of (IV) a blowing agent and (V) a silicone surfactant as additional starting materials.

The organic polyisocyanates that are useful in producing the polyurethanes of this invention are organic compounds that contain at least two isocyanato groups. These compounds are well known in the art of producing polyurethane foams. Suitable organic polyisocyanates include the hydrocarbon diisocyanates, (e.g., the alkylene diisocyanates and the arylene diisocyanates) as well as known triisocyanates and polymethylene poly(phenylene isocyanates). Examples of suitable polyisocyanates are 1,2-diisocyanatoethane, 1,4-diisocyanatobutane, 2,4-diisocyanatotoluene, 2,6-diisocyanato tolylene, 1,3-diisocyanato-*o*-xylene, 1,3-diisocyanato-*m*-xylene, 1,3-diisocyanato-*p*-xylene, 2,4-diisocyanato-1-chlorobenzene, 2,4-diisocyanato-1-nitrobenzene, 2,5-diisocyanato-1-nitrobenzene, 4,4'-diphenylmethylenediisocyanate; 3,3'-diphenylmethylenediisocyanate; and polymethylene poly(phenyleneisocyanates) having the formula:



wherein x has an average value from 1.1 to 5 inclusive (preferably from 1.3 to 2.0). Usually a slight excess of the organic polyisocyanate is employed.

The catalysts that are useful in producing the polyurethanes of this invention include tertiary amines such as bis(dimethylamino ethyl) ether, triethylene diamine, trimethylamine, triethylamine, *N*-methylmorpholine, *N*-ethylmorpholine, *N,N*-dimethylethanolamine, *N,N,N',N'*-tetramethyl-1,3-butanediamine, triethanolamine, 1,4-diazabicyclo[2.2.2]octane and pyridine oxide. These amine catalysts are preferably employed dissolved in a suitable solvent (e.g., dipropylene glycol). Suitable catalysts also include organotin compounds such as dialkyltin salts of carboxylic acids, e.g., dibutyltin diacetate, dibutyltin dilaurate, dibutyltin maleate, dilauryltin diacetate and dioctyltin diacetate. The catalysts are employed in small amounts, for example, from 0.001 per cent to 5 per cent based on weight of the reaction mixture.

The blowing agents useful in producing the polyurethane foams of this invention include water and halogenated hydrocarbons such as trichloromono-fluoromethane, dichlorodifluoromethane, dichloromonofluoromethane, dichloromethane, trichloromethane, 1,1-dichloro-1-fluoroethane, 1,1,2-trichloro-1,2,2-trifluoroethane, hexafluorocyclobutane and octafluorocyclobutane. Another class

(13)

of blowing agents include thermally-unstable compounds which liberate gases upon heating, such as N,N'-dimethyl-N,N'-dinitrosoterephthalamide. The generally preferred method of foaming is the use of water or a combination of water plus a fluorocarbon blowing agent such as trichloromonofluoromethane. The quantity of blowing agent employed will vary with factors such as the density desired in the foamed product.

The silicone surfactants useful in producing the polyurethane foams of this invention include siloxane-oxyalkylene block copolymers, such as those disclosed in United States Patent Specification No. 3,741,917, cyanoalkyl modified siloxane fluids such as those disclosed in Belgian Patent Specification No. 809,978 and cyanoalkoxy-alkyl siloxane fluids such as those disclosed in Belgian Patent Specification No. 809,979. These surfactants are used in amounts of from 0.03 to 2 parts by weight per 100 parts by weight of the polymer/polyol and any other polyol used and are usually employed dissolved in a liquid oxyalkylene polymer. Also useful are low molecular weight silicone oils $[Me_3SiO(Me_2SiO)_xSiMe_3]$ having viscosities of 3 to 7 centistokes at 25°C. However, silicone oils, as contrasted to the other surfactants mentioned above, are only useful within a narrow range of process conditions as disclosed in the patents mentioned above.

Preferably, additional amounts of the polyols employed to produce the polymer/polyol compositions of the present invention are used along with those compositions in producing the polyurethanes of this invention. Additionally, conventional polyols can be employed along with the polymer/polyol compositions of the invention in producing the polyurethanes.

The polyols employed in producing the polymer/polyol compositions of this invention are also materials that represent a further aspect of this invention. Elastomeric polyurethanes derived from these polyols (using the same polyurethane-forming procedure and other starting materials described above in connection with the disclosed polymer/polyol compositions) represent a still further aspect of this invention.

The elastomeric polyurethanes of this invention can be produced by any suitable method. Thus, the foams can be molded or free rise and can be produced by the prepolymer, quasi-prepolymer or one-shot processes.

The polyurethanes of this invention can be employed as automobile seat cushions, crash pads, arm rests, mattresses and automobile bumpers. The improved static fatigue and humid aging properties of the polyurethanes of this invention make them particularly useful in such applications, and in other applications (e.g., furniture cushions).

The following Examples illustrate the present invention, with the exception of Examples 3 and 7 which are presented for comparative purposes.

DEFINITIONS

As used in the Examples appearing below, the following symbols, terms and abbreviations have the indicated meanings:

"%" denotes percent by weight unless otherwise stated.

"A/S" or "A:S" denotes the weight ratio of acrylonitrile to styrene.

"Calc." denotes calculated.

"cks." denotes viscosity in centistokes at 25°C.

"cps." denotes viscosity in centipoises measured at 25°C.

"Cookout" denotes the period a reaction mixture is heated after all starting materials have been added.

"Ft." denotes foot.

"Functionality" denotes the average number of reactive groups in a molecule.

"gm" denotes grams.

"hr" denotes hour.

"Index" denotes the relative amount of isocyanato groups and active hydrogen atoms in a polyurethane-forming formulation and is calculated as follows:

$$\text{Index} = \frac{\text{Equivalents of NCO}}{\text{Equivalents of active hydrogen}} \times 100$$

"Ionol" (Registered Trade Mark) denotes 2,6-di-tert-butyl-4-methylphenol.

"lbs" denotes pounds.

"meq/gms" denotes milli-equivalents per gram.

(16)

	"max." denotes maximum.	
	"min." denotes minutes.	
	"mg" denotes milligrams.	
5	"mm Hg" denotes millimeters of mercury absolute pressure.	5
	"Parts" and "pbw" denotes parts by weight.	
	"pcf" denotes pounds per cubic foot.	
	"Poly A" denotes polyacrylonitrile.	
	"Poly S" denotes polystyrene.	
10	"ppm" denotes parts by weight per million parts by weight.	10
	"psig" denotes pounds per square inch gauge pressure.	
	"pli" denotes pounds per linear inch.	
	"Residuals" denotes unreacted monomers.	
	"RPM" denotes revolutions per minute.	
15	"Stripped" denotes removal of volatile materials by heating at reduced pressure.	15
	"Wt" denotes weight.	

PREPARATION PROCEDURES

The polyols, polymer/polyols and polyurethane foams described in the Examples appearing below were prepared by the following procedures:

A. Polyol Preparation

Due primarily to the limitations imposed by the volume of the reactors used, the desired relatively low hydroxyl numbers (correspond to relatively high combining weights) of the polyols of the Examples appearing below could not be achieved by a one-step procedure. Hence, the polyols were produced by the following five-step procedure. In Step 1, a starter (e.g. erythritol) which usually had been stripped to remove any water, was mixed with KOH containing some absorbed water. The mixture so formed was heated and the starter and KOH reacted to produce an alkoxide and water. In Step 2, the product of Step 1 was reacted with propylene oxide to produce a first polyol intermediate. In Step 3, the first polyol intermediate was mixed with additional KOH and reacted with additional propylene oxide to produce a second polyol intermediate and this intermediate was mixed with KOH to serve as a catalyst in subsequent steps. In Step 4, the product of Step 3 was reacted with propylene oxide to produce a third polyol intermediate. Unreacted propylene oxide was then stripped from this intermediate. In Step 5, the stripped third polyol intermediate was reacted with ethylene oxide to produce the final polyol product. After each addition of KOH, the reaction mixture was stirred with heating for a prolonged period to ensure adequate dispersion of the KOH in the starter or intermediate and to promote alkoxide formation. Further, for the polyols of narrow functionality distribution, the water absorbed by KOH and produced during alkoxide formation was stripped after each addition of KOH. After each addition of alkylene oxide, the reaction mixture was heated for a prolonged period ("cooked out") to maximize reaction of the alkylene oxide.

The following detailed procedure (used in Example 1) illustrates the above-described general procedure.

Step 1 — Molten, anhydrous erythritol (1000 grams) was charged to a two-liter glass flask equipped with a stirrer. Flake KOH containing about 10% water (4.0 grams) were added to the flask. The mixture so formed was stripped for one hour at 150°C and <5 mm Hg with stirring.

Step 2 — The product of Step 1 was added to a 1.5 gallon stainless steel autoclave equipped with a stirrer. The contents of the autoclave were maintained at temperature of about 140°C and propylene oxide fed until the reaction product had a hydroxyl number of 442. KOH was removed by diluting with an isopropanol-water solution containing about 12% water and mixing with an ion exchange resin. The product was filtered. This ion exchange treatment and filtration was not used in the other Examples. After stripping the isopropanol and water, a first polyol intermediate was obtained having a hydroxyl number of 441, a functionality of 3.91 and a viscosity of 1700 centistokes.

Step 3 — The first intermediate polyol (1267 gms) was catalyzed with 20 gms of flake KOH. The mixture so formed was stripped at 130 to 140°C and <5 mm Hg for one hour with stirring. Propylene oxide (7178 gms) was reacted with the stripped mixture in a 2.0 gallon stainless steel autoclave equipped with a stirrer over a period of 7.5 hours at 110°C and 60 psig. Then the mixture was heated at

(17)

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110°C for 5 hours to yield 8760 gms of a second intermediate polyol. In order to increase the KOH content to the level desired in the production of the third intermediate polyol, the second intermediate polyol was mixed with 45 grams of additional KOH and heated at 140°C with stirring for 1 hour at <5 mm Hg.

5 *Step 4* — The second intermediate polyol containing KOH (18.8 pounds) was charged to a 10-gallon stainless steel jacketed autoclave equipped with a stirrer. Propylene oxide (32 pounds) was fed to the autoclave in two increments at 110°C and 52 psi in 5 hours. The contents of the autoclave were heated at 110°C for an additional 6 hours to react nearly all the propylene oxide. The contents of the autoclave were then stripped at 120°C and 6 mm Hg absolute pressure for 3 hours to remove unreacted propylene oxide.

10 *Step 5* — Then 3.9 pounds of ethylene oxide was fed into the autoclave at 110°—114°C in 1 hour after which the contents of the autoclave were heated at 110°C for an additional 1 hour and then was stripped for 1 hour at 16 to 11 mm of Hg. Potassium was removed from the product so obtained by treatment with magnesium silicate ("Bribe Sorb") for 17 hours. After the addition of 0.01 pounds of Ionol, the product was filtered, and the filtrate was stripped to remove water. The final polyol product (39.54 pounds) had the following analyses:

	Hydroxyl number	28.87	
20	Acid number	0.01	20
	Water, %	0.03	
	Alkalinity, meq/gm	0.00009	
	Viscosity, cks at 25°C	1294	
	Primary hydroxyl, mole %	70	
25	Average functionality	3.45	25
	Oxyethylene content, %	8.09	
	Unsaturation, meq/gm	0.076	

B. Polymer/Polyol Preparation

30 The following is the general procedure used to produce the polymer/polyol compositions described in the Examples appearing below:

Equipment

35 A single-stage continuous back-mixed reactor having a volume of 550 cubic centimeters was used. This reactor was agitated with a top-entering radial propeller and contained four equally spaced vertical baffles. The reactor was provided with means for heating and cooling through the side walls. Two feed tanks were used, each on separate scales, and connected by flexible tubes to positive displacement metering pumps. The selected weight ratio of styrene, acrylonitrile and azobisisobutyronitrile was premixed and fed from one tank. The other tank contained the base polyol. The two streams were fed simultaneously, through an in-line mixer prior to entering the bottom of the reactor near the radial propeller. The product was discharged out the top of the reactor through a back-pressure regulator and a cooler that lowered product temperature to about 35°C.

Procedure

45 Initially the reactor was filled with Polyol I and additional Polyol I was fed for the first half hour of operation. Prior to starting the feeds, the reactor and its contents were heated to 140°C. Both the polyol and the monomer-catalyst mixture (e.g., 80 parts acrylonitrile 20 parts styrene and 1.74 parts azobisisobutyronitrile) feeds were started simultaneously and feed rates adjusted to give the desired ratio to yield a polymer/polyol composition having about 79% polyol and 21% polymer. The temperature was adjusted to 120°C. After about 0.5 hour of operation, the polyol feed was switched from Polyol I to the desired polyol via parallel feed systems. After making final feed rate adjustments, feeds were continued for 50 minutes before collection of product was begun. The product was stripped at

130°C and one mm Hg absolute pressure to yield the desired composition. The reaction was begun using Polyol I, rather than the desired polyol, since experience with other polyols has shown that this procedure sometimes minimizes the formation of large granules during start-up.

5 C. Polyurethane Foam Preparation 5

Molded Foam — Laboratory Scale

Prepare mold by waxing with "Perma-Mold Release Agent 804—07 SH" and heat to 170 to 200°F in oven. Wipe off excess mold release agent and allow mold to cool to 120°F. Weigh isocyanate into a beaker and measure water and amine catalysts into another beaker. Weigh polyol and tin catalyst and silicone surfactant into a 0.5 gallon carton and place on drill press. With timer set for total of 90 seconds, mix polyol 30 seconds with a 2.5 inch 6-blade turbine at 400 RPM. Stop mixer, remove carton and add water/amine mixture and baffles to carton. Mix 55 seconds and stop mixer. Add isocyanate and continue mixing for 5 seconds. Mixer will stop (end of 90 sec. preset time) and small timer starts. Allow to drain from mixer a few seconds, remove carton and shake several times into a mold (mold dimensions = 15 in. x 15 in. x 4.75 in.). Mold is at 120°F. Place baffles in can for washing and close mold lid. After 2 minutes, place mold in 250°F oven for 6 minutes. (Total 8 min.) Demold foam and crush foam by hand before running through roller 3 times. Trim foam and weigh. Record exit time, foam weight, tightness, green strength, moldability, etc. and place foam immediately in test laboratory at 50% Reflective Humidity to cure before testing.

Free Rise Foam — Laboratory Scale

The same mixing sequence is used as was used for laboratory-scale molded foams described above. The formulation is poured into an open box (dimensions — 14 in. x 14 in. x 6 in.) and allowed to cure without application of heat from an external source.

Molded Foam — Large Scale

An "Admiral" (Registered Trade Mark) machine (capacity 40 pounds per minute total throughput) is used and is operated in a conventional manner. The machine has a mixing head, metering and dispensing equipment and heat exchangers. The following operating conditions are employed:

	Mixing Head	Low Pressure—High Shear	
	Mixing Speed, rpm	4800	
35	Throughput, lbs./min.	20	35
	Temperature of Starting Materials, °F	75	
	Mold Type	Cast Aluminum	
	Mold Dimensions	15 x 15 x 4½ inches	
40	Venting	Four holes (3/16 in. diameter each) at corners of top of mold)	40
	Mold Temperature, °F	Varied	
	Release Agent	"Perma-Mold Release Agent 804—07SH"	
	Demold Time, min.	8	
45	Crush	Upon Demold	45
	Post-Cure	None	

STARTING MATERIALS

In the Examples appearing below, the following designations are used to denote the indicated starting materials:

A. *Polyols*

5 "Polyol I" denotes a commercially available polyol produced by reacting glycerine and propylene oxide and then capping with ethylene oxide. This polyol contains 85% propylene oxide and 15% ethylene oxide and has an average of 2.6 hydroxyl groups per molecule, a primary OH content of about 73 mole-% and a hydroxyl number of 34.

10 "Polyol II" denotes a commercially available polyol produced by reacting glycerine and propylene oxide and then capping with ethylene oxide. This polyol contains 90% propylene oxide and 10% ethylene oxide and has an average of 2.7 hydroxyl groups per molecule, a primary OH content of about 47 mole-% and a hydroxyl number of 45.

15 "Polyol III" denotes a commercially available polyol produced by reacting glycerine and propylene oxide. This polyol contains an average of about 2.9 hydroxyl groups per molecule and has about 3 mole-% primary hydroxyl group per molecule and a hydroxyl number of 56.

20 "Polyol IV" denotes a commercially available polyol produced by reacting glycerine and propylene oxide and then capping with ethylene oxide. This polyol contains 85% propylene oxide and 15% ethylene oxide and has an average of 2.1 hydroxyl groups per molecule, a primary OH content of about 83 mole-% and a hydroxyl number of 27.

B. *Polymer/Polyol*

25 "Polymer/Polyol I" denotes a commercially available polymer/polyol composition produced by polymerizing a mixture of acrylonitrile and styrene in Polyol I in the presence of 2,2'-azo-bis-isobutyronitrile. The composition consists of about 79% polyol and about 21% polymer. The polymer consists of about 50% acrylonitrile and about 50% styrene.

C. *Catalysts*

30 "VAZO-64" or "VAZO" denotes 2,2'-azo-bis-isobutyronitrile.

"TMSN" is tetramethylsuccinonitrile (a decomposition product of VAZO).

"Amine Catalyst I" denotes a solution consisting of 70% bis(2-dimethyl-aminoethyl) ether and 30% dipropylene glycol.

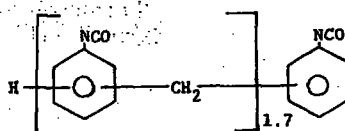
35 "Amine Catalyst II" denotes a solution consisting of 33% triethylene diamine and 67% dipropylene glycol.

"Amine Catalyst III" denotes a catalyst solution consisting of 33% 3-dimethyl-amino-N,N-dimethylpropionamide and 67% $C_9H_{19}C_6H_4(OC_2H_5)_2OH$.

D. *Isocyanates*

40 "TDI" denotes a mixture of 80% 2,4-tolylene diisocyanate and 20% 2,6-tolylene diisocyanate.

"AFPI" denotes a polymethylene poly(phenyleneisocyanate having the average formula:



45 "Isocyanate I" denotes a mixture of 80% TDI and 20% AFPI.

45

E. *Silicone Surfactants*

"Silicone I" denotes a solution of a siloxane block copolymer disclosed in United States Patent Specification No. 3,741,917 sold as "Union Carbide L-5303 Silicone Surfactant".

"Silicone II" denotes a silicone oil having the average formula $\text{Me}_3\text{SiO}(\text{Me}_2\text{SiO})_n\text{SiMe}_3$, where Me is methyl and where the oil has a viscosity of 5 centistokes at 25°C.

"Silicone III" denotes a solution of a siloxane block copolymer disclosed in United States Patent Specification No. 3,741,917 sold as "Union Carbide Y-6608 Silicone Surfactant".

"Silicone IV" denotes a solution of a siloxane block copolymer disclosed in United States Patent Specification No. 3,741,917 sold as "Union Carbide Y-6531 Silicone Surfactant".

F. *Monomers*

"VGN" denotes acrylonitrile.

"STY" denotes styrene.

POLYOL PROPERTIES

A. *Average Number of Hydroxyl Groups Per Polyol Molecule (Functionality)*

(1) *Purpose and Limitations.* The following procedure was developed to determine the average functionality of polyols used in the manufacture of flexible and rigid polyurethane foams. Samples, reagents and all equipment must be thoroughly dried in order to obtain meaningful results. Foreign substances which contain reactive hydrogen groups will interfere.

(2) *Principle.* A series of formulations are prepared whereby predetermined and varying equivalent ratios of the polyol and a diisocyanate (TDI) are reacted so as to cause gelation to occur in some cases, but not in others. The critical-gel ratio, a function of the average functionality of the polyol system, is determined by interpolation between the gel and no-gel sample formulations.

(3) *Apparatus*

- Several 40-milliliter glass vials equipped with plastic screw caps and polyethylene liners. The vials are dried in a circulating oven maintained at 110°C for 24 hours and stored in a desiccator.
- A 100-microliter "Hamilton" syringe calibrated to 1.0 microliter.

(4) *Reagents*

- Dimethylformamide.* Redistilled, or dried with "Linde (Registered Trade Mark) Molecular Sieves Type 4A" or "5A", until the water content is less than 0.01 per cent. Store in capped bottle over "Molecular Sieve Type 4A".
- Tolylenediisocyanate (TDI).* Minimum purity, 99.5 per cent by weight.
- Dry Toluene.* Nitration grade toluene or equivalent dried over "Linde 4A Molecular Sieve" to 0.005 per cent water or less.
- Catalyst Solution.* Dissolve 20 grams of triethylenediamine in 200 ml of dry toluene. Distill off (azeotrope) approximately 150 ml of toluene using a simple side-arm distillation apparatus. Place the remaining solution into a 200-ml volumetric flask and dilute to the mark with dry toluene. This solution should contain less than 0.01 per cent water.

(5) *Procedure*

- Dry approximately 200 grams of the polyol to be analyzed by stripping on a "Rinco Flash Evaporator" at 110°C and <5 millimeters pressure for 2 hours. The water content should be reduced to less than 0.01 per cent.

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- (b) Weigh the prescribed amount of polyol as determined from the formulas shown below into each of 5 sample vials. For polyols with equivalent weights of 1,000 or greater, a two-place pan balance will suffice. For polyols with equivalent weights appreciably less than 1,000 use a 4-place analytical balance.

$$G_p = \frac{5E_p}{R(87.08 + E_p)}$$

where G_p = grams of polyol
 R = estimated critical gel ratio, e.g. 0.67 for basic triols, 0.50 tetrols, etc.
 E_p = equivalent weight of polyol =

10

$$\frac{\text{hydroxyl number} \times 1,000}{56.1}$$

87.08 = equivalent weight of TDI.

15

- (c) Add 15 ml of dry dimethyl formamide (DMF) to each vial and swirl gently to affect the complete solution of the polyol.
(d) Using a four-place balance for weighing, add the amount of TDI prescribed by the formula below to one of the vials. This may be done volumetrically when high equivalent weight polyols (>1,000) are involved. The density of TDI is 1.2196 grams/milliliter at 20°C. To the other vials add incrementally and successively greater and lesser amounts of TDI. Usually ± 10 milligram increments will be satisfactory. Shake well to effect complete solution.

20

$$GT = 5 - G_p$$

Where G_T = grams of TDI
 G_p = grams of polyol

25

- (e) Add 0.5 milliliters of the catalyst solution of paragraph 4(d) to each vial.
(f) The samples are thoroughly mixed and stored in the dark at room temperature for at least 24 hours. After observing the gel/no-gel condition of the formulations, it may become necessary to formulate additional samples in order to obtain an accurate critical gel ratio. The critical gel ratio is determined by interpolation between the gel/no-gel sample formulations.

30

(6) Calculations

At the critical gel ratio:

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$$F_{ave} = \frac{\frac{G_T}{E_T}}{\frac{G_p}{E_p}}$$

where G_T = grams of TDI
 E_T = equivalent weight of TDI, (87.08)
 G_p = grams of polyol
 E_p = equivalent weight of polyol

40

B. Hydroxyl Number

The hydroxyl number of a polyol is the number of milligrams of potassium hydroxide required for the complete hydrolysis of the fully acylated derivative

40

prepared from one gram of polyol. The hydroxyl number can also be defined by the equation:

$$\text{OH No.} = \frac{56.1 \times 1000 \times f}{\text{m.w.}}$$

where: OH is the hydroxyl number of the polyol

5 f is the functionality, that is, average number of hydroxyl groups per molecule of polyol 5

m.w. is the molecular weight of the polyol

C. Oxyethylene Content

Measured by Nuclear Magnetic Resonance ("NMR")

10 D. Primary Hydroxyl Content 10

Measured by infra red determination of rate of reaction of polyol with phenyl isocyanate.

POLYURETHANE FOAM TESTS

A. Stress Relaxation

15 The phenomenon of "static fatigue" in a polyurethane foam is related to the stress relaxation properties of the foam. In the Examples appearing below, a measure of the stress relaxation properties of molded, high resiliency foams at ambient temperature is obtained by determining the time dependent rate of load decrease necessary to maintain a 50% indentation load deflection for a one-hour period. A typical plot of the stress or load relaxation of such a foam as a function of time is shown in Figure I. It is seen that the decrease in load is not a linear function of time, but it appears to be more of an exponential nature. Using the load observed 30 seconds after the 50% indentation deflection has been obtained as a basis for comparison, the fraction of load retained may be calculated for various times. Figure 2 shows that this quantity of retained load (ΔILD) exhibits a linear relationship with logarithmic time. The negative slope of this plot is taken as a measure of the rate of stress relaxation of the foam sample (this slope is reported as " $-\Delta\text{ILD}/\log \text{ time}$ "). The lower the degree of stress relaxation for a foam, the smaller in magnitude is the slope of this plot and the smaller the tendency for the foam to exhibit "static fatigue".

B. Humid Aging Test

The results of the humid aging testing of molded polyurethane foams described in the Examples appearing below were obtained in accordance with ASTM D 2406. The procedure is as follows:

- 35 (a) Age polyurethane foam specimens in steam autoclave for 5 hours at 120°C and 12 to 16 psig pressure. 35
- (b) Dry specimens 3 hours at 70°C in a mechanically convected dry-air-oven.
- (c) Equilibrate for 16 to 24 hours at 23°C and 50% Relative Humidity.
- 40 (d) Determine: 40
 - (i) Percentage compression set after 50% deflection for 22 hours at 70°C (reported as "50% Compression Set, %").
 - (ii) Percentage loss of compression load at 50% deflection (reported as "Load Loss, %").

45 The higher the "50% Compression Set, %" and "Load Loss, %" values as determined by this test, the less satisfactory is the foam with respect to humid aging. 45

The humid aging test results for free rise polyurethane foams were obtained similarly in accordance with ASTM D 1564-69.

C. Mold Exit Time

50 The "Mold Exit Time" is a measure of the reactivity of a polyurethane-forming formulation. In producing a molded polyurethane in accordance with the 50

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Examples appearing below, an isocyanate is mixed with other components of the formulation used to produce the polyurethane at time T_1 . The formulation is then introduced into the pre-heated mold and expands in the mold. The top of the mold has small vent holes. At time T_2 , the foam has expanded to the extent that it first begins to come out of the vent holes. The "Mold Exit Time" is the difference between T_2 and T_1 and is directly proportional to the reactivity of the formulation.

D. Porosity

A polyurethane foam specimen of 0.5 inch in thickness is compressed between two pieces of flanged plastic tubing having a 2.25 inch internal diameter. This assembly is then incorporated as a component in an air flow system. Air at a controlled velocity enters one end of the tubing, flows through the foam specimen and exits through a restriction at the lower end of the assembly. The pressure drop across the foam due to the restriction of air passage is measured by means of an inclined closed manometer. One end of the manometer is connected to the upstream side of the foam and the other end to the downstream side. The flow of air on the upstream side is adjusted to maintain a differential pressure across the specimen of 0.1 inch of water. The air porosity of the foam is reported in units of air flow per unit area of specimen (cubic feet per minute per square foot). The higher the air flow value, the more porous is the foam.

E. Other Test Procedures

In the Examples appearing below, the following properties were measured in accordance with ASTM D1564—69 (in the case of free rise foam) or in accordance with ASTM D2406 (in the case of molded foams):

Indentation Load Deflection ("ILD")

Compression Set

Tensile Strength

Elongation

Tear Resistance

Load Ratio (Sac Factor)

Resilience

Compression Load Deflections ("CLD")

% Return

POLYMER/POLYOL TESTS

A. Filterability

The particle size of the polymer in a polymer/polyol composition is measured by this test. The composition being tested is passed successively through a 150-mesh screen and a 700-mesh screen in the following manner. The screens are cleaned, dried and weighed before the test. A 470 gram sample of the composition being tested is diluted with 940 grams of isopropanol to reduce viscosity effects. The diluted sample is passed through a 2.4 square inch section of the 150 mesh screen and then through a 2.4 square inch section of the 700 mesh screen. Then the screens are washed with isopropanol to remove any polyol, dried and weighed. The difference between the final and initial screen weights corresponds to the amount of polymer that did not pass through the screens. This amount is reported as parts of polymer per million parts of the original (undiluted) sample of the composition. The 150-mesh screen has a square mesh with average mesh opening of 105 microns and it is a "Standard Tyler" 150 square mesh screen. The 700-mesh screen is made with a Dutch twill weave having average mesh openings of 30 microns and is described in Bulletin 46267—R of the Ronningen-Petter Company of Kalamazoo, Michigan.

B. Centrifugable Solids

The stability of a polymer/polyol composition is measured by this test. The composition is centrifuged for about 24 hours at about 3000 revolutions per minute and 1470 radial centrifugal "g" force. Then the centrifuge tube is inverted and allowed to drain for four hours. The non-flowing cake remaining at the bottom of the tube is reported as a percent of the initial weight of the composition tested. The larger this percent is, the less stable is the composition.

C. Hydroxyl Number

(i) *Measured*: This is the value obtained experimentally as disclosed above under Polyol Properties.

(ii) *Calculated*: This is the value obtained from the equation:

$$\text{OH No} = (\text{OH No})_p \times [1 - (\text{WF})_p]$$

where: OH No is the hydroxyl number of the polymer/polyol.

$(\text{OH No})_p$ is the hydroxyl number of the polyol used to make the polymer/polyol (measured value).

$(\text{WF})_p$ is the weight fraction of the polymer in the polymer/polyol.

D. Light Transmission

The polymer/polyol composition is diluted with Polyol III to form a solution containing 0.01% polymer. The % light (wavelength 500 millimicrons) transmitted by this solution is measured.

E. Polymer Contents by Calculation

Polymer content calculations were based on reactor feed rates and residual monomer contents.

Examples 1 to 8.

Examples 1 to 8 illustrate the effects of functionality (i.e., average number of hydroxyl groups per molecule) and functionality distribution of polyols having hydroxyl numbers of 28 and 45. Functionality distribution was varied depending on whether or not the reaction mixture was stripped to remove water after each addition of KOH. The stripped reaction mixtures (Examples 1 to 4) produced polyols that were relatively free of diol and so had relatively "narrow" distribution of functionality. Those Examples in which the reaction mixtures were not stripped to remove water (Examples 5 to 8) contained significant amounts of diol (due to the reaction of the water with propylene oxide) and so the final polyol products had "broad" distribution of functionality. The starters were chosen so that the final polyol products would have functionalities of about 3 to 4 and hydroxyl numbers of about 28 to 45. The polyols contained 7 percent oxyethylene groups. The experimental details relating to the preparation of the polyols of Examples 1 to 8 and their intermediates are tabulated in Tables I and II. The properties of the polyols are tabulated in Table III.

Portions of the polyols of Examples 1 to 8 were converted to polymer/polyols containing 79% polyol and 21% polymer having about 80% acrylonitrile and 20% styrene. The experimental details relating to the preparation of these polymer/polyols are tabulated in Table IV. The properties of the polymer/polyols are tabulated in Table V.

The properties of the polyols and polymer/polyols of Examples 1 to 8 are summarized in Table VI.

Molded, high resiliency flexible foams were prepared with each respective pair of polymer/polyols and polyols using the laboratory-scale procedure described above. The molding conditions for these foams were as described above. Catalyst levels were chosen to produce formulations having reactivities characteristic of typical formulations used to make prior art commercial high resiliency foam. The physical properties of the foams prepared with these polyol-polymer/polyol combinations are given in Table VII and are compared with high resiliency foams based on prior art commercial Polyol I-Polymer/Polyol I combination and Polyol IV-Polymer/Polyol I combination. The amount of water in the formulation and the amount of formulations in the mold were designed to give a nominal overall foam density of 3.0 pcf.

The general effects of the polyol molecular structure variations, i.e., hydroxyl number (equivalent weight), average functionality and functionality distribution, on the physical properties of molded high resiliency foams may be summarized as follows:

- | | | |
|----|--|----|
| 5 | (a) Resiliency properties (as measured by percent ball rebound) are excellent and comparable to foams prepared with the current commercial polyol-polymer/polyol combination (Polyol I and Polymer/Polyol I). | 5 |
| 10 | (b) Indentation load deflection values tend to increase independently with polyol hydroxyl number and average functionality. High resiliency foams prepared with polyols of 29 hydroxyl number and an average functionality of about 3.5 exhibit load bearing properties comparable to the control foam based on the prior art Polyol I-Polymer/Polyol I combination. The 25% return values and load ratios are similar and comparable to the control foam based on the prior art Polyol I-Polymer/Polyol I combination. | 10 |
| 15 | (c) Tensile strength, elongation and tear resistance properties tend to decrease as the hydroxyl number and average functionality of the polyol increases. These properties generally appear to be improved for polyols with the narrow distribution of molecular functionality to some extent. | 15 |
| 20 | (d) Compression set values improve as the hydroxyl number and average functionality of the polyol increases. | 20 |
| 25 | (e) Humid aged compression set values improve as the average functionality of the polyol increases. Humid aged load loss properties tend to improve as the average functionality of the polyol increases and exhibit a substantial improvement as the polyol hydroxyl number decreases. This occurs without an adverse effect on the humid aged compression set properties. | 25 |

30	The rates of stress relaxation for the high resiliency foams prepared with the polyols and polymer/polyols of Examples 1 to 8 are also listed in Table VII. The foams based on polyols of 28 hydroxyl number (Examples 1, 2, 5 and 6) exhibit slightly improved stress relaxation properties as compared to the control foam based on prior art Polyol I and Polymer/Polyol I. Graphical representation of these rates of stress relaxation is shown in Figure 3 where a comparison is also made with a molded foam prepared with a conventional, "hot-cure" formulation. Considerable improvement is also noted for the foams from the polyols and polymer/polyols of Examples 1 to 8 when they are compared to the foam based on prior art Polyol IV and Polymer/Polyol I.	30
35		35

40	In Examples 1 to 8, the polyols having a hydroxyl number of about 28 and an average functionality of about 4 (i.e., the polyol of Example 2 with the narrow functionality distribution and the polyol of Example 6 with the broad functionality distribution) appear to provide high resiliency foams with the best combination of humid aging and stress relaxation properties. Hence, these polyols were foamed on the low pressure/high shear Admiral machine according to the conditions described above. Molded foams so prepared with these polyols exhibited good reactivity, excellent green strength and appeared to have a more open cellular structure at demold. These foams could be demolded five minutes after pour with no apparent green strength deficiencies. The physical properties obtained for these machine-prepared foams are summarized in Table VII A and exhibit similar trends as observed for the bench-molded foams of Table VII.	40
45		45

TABLE I
Preparation of Polyol Intermediates

Example No.	1	2	3	4
Step 1	(7)			
Erythritol, grams	1000			
Sorbitol, grams		720		
Glycerine, grams		180	1032	
Propylene glycol, grams				
Potassium hydroxide, flake, grams	4	10	10	
Temperature, °C	150	150-160	140-150	
Stirring time, hours	1	1	1	
Pressure, mm Hg	<5	<5	<5	
Step 2	(8)			
Polyol from Step 1, grams	989	899(2)	1032(3)	
Propylene oxide feed, grams	3028	3300	4455	
Temperature, °C	132-150	110	110	
Pressure, psig maximum	75	60	60	
Feed time, hours	4.25	6.5	3.5	
Cookout time, hours	2	4	4	
Step 3				
Potassium hydroxide, grams				
Polyol from Step 2, grams				
Propylene oxide feed, grams				
Temperature, °C				
Pressure, psig, maximum				
Feed time, hours				
Cookout time, hours				
Potassium hydroxide, grams				
Temperature, °C				
Pressure, mm Hg				
Time, hours				

TABLE I (Continued)

Example No.	5	6	7	8
Step 1				
Erythritol, grams				700
Sorbitol, grams		815		
Glycerine, grams	765			
Propylene glycol, grams	85			200
Potassium hydroxide, flake, grams	15	20		1.7
Temperature, °C	140	140		140
Stirring time, hours	1	0.25		0.5
Pressure, mm Hg	760	760		760
Step 2				
Polyol from Step 1	847(2)	806(2)		890
Propylene oxide feed, grams	3300	3222		2567
Temperature, °C	122	115		155
Pressure, psig maximum	60	60		80
Feed time, hours	5	5.5		8
Cookout time, hours	2	2		2
Step 3				
Potassium hydroxide, grams				100
Polyol from Step 2		20	62	2455
Propylene oxide feed, grams		1659	1304(6)	5874
Temperature, °C		6625	7013	110
Pressure, psig, maximum		110	110	30
Feed time, hours		60	60	7.5
Cookout time, hours		6	4.5	4
		4.5	6.5	
Potassium hydroxide, grams				
Temperature, °C	80	67		
Pressure, mm Hg	140	140		
Time, hours	760	760		
	1	1.5		

(22)
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Footnotes to Table I

- (1) "A" and "B" throughout this table denote two separate runs conducted in a given Example due to volume limitations of the reactor.
- (2) Reactor was one-gallon stirred autoclave.
- (3) Reactor was two-gallon stirred autoclave.
- (4) Stripped under vacuum in same manner as in Step 1 after mixed with KOH.
- (5) Product of Step 3 of run A of Example 4 (1810 grams) mixed with 12 grams of KOH and reacted with 2838 grams of propylene oxide at 110°C and 60 psig max. Feed time 3.5 hours and cookout time 4 hours. Polyol used as indicated in Table II.
- (6) A mixture of 626 grams of a polyol produced as described in Step 2 of Example I and 626 grams of a polyol produced by reacting 3 moles of propylene oxide with one mole of glycerine in the presence of 0.1% KOH (unstripped).
- (7) Same as in Step 1 of Example 1.
- (8) Same as in Step 2 of Example 1.

29

TABLE II
Preparation of Polyols

Example	1	2	3	4	5	6	7	8
Step 4								
Polyol from Step 3	18.8	17.75	20.15	13.99(a)	17.83	18.0	18.0	18.0
Temperature during propylene oxide feed, °C	108-112	96-110	102-110	100-110	105-110	108-110	108-112	107-114
Propylene oxide fed, lbs.	21.5	33.1	65.0	22	55	45.0	20.0	53.0
Duration of feed period, hrs.	3.0	7.0	7.0	5.0	10.0	8.0	4.25	7.0
Peak pressure, psig	52	58	52	59	60	57	60	60
Cook-out period, hrs.	6.0	10.0	10.5	4.0	8.5	5.0	5.0	5.0
Final pressure, psig	0	12	0	0	24	3	8	2
Hydroxyl number	36.35	35.12	51.39	5.166	--	--	52.82	--
Stripping temperature, °C	10.5	9.8	7.4	2.4	--	--	3.8	--
Stripping pressure, mm Hg	120	120	110-120	119-122	116-120	117-120	120	120
Stripping period, hrs.	6	6	7	12-14	7	6-7	6-5	12-7
Hydroxyl number	3	3	4	4	3	3	3	5
Alkalinity, meq/gm	31.47	31.13	48.59	47.36(b)	28.86	31.77	47.18	46.86
	0.231	0.249	0.245	0.245	0.239	0.237(c)	0.274	0.252
Step 5								
Ethylene oxide fed, lbs.	3.9	3.85	6.2	3.4	5.5	4.2	3.1	5.3
Capping temperature, °C	110-114	112-130	110-115	106-110	110-112	110-120	110	111-120
Feed and cook-out periods, hrs.	2	0.5	4	2.5	3.5	4.0	2.75	2.5
Stripping temperature, °C	110	130-108	110	110	110	110	110	110
Stripping pressure, mm Hg	16-11	6	22-13	12	10	7	7	7
Stripping period, hrs.	1	1	1.5	1	1	1	1	1
Crude product recovered, lbs.	50.5	59	77	48	72	53	42	70
Magnesium silicate added, lbs.	1.01	1.18	1.54	0.96	1.44	1.33	0.84	1.4
Agitation period, hrs.	17	12	9.5	14.5	11	10	8	8
Autoclave temperature, °C	81-98	100	94-96	98-100	100	100	95-100	90-99
Ionol added, lbs.	0.01	0.0118	0.015	0.0096	0.014	0.013	0.008	0.014
Filtered product recovered, lbs.	45.2	48.0	67.0	45.0	66	58.0	41.4	53
Filtration period, hrs.	10.5	16.0	19.5	4.0	12.0	9.0	3.0	17
Final stripping period, hrs.	3	3.5	4	3	8	3	3	3
Autoclave temperature, °C	101-108	100	99-105	98-100	100	98-100	100-102	99-108
Autoclave pressure, mm Hg	18-14	15-13	16-20	16-5	13	6-7	7	10-8
Final product recovered, lbs.	39.54	43.33	54.7	41.4	63.0	51.9	38.2	48.8

(a) Polyol of run 4B of Table I

(b) Added 1.5 gallons of polyol of run 4A of Table I.

(c) Added potassium metal to increase alkalinity from 0.209 to 0.237 meq/gm

30

TABLE III
Properties of Polyols

Examples	1	2	3	4	5	6	7	8
Analyses of final product								
Hydroxyl number	28.87	29.15	45.95	44.89	27.84	29.14	44.15	43.62
Acid number	0.01	0.014	0.021	0.018	0.017	0.013	0.008	0.013
Water, %	0.013	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Total alkalinity, meq/gm	0.00009	0.00014	0.000095	0.00015	0.00014	0.00012	0.00012	0.000094
Viscosity, cks at 25°C	1294	1471	619	763	1464	1441	645	792
Primary hydroxyl, mole - %	70	63	58	51	75	63	60	47
Average functionality	3.45	3.86	2.99	3.78	3.68	4.07	2.99	4.18
Oxyethylene, %	8.09	5.65	5.74	7.25	7.29	6.31	5.63	6.72
Unsaturation, meq/gm	0.076	0.074	0.040	0.040	0.084	0.077	0.041	0.041

31

22

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22

TABLE IV
Preparation of polymer/polyols

Polyol of Example	1	2	3
Polyol Properties (analytical)			
Average Functionality	3.45	3.86	2.99
Primary Hydroxyl, mole — %	70	63	58
Oxyethylene, %	8.09	5.65	5.74
Reaction Conditions			
Reaction Temperature, °C	120	120	120
Residence Time, min.	12	12	12
VAZO Conc., wt. % in total feed	0.41	0.41	0.41
Monomer + VAZO Content in Feed %	23.4	23.2	23.1
Ratio of Acrylonitrile to Styrene in Feed, by wt.	80/20	80/20	80/20
Polyol Feed Rate, gm/hr	2105	2130	2131
Monomer + VAZO Feed Rate, gm/hr	641	644	642
Product Weight, gm/hr	2740	2764	2766
total, gm	7803	9286	11,20
Material Balance, %	99.8	99.7	99.7
Residual Acrylonitrile, %	1.94	1.81	2.13
Styrene, %	0.28	0.29	0.32
TMSN, %	0.15	0.18	0.16
Conversions, Acrylonitrile, %	89.5	90.1	88.3
Styrene, %	93.9	93.7	93.0
Combined, %	90.3	90.8	89.3

TABLE IV (Continued)

Polyol of Example	5	6	7	8
<u>Polyol Properties (analytical)</u>				
Average Functionality	3.68	4.07	2.99	4.18
Primary Hydroxyl, mole -- %	75	63	60	47
Oxyethylene, %	7.29	6.31	5.63	6.72
<u>Reaction Conditions</u>				
Reaction Temperature, °C	120	120	120	120
Residence Time, min.	12	12	12	12
VAZO Conc., wt. % in total feed	0.41	0.41	0.41	0.40
Monomer + VAZO Content in Feed, %	23.3	23.5	23.4	23.1
Ratio of Acrylonitrile to Styrene in Feed, by wt.	80/20	80/20	80/20	80/20
Polyol Feed Rate, gm/hr	2106	2102	2126	2144
Monomer + VAZO Feed Rate, gm/hr	641	646	648	643
Product Weight, gm/hr	2767	2741	2762	2782
total, gm	15,085	10,401	7955	9736
Material Balance, %	100.7	99.7	99.6	99.8
Residual Acrylonitrile, wt. %	1.77	1.74	2.13	2.11
Styrene, wt. %	0.25	0.26	0.31	0.32
TMSN, wt. %	0.16	0.10	0.12	0.10
Conversions, Acrylonitrile, %	90.3	90.6	88.5	88.4
Styrene, %	94.5	94.4	93.3	93.0
Combined, %	91.1	91.4	89.4	89.3

TABLE V

Properties of Polymer/Polyols

Polymer/Polyol From Polyol of Example	1	2	3	4
Total Poly A by Calc., %	16.80	16.80	16.47	16.48
Total Poly S by Calc., %	4.41	4.37	4.34	4.40
Total Polymer by Calc., %	21.25	21.17	20.81	20.88
Viscosity at 25°C, Hoeppler, cps	3239	3498	1453	1749
Hydroxyl No. :				
Calculated	22.75	22.98	36.39	35.52
Measured	22.75	23.18	35.21	34.80
Water, %	0.01	0.02	0.01	0.01
Filterability,				
150 Mesh Screen, % Through	100	100	100	100
Solids on Screen, ppm	7	4	7	3
700 Mesh Screen,				
Time, Sec.	278	280	278	201
% Through	100	100	100	100
Solids on screen, ppm	18	9	18	10
Centrifugible Solids	1.68	1.87	2.50	1.78

TABLE V (Continued)

Polymer/Polyol From Polyol of Example	5	6	7	8
Total Poly A by Calc., %	16.91	17.09	16.66	16.44
Total Poly S by Calc., %	4.43	4.46	4.39	4.33
Total Polymer by Calc., %	21.34	21.55	21.05	20.73
Viscosity at 25°C, Hoeppler, cps	3691	3676	1497	1800
Hydroxyl No.:				
Calculated	21.90	21.86	34.86	34.60
Measured	21.75	22.66	35.06	34.70
Water, %	0.01	0.01	0.01	0.01
Filterability,				
150 Mesh Screen, %				
Through	100	100	100	100
Solids on Screen, ppm	7	5	7	4
700 Mesh Screen,				
Time, Sec,	200	274	195	199
% Through	100	100	100	100
Solids on screen, ppm	12	17	8	7
Centrifugible Solids	1.80	0.75	1.10	1.46

(34)

TABLE VI

A SUMMARY OF PROPERTIES OF POLYOLS AND POLYMER/POLYOLS

Example	1	2	3	4
Polyols Target Properties (1)				
Hydroxyl No.	28	28	45	45
Equivalent Weight	2000	2000	1250	1250
Average Functionality	3	4	3	4
Functionality Distribution	Narrow	Narrow	Narrow	Narrow
Capping	7% Ethylene Oxide			
				→ (2)
Analytical Properties (3)				
Polyols				
Hydroxyl No.	28.9	29.15	45.95	44.9
Functionality	3.45	3.86	2.99	3.78
Primary Hydroxyls, mole-%	70	63	58	51
Viscosity, centistokes at 25°C	1294	1471	619	763
Polymer Polyols				
Hydroxyl No.	22.75	23.2	35.2	34.8
Viscosity, centipoises at 25°C (Hoepler)	3239	3498	1453	1749

TABLE VI (Continued)

Example	5	6	7	8
Polyols Target Properties				
Hydroxyl No.	28	28	45	45
Equivalent Weight	2000	2000	1250	1250
Average Functionality	3	4	3	4
Functionality Distribution	Broad	Broad	Broad	Broad
Capping	7% Ethylene Oxide			
				→
Analytical Properties				
Polyols				
Hydroxyl No.	27.8	29.1	44.15	43.6
Functionality	3.68	4.07	2.99	4.18
Primary Hydroxyls, mole-%	75	63	60	47
Viscosity, centistokes at 25°C	1464	1441	645	792
Polymer/Polyols				
Hydroxyl No.	21.75	22.7	35.1	34.7
Viscosity, centipoises at 25°C (Hoepler)	3691	3676	1497	1800

Footnotes to Table VI

(1) The amounts of starting materials employed in producing the polyols of Examples 1 to 8 were selected to result in polyols having these ("target") properties.

(2) This arrow and the arrows in the other Tables indicate that the amounts of materials and/or reaction conditions shown for the first Example or experiment were also employed in the Examples or experiments through which the arrow was drawn.

(3) These are the properties of the polyols produced in the Examples as determined by analysis.

TABLE VII
FORMULATIONS AND PHYSICAL PROPERTIES OF POLYURETHANE FOAMS
(Laboratory Scale Preparations)

Example			1	2	3
Polyol Properties(Analytical)					
Hydroxyl No.			28.9	29.15	45.95
Average Functionality			3.45	3.86	2.99
Functionality Distribution			Narrow	Narrow	Narrow
Formulation, pbw(1)					
Polyol I	60				
Polyol IV		60			
Polymer/Polyol I	40	40			
Polyol of Example			60	60	60
Polymer/Polyol of Example			40	40	40
Amine Catalyst I	0.10	0.10	0.10	0.10	0.15
Amine Catalyst II	0.36	0.36	0.36	0.30	0.36
Amine Catalyst III	0.30	0.30	0.30	0.30	0.30
Dibutyltindilaurate	0.015	0.03	0.03	0.03	0.03
Silicone I	1.7	1.7	1.7	1.7	1.7
Physical Properties					
Mold Exit Time, sec.	60	55	63	64	45
Density, Overall, pcf	3.00	2.93	2.95	2.99	3.00
Core, pcf	2.66	2.60	2.62	2.78	2.73
Porosity, ft ³ /min/ft ²	14.9	28.5	14.4	17.2	11.7
Resiliency, % ball rebound	63	64	65	64	59
ILD (lbs/50 in ³)					
25%	40.0	36.0	41.6	42.6	43.2
65%	105.0	95.4	106.7	111.0	113.5
25% Return, %	82.2	79.7	83.6	82.1	83.4
Load Ratio	2.63	2.65	2.57	2.60	2.63
Tensile Strength, psi	23.2	26.0	20.5	18.3	20.2
Elongation, %	154	197	143	122	124
Tear Resistance, pli	2.20	2.65	1.41	1.28	1.68
75% Compression Set, %	8.0	10.9	8.0	7.6	7.9
Humid Aging (5 hrs at 120°C)					
50% Compression Set, %	17.2	21.8	16.0	13.1	19.3
Load Loss, %	28.9	13.6	8.7	6.6	25.7
Rate of Stress Relaxation,					
- Δ ILD/log time	0.072	0.085	0.066	0.065	0.072

TABLE VII (Continued)

Example	4	5	6	7	8
Polyol Properties (Analytical)					
Hydroxyl No.	44.9	27.8	29.1	44.15	43.6
Average Functionality	3.78	3.68	4.07	2.99	4.18
Functionality Distribution	Narrow	Broad	Broad	Broad	Broad
Formulation, pbw(1)					
Polyol I					
Polyol IV					
Polymer/Polyol I					
Polyol of Example	60	60	60	60	60
Polymer/Polyol of Example	40	40	40	40	40
Amine Catalyst I	0.10	0.10	0.10	0.20	0.10
Amine Catalyst II	0.36	0.36	0.30	0.36	0.36
Amine Catalyst III	0.30	0.30	0.30	0.30	0.30
Dibutyltin dilaurate	0.015	0.03	0.03	0.03	0.015
Silicone I	1.5	1.7	1.7	2.0	1.5
Physical Properties					
Mold Exit Time, sec.	53	67	61	37	52
Density, Overall, pcf	3.02	2.91	2.95	3.02	3.06
Core, pcf	2.73	2.71	2.66	2.76	2.74
Porosity, ft ³ /min/ft ²	23.0	33.9	12.4	14.5	22.0
Resiliency, % ball rebound	62	67	63	60	63
ILD (lbs/50 in ²)					
25%	47.9	37.9	41.7	45.5	41.0
65%	125.8	100.0	108.5	117.0	130.5
25% Return, %	83.7	83.9	83.2	83.2	84.0
Load Ratio	2.62	2.64	2.60	2.57	2.56
Tensile Strength, psi	18.1	18.9	18.6	20.4	16.1
Elongation, %	98	130	124	121	87
Tear Resistance, pli	0.98	1.42	1.00	1.25	0.87
75% Compression Set, %	6.7	9.6	9.3	7.2	6.5
Humid Aging (5 hrs at 120°C)					
50% Compression Set, %	13.1	17.1	16.1	17.2	13.4
Load Loss, %	22.8	2.3	7.4	24.7	22.8
Rate of Stress Relaxation,					
- Δ ILD/log time	0.069	0.069	0.067	0.069	0.070

(1) All formulations contained 2.6 parts by weight water and contained Isocyanate I (105 Index).

37

TABLE VIIA
Formulation and Physical Properties of Polyurethane Foam
(Large Scale Preparations)

Polyol	I	Ex. 2	Ex. 6
Hydroxyl Number (analytical)	34	29.15	29.14
Functionality (analytical)	2.6	3.86	4.07
Functionality Distribution	Broad	Narrow	Broad
<u>Formulation, pbw</u>			
Polyol	60	} —————→	
Polymer Polyol	40		
Water	2.6		
Amine Catalyst I	0.10	0.10	0.10
Triethylene Diamine (Solid)	0.12	—	—
Amine Catalyst II	—	0.36	0.36
Amine Catalyst III	0.30	0.30	0.30
Dibutyltindilaurate	0.015	0.03	0.03
Silicone III	0.75	—	—
Silicone I	—	1.7	1.7
Isocyanate I	105	Index	—————→
<u>Physical Properties</u>			
Mold Exit Time, seconds	55	51	53
Density, overall, pcf	2.95	2.97	3.01
core, pcf	2.72	2.73	2.73
Porosity, ft ³ /min/ft ²	18.5	18.5	26.1
Resiliency, % ball rebound	63	66	67
ILD (lbs/50 in ²)			
25%	42.5	39.9	44.9
65%	111.8	105.0	118.5
25% Return	—	84.2	—
Load Ratio	2.63	2.63	2.64
Tensile Strength, psi	23.4	20.1	21.5
Elongation, percent	152	134	130
Tear Resistance, pli	1.55	1.17	1.15
75% Compression Set, %	8.3	8.0	8.3
<u>Humid Aging (5 Hours at 120°C)</u>			
50% Compression Set, %	18.0	12.3	13.1
Load Loss, %	29.0	8.4	11.3
<u>Rate of Stress Relaxation</u>			
-Δ ILD/log time	.069	.063	.064

Examples 9 to 20.

Since the sorbitol-started polyol of Example 6 (29 hydroxyl number and 4 average functionality) provided foams with an excellent combination of stress relaxation and humid aging properties, this starter was selected to investigate the effects of polyol equivalent weight (hydroxyl number) over a rather narrow range of hydroxyl numbers (i.e., 26 to 34) in Examples 9 to 20. Since no significant difference was observed between the polyols of narrow and broad distribution of average functionality in Examples 1 to 8, the polyols of Examples 9 to 20 were made with a broad distribution. Polyols with a broad functionality distribution do not require special stripping procedures or anhydrous potassium catalysis and so are readily produced by current production technology.

Hence, Examples 9, 10 and 11 were conducted to produce polyols having hydroxyl numbers from 26 to 34, using sorbitol as the starter, 7% ethylene oxide as the cap and broad distribution of functionality. Example 12 was similar to Example 10 but with 5% ethylene oxide. Steps 1 to 3 for the preparation of the polyols of Examples 9 to 12 are shown in Table VIII. Steps 4 and 5 are shown in Table IX. The properties of the polyols are shown in Table X.

The formulations and physical properties of molded, high resiliency foams prepared from the polyols of Examples 6 and 8 to 11 are given in Table XI. Utilizing the formulations presented, excellent foams were produced with the usual molding conditions given above. The foams tended to be less tight as the hydroxyl number of polyols was reduced. Since the average functionality of the polyols used in the formulations of Table XI varied, a strict comparison of foam physical properties based on polyol equivalent weight (hydroxyl number) differences should be made with reservations. However, it may be generally concluded that foam load-bearing properties increase in accord with lower polyol equivalent weights (higher polyol hydroxyl numbers). In addition, elongation and tear resistance properties tend to decrease with lower equivalent weights (higher hydroxyl numbers) of the polyols. Although humid aged compression set values appear to be unaffected by the polyol equivalent weight, the humid aged load loss values exhibit a trend of becoming progressively worse at lower polyol equivalent weights (higher hydroxyl numbers). The rates of foam stress relaxation appear to be better for polyols in the hydroxyl number range of 28 to 34. Hence, hydroxyl numbers of 30 and 34 were chosen for Examples 12 to 20.

Thus, series of polyols were made with ethylene oxide contents from 0 to 6 and with either hydroxyl numbers of about 30 (Examples 12 to 16) or hydroxyl numbers of about 34 (Examples 17 to 20) to determine the optimum ethylene oxide content. Steps 1 to 3 in the preparation of the polyols of Examples 13 to 20 are shown in Table XII; Steps 4 and 5 are shown in Table XIII. The properties of the polyols are shown in Table XIV.

Polymer/polyols were prepared from the polyols of Examples 9 to 20. These preparations are tabulated in Tables XV and XVI. The properties of the polymer/polyols are shown in Tables XVII and XVIII.

The properties of the polyols and polymer/polyols of Examples 13 to 16, having hydroxyl numbers of about 30 and varying ethylene oxide content, are shown in Table XIX. The number of primary hydroxyls in the polyols varied from 0 to 67 percent in accordance with the amount of ethylene oxide (0 to 7 percent by weight) used for capping. A typical molded, high resiliency foam formulation based on 2.6 pbw of water was used to evaluate these polyol/polymer combinations. As shown in Table XX, the amount of silicone surfactant was adjusted in an attempt to prepare suitable foams. For the polyol containing no ethylene oxide capping, stable foams could not be prepared. At the polyol capping level of 3 percent by weight ethylene oxide, stable foams were produced, but they contained significant surface voids. Excellent molded foams were produced at typical levels with the polyols containing 5 and 7 percent by weight ethylene oxide capping. The physical properties of these foams were comparable. The slight differences in tensile, elongation and tear resistance properties may be attributed to the differences in the average functionality of the base polyols, as given in Table XX. Based on these data, it may be concluded that for polyols of average functionality greater than four, at least 45 mole % primary hydroxyls (5 percent by weight ethylene oxide capping) are very desirable for the preparation of suitable molded, high resiliency foams with current formulations.

Similarly, the effect of varying the ethylene oxide capping at a hydroxyl number of 34 was studied in Examples 17 to 20. The foam formulation and foam properties are shown in Table XXI. The data in Table XXI lend support to the con-

39

clusions reached above in connection with Table XX and extends desirable range of primary hydroxyls to 35 mole percent.

The higher functionality polyols prepared with 5 and 7 percent ethylene oxide capping (i.e., those of Examples 9—12, 15, 16, 19 and 20) reduced the humidity sensitivity of the molded high resiliency foams made therefrom. Although the primary hydroxyl content of these polyols is lower than current commercial high resiliency foam polyols (prepared with 15 percent ethylene oxide) each of these polyols provided molded foams with good reactivity as evidenced by their excellent demold characteristics.

TABLE VIII
Preparation of Polyol Intermediates For Examples 9 to 12

	Step 1	Step 3
Autoclave charge, lbs.		
Sorbitol (70% aqueous) (a)	25.17	
Step 2 product		20
Stripping data		
Temperature, °C	125	
Pressure, mm Hg	18—20	
Time, hours	3	
Potassium hydroxide (Flake)	0.13 (b)	0.13 (c)
	Step 2	
Feed data		
Propylene oxide, lbs.	67.4	75
Temperature, °C	115	110
Pressure, psig max.	59	61
Feed Time, Hours	10	
Cookout time, hours	2	
Analysis of Crude Stripped Polyol		
Hydroxyl number	394	92.74
Alkalinity, % KOH	0.13	0.061
Viscosity, cks at 25°C	12,356	

(a) Equivalent to 17.67 lbs. of dry sorbitol.

(b) KOH added after 3 hours stripping period and dissolved for 1 hour at 125°C.

(c) KOH dissolved in starter for 1 hour at 125°C.

TABLE IX
Preparation of Polyols

Example	9	10	11	12
Step 4				
Autoclave charge, lbs.				
Starter from Step 3 of Table VIII	18.0	21.0	25.0	21.0
Potassium hydroxide (flake), lbs.	0.25	0.17	0.19	0.24
Agitation period to dissolve KOH, hrs.	2	2	2	2
Reactor temperature to dissolve KOH, °C (1)	128-131	130	130	124-130
Temperature during propylene oxide feed, °C	110	110	110	110
Propylene oxide feed, lbs.	63.0	54.0	54.0	58.0
Maximum pressure, psig	57	54	60	61
Feed period, hrs.	9.5	10	17	10.5
Cookout period, hrs.	7	4	9	7
Stripping period, hrs.	3	3	3	3
Stripping temperature, °C	110	110	110	110
Stripping pressure, mm/Hg	20-24	20	20	18-20
Hydroxyl number	28.09	32.2	35.04	31.48
Alkalinity, % KOH	0.25	0.24	0.22	0.22
Step 5				
Ethylene oxide added, cc's	3140	2990	3050	2130
Ethylene oxide, feed temperature, °C	110	110	110	110
Ethylene oxide feed period, hrs.	2.67	1.83	1.58	1.50
Maximum pressure, psig	44	51	46	42
Cookout period, hrs.	1.75	1.25	0.75	2.0
Stripping period, hrs.	1.0	1.0	1.0	1.0
Stripping temperature, °C	110	110	110	110
Stripping pressure, mm/Hg	20	20	20	18-19
Crude product recovered, lbs.	81.9	69.0	74.7	77.8
Magnesium silicate added, lbs.	1.62	1.37	1.46	1.56
Agitation period, hrs.	9	9.5	8	8
Reactor temperature, °C	86-90	84-94	80-95	93
Ionol added, lbs.	0.016	0.014	0.015	0.016
Filtration period, hrs.	25	15.5	16	19
Filtrate recovered, lbs.	75.2	64.2	68.3	72.1
Stripping period, hrs.	3	3	3	3
Stripping temperature, °C	99-102	96-108	100	100
Stripping pressure, mm/Hg	12-15	18-20	20-25	9-12
Refined product recovered, lbs.	72.7	57.8	56.2 (2)	69.2

(1) Sparged nitrogen up through unit to keep KOH suspended.

(2) No apparent reason for low yield.

TABLE X
Properties of Polyols

Polyol of Examples	9	10	11	12
Product analysis:				
Hydroxyl number	26.73	29.79	33.12	29.81
Acid number	0.005	0.004	0.003	0.004
Water, %	0.03	0.05	0.04	0.03
Total alkalinity, meq/gm	0.00005	0.00012	0.00007	0.00007
Viscosity, cks at 25°C	1737	1494	1331	1496
Primary hydroxyl, mole %	67	67	57	53
Average functionality	4.04	4.37	4.86	4.38
Oxyethylene, %	7	7	7	4.8
Unsaturation, meq/gm	0.096	0.071	0.053	0.075

TABLE XI
Preparation of Polyurethane Foams
(Variation of Polyol OH No.)

Polyol (OH No)	Control Polyol I	6	8	9	10	11
	(34)	(29.14)	(43.62)	(26.73)	(29.79)	(33.12)
<u>Formulation, pbw</u>						
Polyol	60	60	60	60	60	60
Polymer-Polyol*	40	40	40	40	40	40
Water	2.6					
Amine Catalyst I	0.10	0.10	0.10	0.10	0.10	0.10
Amine Catalyst II	0.36	0.30	0.36	0.30	0.30	0.30
Amine Catalyst III	0.30	0.30	0.30	0.30	0.30	0.30
Dibutyltindilaurate	0.015	0.03	0.015	0.03	0.03	0.03
Silicone I	1.7	1.7	1.7	1.7	1.7	1.7
Isocyanate I	105 Index					
<u>Physical Properties</u>						
Mold Exit Time, seconds	60	61	52	60	61	63
Density, overall, pcf	3.00	3.00	3.06	2.98	2.95	2.97
core, pcf	2.68	2.64	2.74	2.63	2.58	2.61
Porosity, ft ³ /min/ft ²	16.1	23.0	22.0	29.2	26.5	27.0
Resiliency, % ball rebound	62	66	63	66	64	69
ILD (lbs/50 in ²)						
25%	43.1	43.7	51.0	42.0	43.0	46.4
65%	114.0	118.0	130.5	105.0	108.0	114.0
25% Return, %	81.0	84.7	84.0	82.6	83.0	82.7
Load Ratio	2.65	2.70	2.56	2.50	2.51	2.46
Tensile Strength, psi	23.5	19.3	16.1	17.8	14.2	14.2
Elongation, percent	151	121	87	118	94	87
Tear Resistance, pli	1.82	1.12	0.87	1.36	0.99	0.83
75% Compression Set, %	7.8	7.5	6.6	8.9	8.0	7.5
<u>Humid Aging (5 hrs. at 120°C)</u>						
50% Compression Set, %	18.9	13.5	13.4	13.6	12.0	12.3
Load Loss, %	25.3	5.5	22.8	49.2	9.2	11.9
<u>Rate of Stress Relaxation</u>						
-ΔILD/log time	.072	.066	.070	.070	.064	.065

* made from polyol listed in same column; preparation summarized in Tables IV and XV

(42)

TABLE XII
Preparation of Polyol Intermediates
For Examples 13 to 20

	Step 1	Step 3	Step 3 (repeat)	Composite (e)
Autoclave charge, lbs.				
Sorbitol (70% aqueous) (a)	25.17	20	20	
Step 2				
Potassium hydroxide (flake)	0.13(b)	0.13 (c)	0.13 (c)	
Stripping data				
Temperature, °C	126			
Pressure, mm Hg	20			
Time, hours	3			
Feed data	Step 2			
Propylene oxide, lbs.	67.4	75	75	
Temperature, °C	110	112	112	
Pressure, psig max.	57	59	60	
Feed time, hours	13	16	15	
Cookout time, hours	3	5	7	
Analysis of crude stripped product				
Hydroxyl number	378	82.94	83.83	85.65
Alkalinity, % KOH	0.085	.302 (d)	0.276	0.262
Viscosity, cks at 25°C	8.731	1.002	945	942

(a) Equivalent to 17.67 lbs. of dry sorbitol.

(b) KOH added after 3 hours stripping period and dissolved for 1 hour at 126°C.

(c) KOH dissolved in starter for 1 hour at 125°C.

(d) High alkalinity assumed because of residual KOH left in reactor.

(e) Composite of the two Step 3 runs shown in this Table and another run made under essentially the same conditions.

(43)

34

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34

TABLE XIII
Preparation of Polyols

Example	13	14	15	16
Step 4				
Autoclave charge, lbs.				
Starter (Composite of Table XII)	24	24	24	24
Potassium hydroxide (flake)	0.11	0.18	0.18	0.18
Agitation period to dissolve KOH, hrs.	1	1	2	1
Reactor temperature to dissolve KOH, °C (1)	130	130	130	125
Propylene oxide feed temperature, °C	110	110	110	112
Propylene oxide, lbs.	615	59	58	55.5
Pressure, psig max.	58	59	46	60
Feed time, hours	14	9.5	8	11
Cookout time, hours	9	6	3	6.5
Stripping period, hours	—	3	3	3
Stripping temperature, °C		110	110	110
Stripping pressure, mm Hg		20	20	20
Hydroxyl number		30.93	38.73	31.51
Alkalinity, % KOH		0.26	0.24	0.275
Step 5				
Ethylene oxide feed, grams		1367	1925	2682
Ethylene oxide feed temperature, °C		110	110	110
Ethylene oxide feed time, hours		0.83	0.62	2.5
Pressures, psig max.		20	32	29
Cookout period, hours		1	1	1
Stripping period, hours	1	1	1	1
Stripping temperature, °C	110	110	110	110
Stripping pressure, mm Hg	20	15	20	20
Crude product recovered, lbs.	74	80	83	75.9
Magnesium Silicate, lbs.	1.58	1.57	1.64	1.50
Agitation period, hours	24	10	12	9
Refining temperature, °C	91	93	100	92
Ionol added, lbs.	0.016	0.016	0.016	0.015
Filtration period, hours	60	20	15	14
Filtrate recovered, lbs.	68.3	74.4	75.8	64.8
Stripping period hours	3	3	3	3
Stripping temperature, °C	99	100	100	95
Stripping pressure, mm Hg	7	5	5	3
Refined Product recovered, lbs.	64.8	70.7	72.2	56.8

TABLE XIII
(Continued)

Example	17	18	19	20
Step 4				
Autoclave charge, lbs.				
Starter (Composite of Table XI)				
Potassium hydroxide (flake)	30	30	30	30
Agitation period to dissolve KOH, hours	0.11	0.16	0.16	0.16
Reactor temperature to dissolve KOH, °C (1)	1	2	1	2
Propylene oxide feed temperature, °C	130	130	130	130
Propylene oxide, lbs.	110	110	110	110
Pressure, psig max.	54.5	54.5	56.0	56
Feed time, hours	60	36	62	51
Cookout time, hours	13	11	17.5	9.5
Stripping period, hours	6	2	5	5
Stripping temperature, °C		3	3	3
Stripping pressure, mm Hg		110	110	110
Hydroxyl number		7	20	20
Alkalinity, % KOH		34.22		35.8
		0.263		0.166
Step 5				
Ethylene oxide feed, grams		1176	2024	2803
Ethylene oxide feed temperature, °C		110	110	110
Ethylene oxide feed time, hours		0.5	0.5	0.7
Pressures, psig max.		24	14	24
Cookout period, hours		1	1	1
Stripping period, hours		1	1	1
Stripping temperature, °C		110	110	110
Stripping pressure, mm Hg		20	20	20
Crude product recovered, lbs.	83.1	78.5	76	82.5
Magnesium Silicate, lbs.	1.70	1.45	1.5	1.65
Agitation period, hours	8	8	8	8
Refining temperature, °C	89	94	100	100
Ionol added, lbs.	0.017		.015	0.16
Filtration period, hours	19	34	16	30
Filtrate recovered, lbs.	80.9	75	71.5	72
Stripping period, hours	3	4	3	3
Stripping temperature, °C	100	100	100	100
Stripping pressure, mm Hg	7	5	<10	5
Refined Product recovered, lbs.	73.9	73.1	67.5	70.5

(1) Sparged nitrogen up through unit to keep KOH suspended.

TABLE XIV
Properties of Polyols

Example	13	14	15	16
Product analysis:				
Hydroxyl number	29.27	30.57	29.24	29.11
Acid number	0.004	0.004	0.004	0.005
Water, %	0.02	0.02	0.01	0.02
Total alkalinity, meq/gm	0.00009	0.00006	0.00011	0.00017
Viscosity, cks at 25°C	1456	1478	1552	1522
Primary hydroxyl, mole-%	0	45	58	67
Average functionality	4.6	4.35	4.17	4.15
Oxyethylene, %	0	3.5	3.3*	6.2
Unsaturation, meq/gm	0.071	0.071	0.082	0.079
Example	17	18	19	20
Product analysis:				
Hydroxyl number	34.33	34.01	35.88	32.78
Acid number	0.003	0.007	0.008	0.006
Water, %	0.02	0.01	0.02	0.03
Total alkalinity, meq/gm	0.00013	0.00010	0.00002	0.00007
Viscosity, cks at 25°C	1293	1359	1202	1342
Primary hydroxyl, mole-%	0	39	38*	59
Average functionality	4.76	4.59	4.61	4.71
Oxyethylene, %	0	1.8*	3.1*	4.7*
Unsaturation, meq/gm	0.053	0.057	0.041	0.053

* These values are believed to be in error (i.e., too low)

TABLE XV
Preparation of Polymer/Polyols

Polyol of Example	9	10	11	12	13	14
Average Functionality#	4.04	4.37	4.86	4.38	4.6	4.35
Primary Hydroxyl, mole-% #	67	67	57	53	0	45
Oxyethylene, % #	7	7	7	4.8	0	3.5
Reaction Temperature, °C	120	120	120	120	120	120
Residence Time, min.	12	12	12	12	12	12
Monomer + VAZO Content in Feed, %	23.2	23.2	23.5	23.3	23.4	23.2
VAZO Conc., % in Total Feed	0.40	0.40	0.41	0.41	0.41	0.40
Ratio of Acrylonitrile to Styrene in Feed, by wt.	80/20	80/20	80/20	80/20	78/22	78/22
Polyol Feed Rate, gm/hr.	2131	2132	2158	2124	2122	2143
Monomer + VAZO Feed Rate, gm/hr	643	645	663	646	650	648
	2767	2762	2801	2764	2764	2785
Product weight, gm/hr.	15218	9668	9802	13683	12438	14745
Material Balance, %	99.7	99.5	99.3	99.9	99.8	99.8
Residual Acrylonitrile, %	1.71	1.73	1.80	1.55	1.36	1.50
Styrene, %	0.28	0.30	0.22	0.23	0.27	0.27
TMSN, %	0.21	0.15	0.15	0.20	0.19	0.22
Conversions, Acrylonitrile, %	90.6	90.6	90.3	91.6	92.4	91.6
Styrene, %	93.9	93.5	95.3	95.0	94.7	94.6
Combined, %	91.3	91.1	91.3	92.3	92.9	92.3

Analytical

(46)

TABLE XVI

Preparation of Polymer/Polyols

Polyol of Example	15	16	17	18	19	20
Average Functionality #	4.17	4.15	4.76	4.59	4.61	4.71
Primary Hydroxyl, mole-% #	58	67	0	39	38*	59
Oxyethylene, % #	3.3*	6.2	0	1.8*	3.1*	4.7*
Reaction Temperature, °C	120	120	120	120	120	120
Residence Time, min.	12	12	12	12	12	12
Monomer + VAZO Content in Feed, %	23.3	23.1	23.3	23.4	23.5	23.3
VAZO Conc., wt. % in Total Feed	0.40	0.40	0.40	0.41	0.41	0.40
Ratio of Acrylonitrile to Styrene in Feed, by wt.	78/22	78/22	78/22	78/22	78/22	78/22
Polyol Feed Rate, gm/hr.	2137	2144	2127	2113	2110	2120
Monomer + VAZO Feed Rate, gm/hr.	650	645	646	645	646	643
	2796	2781	2766	2747	2748	2754
Product weight, gm/hr.	16610	12531	13971	15195	14797	15147
Material Balance, %	100.3	99.7	99.8	99.7	99.7	99.7
Residual Acrylonitrile, %	1.47	1.49	1.68	1.58	1.71	1.72
Styrene, %	0.30	0.29	0.39	0.35	0.39	0.35
TMSN, %	0.16	0.21	0.24	0.20	0.18	0.18
Conversion, Acrylonitrile, %	91.7	91.6	90.6	91.2	90.5	90.4
Styrene, %	94.0	94.2	92.3	93.1	92.3	93.1
Combined, %	92.2	92.2	91.0	91.6	90.9	91.0

*These values believed to be in error (i.e., too low).

analytical

TABLE XVII

Properties of Polymer/Polyols

Polymer/Polyol From Polyol of Example	9	10	11	12	13	14
Stripped Product Properties						
Total Poly A by Calc., %	16.86	16.88	17.03	17.10	16.89	16.59
Total Poly S by Calc., %	4.37	4.35	4.49	4.43	4.88	4.84
Total Polymer by Calc., %	21.23	21.23	21.52	21.53	21.77	21.43
Viscosity at 25°C. Hoeppler, cps.	4632	3676	3172	3765	—	—
Brookfield, cps.	—	—	—	3890	3240	3400
Hydroxyl No. : Calculated	21.06	23.47	25.99	23.39	22.90	24.02
Measured	20.45	23.15	25.43	22.95	22.51	23.68
Water, %	0.03	0.02	0.01	0.01	0.03	0.02
Styrene After Stripping, %	—	—	—	—	0.03	—
150 Mesh Screen, % Through	150	100	100	100	100	100
Solids on screen, ppm	7	3	3	5	4	4
700 Mesh Screen, time, sec.	280	238	228	223	262	269
% Through	100	100	100	100	100	100
Solids on Screen, ppm	12	9	15	10	6	7
Centrifugible Solids	1.67	1.61	1.65	1.67	1.78	1.71
Light transmission, %	—	—	—	77.5	—	—

TABLE XVIII

Properties of Polymer/Polyols

Polymer/Polyol From Polyol of Example	15	16	17	18	19	20
Stripped Product Properties						
Total Poly A by Calc., %	16.69	16.54	16.52	16.67	16.61	16.46
Total Poly S by Calc., %	4.82	4.80	4.74	4.80	4.78	4.78
Total Polymer by Calc., %	21.51	21.34	21.26	21.47	21.39	21.24
Viscosity at 25°C. Hoeppler cps.	—	—	—	—	—	—
Brookfield, cps.	3,750	3,600	3,100	3,150	2,740	3,070
Hydroxyl No. : Calculated	22.95	22.90	27.03	26.71	28.21	25.82
Measured	22.62	22.91	26.15	25.86	27.18	25.56
Water, %	0.02	0.03	0.01	0.03	0.02	0.03
Styrene After Stripping, %	0.04	0.04	0.04	0.04	0.03	0.03
150 Mesh Screen, % Through	100	100	100	100	100	100
Solids on screen, ppm	1	3	4	16	6	9
700 Mesh Screen, time, sec.	277	280	258	227	248	236
% Through	100	100	100	100	100	100
Solids on Screen, ppm	9	8	3	9	10	26
Centrifugible Solids	1.88	1.70	1.70	1.83	1.84	1.62
Light Transmission, %	—	—	—	—	—	—

TABLE XIX

SUMMARY OF PROPERTIES OF SORBITOL STARTED POLYOLS AND
POLYMER/POLYOLS VARYING ETHYLENE OXIDE CONTENTS

Polyols of Example	13	14	15	16
Hydroxyl Number, #	29.3	30.6	29.2	29.1
Oxyethylene Content, %*	0	3	5	7
Primary Hydroxyls, mole-% #	0	45	58	67
Average Functionality #	4.60	4.35	4.17	4.15
Viscosity, cks at 25°C	1456	1478	1552	1552
Polymer/Polyols				
Hydroxyl Number #	22.5	23.7	22.6	22.9
VCN/STY Ratio	79/21	79/21	79/21	79/21
Viscosity, cps at 25°C	3240	3400	3750	3600

Analytical

* Target

48

TABLE XX

Preparation of Polyurethane Foam
(Variation of C_2H_4O at OH No. of 30)

Polyol of Example Polyol OH No. # Polyol C_2H_4O Content, %*	13	13	13	14	14	14	14	14	15	15	16
	29.3	29.3	29.3	30.6	30.6	30.6	30.6	30.6	29.2	29.2	29.1
	0	0	0	3	3	3	3	3	5	5	7
Formulations, pbw											
Polyol											
Polymer-Polyol**											
Water	60										
Amine Catalyst I	40										
Amine Catalyst II	2.6										
Amine Catalyst III	0.10										
	0.30										
	0.30										
Dibutyltin dilaurate	0.05	0.10	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Silicone I	2.0	5.0	1.7	1.7	2.0	2.0	3.0	1.7	1.7	1.7	1.7
Isocyanate I	105 Index										
Remarks	Collapsed	-	Voids and Coarse Cells	Voids and Coarse Cells	Voids	Voids	Partial Voids and Shrinking	Good	Good	Good	Good

Analytical

* Target

** Made from polyol listed in same column; preparation summarized in Tables XV and XVI.

49

TABLE XX (Continued)

Polyol of Example	13	13	14	14	14	12	15	16
Physical Properties								
Density, overall, pcf						2.93	3.00	3.03
core, pcf						2.64	2.88	2.83
Porosity, ft ³ /min/ft ²						36.0	31.8	26.7
Resiliency, % ball rebound						69	66	66
ILD (lbs/50 in²)								
25%						40.2	39.9	48.3
65%						102.0	103.9	123.5
25% Return, %						83.1	83.4	82.6
Load Ratio						2.54	2.60	2.56
Tensile Strength, psi						15.2	14.2	15.5
Elongation, percent						104	102	98
Tear Resistance, pli						0.98	0.94	0.80
75% Compression Set, %						7.3	6.1	6.0
Humid Aging (5 hours at 120°C)								
50% Compression Set, %						12.7	10.9	11.7
Load Loss, %						8.0	9.5	7.8
Rate of Stress Relaxation								
-ΔILD/log time						0.065	-	-

← NOT TESTED →

TABLE XXI
Preparation of Polyurethane Foam
(Variation of C₂H₄O in Polyol at OH No. of 34)

Polyol of Example	17	18	19	20
Polyol OH No. #	34.3	34.0	35.9	32.8
Oxyethylene Content, %*	0	3	5	7
<u>Formulations, pbw</u>				
Polyol	60			
Polymer/Polyol**	40			
Water	2.6			
Amine Catalyst I	0.1			
Amine Catalyst II	0.3			
Amine Catalyst III	0.3			
Dibutyltin dilaurate	0.03			
Silicone I	2.0	1.7	1.7	1.7
Isocyanate I	105 Index			
<u>Remarks</u>	Collapsed	Voids	Good	Good
<u>Mold Exit Time, sec.</u>	--	70	65	64
<u>Physical Properties</u>				
Density, Overall, pcf		3.01	3.03	3.00
Core, pcf	Not	2.67	2.73	2.65
Porosity, ft ³ /min/ft ²		29.2	24.0	20.8
Resiliency, % ball rebound		66	65	67
<u>ILD (lbs/50 in³)</u>				
25%	Tested	44.2	47.2	46.1
65%		110.7	119.0	113.0
25% Return		84.2	84.0	84.5
Load Ratio		2.51	2.52	2.45
Tensile Strength, psi		13.1	15.6	13.6
Elongation, %		90	90	86
Tear Resistance, pli		0.71	0.77	0.69
75% Compression Set, %		5.7	6.1	6.4
<u>Humid Aging (5 hours at 120°C)</u>				
50% Compression Set, %		9.7	10.8	11.2
50% CLD Load Loss, %		13.8	18.9	16.6
<u>Rate of Stress Relaxation</u>				
-ΔILD/log time		.063	.064	.063

analytical

* target

** Made from polyol listed in same column; preparations summarized in Table XVI.

51

Examples 21 to 24.

5 Examples 21 to 24 demonstrate the use of amine starters in producing polyols in accordance with the practice of the present invention. The details of the preparation of the polyol intermediates and the final polyols are shown in Tables XXII and XXIII. The procedures used were similar to those described above for the preparation of polyols from polyhydric alcohol starters. The properties of the amine-started polyols are shown in Table XXIV. 5

10 As shown in Table XXV, the physical properties of the molded, high resiliency foams prepared with the amine-started polyols are comparable to those obtained with the polyols of this invention based on hydroxyl-containing starter and no significant improvements were observed for either the stress relaxation or humid aging properties. Table XXV also shows that the foams prepared from amine-started polyols were superior to the prior art foams. Since these formulations contained only 60 pbw of the amine-started polyols, further reductions in amine catalysis would be anticipated for formulations based on an additional 40 pbw of the comparable amine-started polymer/polyol (since no polymer/polyols were made from the amine-started polyols of Examples 22 and 24, polymer/polyols made from hydroxy starters were used in making the foams from the polyols of Examples 22 and 24 as indicated by footnote (b) in Table XXV). Better control of formulation reactivity can probably be achieved by amine catalysis, rather than the inherent catalytic nature of amine-started polyols. 20

TABLE XXII
Preparation of Polyol Intermediates From Amine Starters

Example	21	22	(b)	23	24
Charge, grams					
DETA-PO(a)	2078	1075			
Ethylene diamine			825		
Intermediate From (b)				1890	980
Potassium hydroxide	20	20		20	15
Oxide Feed Date					
Propylene oxide, grams	6188	7178	3185	6311	7013
Temperature, °C	110	110	89	110	110
Pressure, psig max.	60	62	30	68	65
Feed time, hours	9.5	11	2.75	10.75	10.5
Cookout time, hours	3	5.75	3	6	8
Analysis of Crude Product(c)					
Hydroxyl number	180.8	100.5		181.4	97.8
Alkalinity, %					
KOH	0.14	0.175		0.199	0.169
Viscosity, cks. at 25°C.	1008	767		713	615

(a) Polyol intermediate made from one mole of diethylene triamine (DETA) and 5 moles of propylene oxide (PO). DETA was also the catalyst.

(b) Preparation of polyol intermediate used in Examples 23 and 24.

(c) Each of the above intermediates were catalyzed and delivered hot to the reactor used to produce final polyol products as tabulated in Table XXIII. It was necessary to use temperatures in excess of 150°C in some cases to dissolve the potassium hydroxide.

S-2

TABLE XXIII

Preparation of Polyols From Amine-Started Intermediates

Example	21	22	23	24
Autoclave charge, lbs.				
Ethylene diamine intermediate	0	0	17.87	17.4
Diethylene triamine intermediate	18.07	17.8	0	0
Potassium hydroxide, contained	0.176	0.187	0.187	0.209
Temperature during propylene oxide feed, °C	108-116	100-122	110	100-114
Propylene oxide feed, lbs.	55	55	60	60
Feed period, hrs.	6.5	9.0	6.0	6.0
Peak pressure, psig	54	55	57	48
Cook-out period, hrs.	3.5	3.0	3.5	2
Final pressure, psig	3	2	2	2
Hydroxyl number	53.41	35.44	49.84	34.4
Additional propylene oxide added, lbs.	7.5	16.4	2.2	11.2
Final hydroxyl number	49.4	31.37	50.57	30.86
Alkalinity, per cent KOH	0.256	0.252	0.235	0.247
Stripping temperature, °C	116-120	120	120	120
Stripping pressure, mm/Hg	7-5	5	7	5
Stripping period, hrs.	3	2	3	3
Ethylene oxide fed, lbs.	6	6.3	6.0	6.2
Capping temperature, °C	108-112	110-115	110-124	110
Feed and cook-out periods, hrs.	2	2	2.5	2.5
Stripping temperature, °C	110	110	110	110
Stripping pressure, mm/Hg	7	4	5	6-3
Crude product recovered, lbs.	77	79	83	64(1)
Magnesium silicate	1.54	1.58	1.66	1.28
Agitation period, at 100°C, hrs.	8	8	8	8
Ionol added, lbs.	0.0154	0.0158	0.0166	0.0128
Filtered product recovered, lbs.	67.5	76	78.5	57
Filtration period, hrs.	13.5	17	21.5	6.0
Final stripping period, hrs.	3	3	3	3
Autoclave temperature, °C	120-99	100	100	100
Autoclave pressure, mm/Hg.	4	5	5	5
Final product recovered, lbs.	60.4	70.8	76.0	56.5

(1) Estimated 2 gallons lost during transfer spill.

TABLE XXIV

Properties of Polyols From Amine Starters

Example	21	22	23	24
Hydroxyl number (a)	43.92	29.36	45.51	28.72
Water, % (a)	0.013	0.014	0.017	0.018
Total alkalinity meq/gm (a)	0.405	0.197	0.327	0.157
Functionality (a)	4.47	3.59	3.52	3.01
Primary hydroxyl, mole % (b)	>50	>50	>50	>50

(a) Analytical

(b) Estimate; primary hydroxyl not determined but can be determined by NMR derivative method.

53

TABLE XXV

Preparation of Polyurethanes From Amine-Started Polyols

Polyol from Example	6	22	24
Starter	Sorbitol	Diethylene Triamine	Ethylene Diamine
Hydroxyl No. (analytical)	29.1	29.4	28.7
Average Functionality (analytical)	4.07	3.59	3.01
Viscosity, cks at 25°C	1441	1343	1251
<u>Formulation, pbw</u>			
Polyol	60	60	60
Polymer/Polyol	40(a)	40(b)	40(b)
Water	2.6	2.6	2.6
Amine Catalyst I	0.10	0.10	0.10
Amine Catalyst II	0.30	0.275	0.275
Amine Catalyst III	0.30	0.30	0.30
Dibutyltindilaurate	0.03	0.03	0.03
Silicone I	1.7	1.7	2.0
Isocyanate I	105 Index	105 Index	105 Index
<u>Physical Properties</u>			
Mold Exit Time, sec.	61	55	55
Density, Overall, pcf	3.00	2.99	2.97
Core, pcf	2.84	2.84	2.86
Porosity, ft ³ /min/ft ²	23.0	24.0	26.0
Resiliency, % ball rebound	66	65	66
<u>ILD (lbs/50 in³)</u>			
25%	43.7	40.7	42.0
65%	118.0	103.2	108.0
25% Return	84.7	83.0	83.4
Load Ratio	2.70	2.54	2.58
Tensile Strength, psi	19.3	19.6	23.5
Elongation, %	121	128	155
Tear Resistance, pli	1.12	1.55	1.84
75% Compression Set, %	7.5	8.5	7.5
<u>Humid Aging (5 hours at 120°C)</u>			
50% Compression Set, %	13.5	16.1	15.9
Load Loss, %	5.5	4.1	9.7
<u>Rate of Stress Relaxation</u>			
-ΔILD/log time	.066	.068	.068

(a) Made as described above from the polyol of Example 6.

(b) Made as described above from the polyol of Example 1.

Example 25.

A polyol was prepared essentially the same in composition as Polyol I but having 93% oxypropylene groups and 7% oxyethylene groups. Large scale foam preparations using this polyol and Polymer/Polyol I yielded foams having poor demold properties using a formulation as in Table VII.

Examples 26 to 33.

A comparison was made of molded and free rise high resiliency polyurethane foams made from a polyols of this invention as the sole polyol component and from other polyols and polymer/polyols. The formulations and foam properties are shown in Table XXVI.

As is shown by the data in Table XXVI, acceptable molded foams were prepared with the novel Polyol of Example 12 as the sole polyol component using Silicone II for cell stabilization and carbon black to open the cells. Compared to prior art Polymer/Polyol I, this foam exhibited about 25 percent lower loads, improved humid aging values and superior stress relaxation properties. However, the use of this polyol as the sole polyol component results in reduced tensile strength and tear resistance values which can be improved by using this polyol in combination with a polymer/polyol of this invention as shown in Example 27.

As is also shown by the data in Table XXVI, free-rise foams prepared with Silicone I were closed and shrank very badly. Lower levels of Silicone I (not shown in Table XXVI) produce foams with poor cell stabilization. Use of Silicone II provided free-rise foams which did not shrink nearly as much as those based on Silicone I. The foam prepared with the novel polyol of Example 12 as the sole polyol component exhibited only slight signs of shrinkage. Addition of "Coloidex No. 3 Carbon Black" (1.0 pbw) produced foams with even more open-cell character. In all cases, the foams prepared with the novel Polyol of Example 12 as the sole polyol component were rated significantly better than those based on prior art Polyol I as the sole polyol component. Similar studies (not shown in Table XXVI) with prior art Polyol II showed such foams to shrink even more than foams based on Polyol I.

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46

1,512,710

46

TABLE XXVI
Preparation of Polyurethane Foams
(with and without Polymer/Polyol)

Example	26	27	28	29
Formulations, pbw				
Polyol I (1)	60	—	100	—
Polymer/Polyol I (2)	40	—	—	—
Polyol of Example 12	—	60	—	100 (5)
Polymer/Polyol of Example 12 (3)	—	40	—	—
Water	2.6	2.6	2.6	2.6
Amine Catalyst I	0.10	0.10	0.10	0.10
Amine Catalyst II	0.36	0.30	0.30	0.30
Amine Catalyst III	0.30	0.30	0.30	0.30
Dibutyltindilaurate	0.015	0.03	0.03	0.03
Silicone I	1.7	1.7	1.7	1.7
Silicone II	—	—	—	—
"Coloidex No. 3" Carbon Black	—	—	—	—
Isocyanate I	105 Index	105 Index	105 Index	105 Index
Free-Rise Foams: (4)				
Remarks	No Shrinkage		Very Bad Shrink	Very Bad Shrink
Physical Properties				
Density, Overall, pcf	3.00	2.93	2.93	3.03
Core, pcf	2.68	2.64	2.63	2.70
Porosity, ft ³ /min/ft ²	16.1	36.0	14.8	31.9
Resiliency, % ball rebound	62	69	56	66
ILD (lbs/50 in³)				
25%	43.1	40.2	27.0	30.2
65%	114.0	102.0	73.0	76.9
25% Return	81.0	83.1	82.8	85.0
Load Ratio	2.65	2.54	2.71	2.55
Tensile Strength, psi	23.5	15.2	19.9	12.8
Elongation, %	151	104	188	113
Tear Resistance, pli	1.82	0.98	1.52	0.70
75% Compression Set, %	7.8	7.3	14.8	8.6
Humid Aging (5 hours at 120°C)				
50% Compression Set, %	18.9	12.7	24.3	12.0
50% CLD Load Loss, %	25.3	8.0	27.0	7.7
Rate of Stress Relaxation				
-ΔILD/log time	.072	.065	—	—
Flammability, ASTM D1692				
Burn Extent, inches	—	—	—	—
Burn Rate, in/min	—	—	—	—

TABLE XXVI (Continued)

Example	30	31	32	33
<u>Formulations, pbw</u>				
Polyol I (1)	100	—	100	—
Polymer/Polyol I (2)	—	—	—	—
Polyol of Example 12	—	100(5)	—	100(5)
Polymer/Polyol of Example 12 (3)	—	—	—	—
Water	2.6	}	→	→
Amine Catalyst I	0.10			
Amine Catalyst II	0.30			
Amine Catalyst III	0.30			
Dibutyltindilaurate	0.03			
Silicone I	—	—	—	—
Silicone II	0.02	0.02	0.02	0.02
"Coloidex No. 3" Carbon Black	—	—	1.0	1.0
Isocyanate I	105 Index	→		
<u>Free-Rise Foams: (4)</u>				
<u>Remarks</u>	Bad Shrink	Slight Shrink	Slight Shrink	Good
<u>Physical Properties</u>				
Density, Overall, pcf	3.01	3.02	3.02	3.03
Core, pcf	2.42	2.61	2.62	2.65
Porosity, ft ³ /min/ft ²	65.5	78.0	68.3	77.5
Resiliency, % ball rebound	67	70	67	72
<u>ILD (lbs/50 in³)</u>				
25%	28.4	30.9	29.0	31.1
65%	72.4	79.4	75.0	80.0
25% Return	84.4	85.8	82.8	85.2
Load Ratio	2.55	2.57	2.59	2.57
Tensile Strength, psi	15.0	12.7	18.8	12.2
Elongation, %	162	121	188	116
Tear Resistance, pli	1.50	0.70	1.79	0.82
75% Compression Set, %	8.5	6.3	7.4	5.4
<u>Humid Aging (5 hours at 120°C)</u>				
50% Compression Set, %	13.9	8.1	13.8	8.6
50% CLD Load Loss, %	27.3	10.5	27.9	9.1
<u>Rate of Stress Relaxation</u>				
-ΔILD/log time	—	—	.065	.056
<u>Flammability, ASTM D1692</u>				
Burn Extent, inches	—	—	5.0	5.0
Burn Rate, in/min	—	—	3.4	4.4

(1) Commercially available prior art polyol described above.

(2) Commercially available prior art polymer/polyol described above.

(3) Polymer/polyol of this invention produced as described above from the polyol of Example 12.

(4) All other properties are for molded foams. The same formulations were used for both the molded and free-rise foams.

(5) Polyol made as in Example 12 but on a larger scale.

Examples 34 to 37.

Another comparison was made of molded, high resiliency polyurethane foams made from a polyol of this invention as the sole polyol component and from other polyol and polymer/polyols. In these Examples a formulation was used having less water than the formulation used in Examples 25 to 33 and would be expected to produce foams having better stress relaxation and poorer humid aging load loss properties. The results are shown in Table XXVII and support the conclusion drawn above from the results shown in Table XXVI concerning the utility of the polyol of Example 12 as the sole polyol component.

TABLE XXVII
Preparation of Polyurethane Foams
(with and without Polymer/Polyol)

Example	34	35	36	37
<u>Formulations; pbw</u>				
Polyol I (1)	60	—	100	—
Polymer/Polyol I (2)	40	—	—	—
Polyol of Example 12	—	60	—	100 (4)
Polymer/Polyol of Example 12 (3)	—	40	—	—
Water	2.0	} —————→		
Amine Catalyst I	0.10			
Amine Catalyst II	0.30			
Amine Catalyst III	0.30			
Dibutyltindilaurate	0.03			
Silicone I	1.7			
Trichloromonofluoromethane	5.0			
Isocyanate I, Index	105			
<u>Molded Foam:</u>				
Remarks	Shrink	Slight Shrink	Very Bad Shrink	Bad Shrink
<u>Physical Properties</u>				
Density, Overall, pcf	3.11	3.12	3.03	3.08
Core, pcf	2.72	2.83	2.78	2.78
Porosity, ft ³ /min/ft ²	15.5	29.2	17.1	33.5
Resiliency, % ball rebound	58	66	53	65
ILD (lbs/50 in ²)				
25%	32.2	29.0	20.0	23.6
65%	85.0	77.7	60.0	62.5
25% Return	83.3	85.5	84.5	86.0
Load Ratio	2.64	2.68	3.00	2.65
Tensile Strength, psi	19.9	11.1	14.2	8.4
Elongation, %	173	107	161	98
Tear Resistance, pli	1.71	0.74	1.03	0.44
75% Compression Set, %	9.6	8.0	14.4	8.9
<u>Humid Aging (5 hours at 120°C)</u>				
50% Compression Set, %	20.3	12.8	24.1	10.1
50% CLD Load Loss, %	42.1	15.5	40.6	21.0
<u>Rate of Stress Relaxation</u>				
-ΔILD/log time	.065	.057	—	—

(1) Commercially available prior art polyol described above.

(2) Commercially available prior art polymer/polyol described above.

(3) Polymer/polyol of this invention produced as described above from the polyol of Example 12.

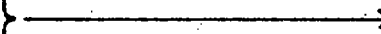
(4) Polyol made as in Example 12 but on a larger scale.

Examples 38 to 41.

Experiments were conducted to determine whether or not the addition of a crosslinker (triethanol amine) to a formulation containing a prior art polyol and a prior art polymer/polyol would result in polyurethane foams of improved humid aging and stress relaxation properties. The results of these experiments are shown in Table XXVIII. The results show that the formulations containing the crosslinker resulted in foams having poorer humid aging compression set.

TABLE XXVIII

Effect of Triethanolamine (TEOA) on HR Foam Properties

Example	38	39	40	41
<u>Formulations, plow</u>				
Polyol I	60			
Polymer/Polyol I	40			
Water	2.8			
Amine Catalyst I	0.08			
Triethylene Diamine (Solid)	0.08			
N-Ethylmorpholine	0.80			
Dibutyltindilaurate	0.03			
Silicone I	1.5			
TEOA	—	1	2	4
Isocyanate I	105 Index			
Mold Exit Time, secs.	68	56	53	40
<u>Physical Properties</u>				
Density, overall, pcf	2.77	2.82	2.93	3.13
core, pcf	2.58	2.51	2.53	2.63
Resiliency, % ball rebound	63	63	63	64
<u>ILD (lbs/50 in²)</u>				
25%	27.2	27.6	29.8	33.4
65%	72.6	76.1	84.8	102.3
Load Ratio	2.67	2.76	2.92	3.07
Tensile Strength, psi	22.7	18.8	18.9	17.6
Elongation, %	170	133	126	102
Tear Resistance, pli	2.2	1.6	1.4	1.0
75% Compression Set, %	9.4	9.4	8.7	8.1
<u>Humid Aging (5 hours at 120°C)</u>				
50% Compression Set, %	20.0	24.3	25.0	27.2
CLD Load Loss, %	34.7	31.5	28.3	28.6

Examples 42 to 47.

Experiments were conducted to determine whether or not decreasing the TDI to AFPI ratio would result in polyurethane foams of improved humid aging and stress relaxation properties in a formulation containing a prior art polyol and a prior art polymer/polyol. To this end isocyanates having various TDI to AFPI ratios were employed. The results are shown in Tables XXIX and XXX and indicate no improvement in stress relaxation properties when the functionality of the isocyanate is increased.

59

TABLE XXIX
Effect of TDI/AFPI Ratios on HR Foam Properties

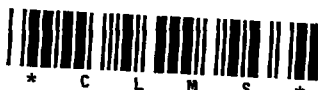
Example	42	43	44	45	46	47
Polyol I	60					
Polymer/Polyol I	40					
Water	2.6					
Amine Catalyst I	0.87	0.10	0.13	0.136	0.15	0.17
Amine Catalyst II	0.32	0.36	0.48	0.49	0.53	0.60
Amine Catalyst III	0.26	0.30	0.40	0.41	0.44	0.50
Dibutyltindilaurate	0.015					
Silicone I	1.5					
Isocyanate Ratio (100 Index)						
TDI	100	80*	60	40	20	0
AFPI	0	20*	40	60	80	100
Mold Exit Time, secs.	64	65	74	110	110	104
<u>Physical Properties</u>						
Density, overall pcf	2.97	3.02	2.98	3.02	3.03	3.03
core, pcf	2.52	2.39	2.46	2.47	2.45	2.48
ILD (lbs/50 in ²)						
25%	52.5	32.8	25.7	28.7	33.2	34.6
65%	113.8	88.2	81.3	82.1	87.0	91.0
Load Ratio	2.17	2.69	2.78	2.86	2.62	2.63
Tensile Strength, psi	22.4	22.6	16.4	14.4	13.4	11.1
Elongation, %	200	177	135	107	98	72
Tear Resistance, pli	3.6	1.8	1.2	0.9	0.7	0.5
Compression Set, %						
75%	8.7	9.9	8.8	7.3	7.9	7.8
90%	7.6	8.8	7.7	7.5	7.1	7.1
<u>Humid Aging (5 hours at 120°C)</u>						
50% Compression Set, %	13.2	19.7	25.1	19.0	16.8	12.2
Load Loss, %	31.8	21.9	29.1	34.7	25.8	17.0

* TDI to AFPI ratio used in commercial process of prior art.

TABLE XXX
Effect of TDI/AFPI Ratio on Rate of Stress Relaxation for Molded HR Foams

Example	48	49
<u>Formulation, pbw</u>		
Polyol I	60	60
Polymer/Polyol I	40	40
Water	2.8	2.8
Amine Catalyst I	0.08	0.08
Triethylene diamine (solid)	0.08	0.08
N-Ethyl Morpholine	0.80	0.80
Dibutyltindilaurate	0.03	0.03
Silicone IV	0.75	0.75
TDI/AFPI Ratio (100 Index)	80/20*	70/30
<u>Rate of Stress Relaxation</u>		
-Δ ILD/log time	0.074	0.077

*TDI to AFPI ratio used in commercial process of prior art.



WHAT WE CLAIM IS:—

1. A normally liquid polyoxyalkylene-polyoxyethylene polyol consisting essentially of: (1) polyoxyalkylene blocks that consist of oxalkylene groups containing at least 3 carbon atoms, (2) polyoxyethylene blocks that consist of oxyethylene groups, that end-block at least 35 mole percent of the said polyoxyalkylene blocks and that are terminated with primary hydroxyl groups and (3) the residue of at least one starter (as hereinbefore defined), the said polyol comprising from 90 to 97 weight percent of the said polyoxyalkylene blocks and from 10 to 3 weight percent of the said polyoxyethylene blocks, based on the total weight of blocks in the polyol, and having (a) an average of at least 3.2 hydroxyl groups per molecule, (b) a hydroxyl number no greater than 45 and (c) at least 35 mole percent of primary hydroxyl groups, based on the total number of moles of hydroxyl groups in the polyol.

2. A polyol as claimed in claim 1 consisting of from 93 to 97 weight percent of the said polyoxyalkylene blocks and from 7 to 3 weight percent of the said polyoxyethylene blocks, based on the total weight of blocks in the polyol.

3. A polyol as claimed in claim 1 or claim 2 having an average of from 3.8 to 4.8 hydroxyl groups per molecule.

4. A polyol as claimed in any one of claims 1 to 3 having a hydroxyl number of from 25 to 35.

5. A polyol as claimed in any one of the preceding claims having at least 50 mole-% of primary hydroxyl groups, based on the total number of moles of hydroxyl groups in the polyol.

6. A polyol as claimed in claim 1 substantially as hereinbefore described in any one of Examples 1, 2, 4 to 6, or 8 to 47.

7. A method of producing a polyol as claimed in any one of the preceding claims which method comprises reacting at least one starter (as hereinbefore defined) with propylene oxide to form a polyol intermediate and then reacting the polyol intermediate with ethylene oxide to yield the required polyol.

8. A method as claimed in claim 7 wherein a potassium hydroxide catalyst is used to assist the formation of the polyol intermediate.

9. A method as claimed in claim 7 or claim 8 wherein the starter is either water, or an organic compound having at least four active hydrogen atoms and up to 20 carbon atoms.

10. A method as claimed in claim 9 wherein the organic compound is a polyhydric alcohol, or a primary or secondary amine.

11. A method of producing a polyol as claimed in claim 7 substantially as hereinbefore described in any one of Examples 1, 2, 4 to 6, or 8 to 25.

12. A polyol when producing a method as claimed in any one of claims 7 to 11.

13. A polymer/polyol composition consisting essentially of:

(A) a major amount of a normally liquid polyoxyalkylene-polyoxyethylene polyol consisting essentially of: (1) polyoxyalkylene blocks that consist of oxalkylene groups containing at least 3 carbon atoms, (2) polyoxyethylene blocks that consist of oxyethylene groups, that end-block at least 35 mole percent of the polyoxyalkylene blocks and that are terminated with primary hydroxyl groups and (3) the residue of at least one starter (as hereinbefore defined), the said polyol comprising from 90 to 97 weight percent of the said polyoxyalkylene blocks and from 10 to 3 weight percent of the said polyoxyethylene blocks, based on the total weight of blocks in the polyol, and having (a) an average of at least 3.2 hydroxyl groups per molecule, (b) a hydroxyl number no greater than 45 and (c) at least 35 mole percent of primary hydroxyl groups, based on the total number of moles of hydroxyl groups in the polyol; and,

(B) a minor amount of a polymer formed by polymerizing at least one ethylenically unsaturated monomer in the said polyol by free radical polymerization, the polymer being in the form of particles that are stably dispersed in the polyol.

14. A composition as claimed in claim 13 wherein the polyol thereof consists essentially of from 93 to 97 weight percent of the said polyoxyalkylene blocks and from 7 to 3 weight percent of the said polyoxyethylene blocks, based on the total weight of blocks in the polyol.

15. A composition as claimed in claim 13 or claim 14 wherein the polyol thereof has an average of from 3.8 to 4.8 hydroxyl groups per molecule.

16. A composition as claimed in any one of claims 13 to 15 wherein the polyol thereof has a hydroxyl number of from 25 to 35.

17. A composition as claimed in any one of claims 13 to 16 wherein the polyol

(61)

52

1,512,710

52



thereof has at least 50 mole-% of primary hydroxyl groups, based on the total number of moles of hydroxyl groups in the polyol.

18. A composition as claimed in any one of claims 13 to 17 consisting essentially of from 3 to 35 weight percent of the polymer and from 97 to 65 weight percent of the polyol, based on the combined weight of the polymer and polyol.

19. A composition as claimed in any one of claims 13 to 18 wherein the polymer is formed by the copolymerization of from 40 to 85 weight percent acrylonitrile and from 60 to 15 weight percent of styrene, based on the total weight of acrylonitrile and styrene.

20. A composition as claimed in claim 13 substantially as hereinbefore described in any one of Examples 1, 2, 4 to 6, or 8 to 47.

21. A method of producing a composition as claimed in any one of claims 13 to 20 which method comprises polymerising a minor amount of at least one ethylenically unsaturated monomer in a major amount of a polyol as claimed in any one of claims 1 to 6 or claim 12, using a free radical polymerisation catalyst at a temperature at which the half-life of the catalyst is no longer than six minutes.

22. A method of producing a composition as claimed in claim 21 substantially as hereinbefore described in any one of Examples 1, 2, 4 to 6, or 8 to 47.

23. A composition when produced by a method as claimed in claim 21 or claim 22.

24. A process for producing an elastomeric polyurethane which process comprises reacting: (a) a polymer/polyol composition as claimed in any one of claims 13 to 20 or claim 23 or a polyol as claimed in any one of claims 1 to 6 or claim 12 and (b) an organic polyisocyanate in the presence of a catalyst for the reaction producing the polyurethane.

25. A process as claimed in claim 24 wherein the reaction is conducted in the presence of a blowing agent and a silicone surfactant.

26. A process as claimed in claim 24 substantially as hereinbefore described in any one of Examples 1, 2, 4 to 6, or 8 to 47.

27. A polyurethane when produced by a process as claimed in any one of claims 24 to 26.

BOULT, WADE & TENNANT,
Chartered Patent Agents,
34 Cursitor Street,
London, EC4A 1PQ.

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