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(71) Applicant: **BECTON, DICKINSON AND COMPANY** [US/US]; 1 Becton Drive, MC 110, Franklin Lakes, New Jersey 07417-1880 (US).

(72) Inventors: **HERMEL-DAVIDOCK, Theresa**; 4 Hunters Way, Newton, New Jersey 07806 (US). **LIM, Lisa**; 7908 S. Twelve Pines Dr., Sandy, Utah 84094 (US).

(74) Agents: **HIGHET, David W.** et al.; VP & Chief IP Counsel, Becton, Dickinson and Company, (Servilla Whitney LLC), 1 Becton Drive, MC 110, Franklin Lakes, New Jersey 07417-1880 (US).

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(54) Title: SELF-LUBRICATING POLYMER COMPOSITION

(57) Abstract: A polymer resin composition is disclosed including a chemically attached lubricant structure to produce a self-lubricating medical device thereby eliminating the need of a secondary lubrication step currently required which is useful in medical and surgical devices.

SELF-LUBRICATING POLYMER COMPOSITION

TECHNICAL FIELD

[0001] The present invention relates to a polymer resin composition including a chemically attached lubricant structure which may be used to produce a self-lubricating medical device thereby eliminating the need of a secondary lubrication step currently required.

BACKGROUND

[0002] Infusion therapy products have multiple components that require lubrication, including a cannula, catheter, wedge, tipping and blood control actuator. The lubricants are currently applied in a secondary, solvent-based process during the manufacture of the components. The solvents used during the secondary lubrication application process are constantly under scrutiny from regulatory agencies. Manufacturers are constantly seeking to upgrade their manufacturing processes to utilize acceptable solvents to ensure compliance with constantly changing regulatory standards. However, constant conversions and upgrades to manufacturing processes to comply with constantly changing regulatory standards, e.g. a conversion from the use of a HCFC solvents to a VOC-flammable solvent, can be both capital and resource intensive for the manufacturer. Thus, the elimination of the secondary, solvent based lubrication step would lead to substantial savings, not only from the elimination of the solvent but also with respect to the cost of the secondary process itself with regards to capital equipment, time and resources. The elimination of the secondary, solvent based lubrication step would also lead to a substantial environmental benefit and an increase in work-place safety resulting from the elimination of the solvent in the manufacturing process.

[0003] Lubricants which are applied as a coating or blended into the plastic itself can leach out into patient's blood stream. While the regulatory bodies currently allow for some controlled amount of silicone based (or other) lubricant into the patient. Thus, the elimination of the potential leaching would result in an increase to patient safety.

[0004] Thus, there is a need for a self-lubricating polymer composition which does not require a secondary, solvent based lubrication step while allowing for tailorability without additives or an extra coating. There is also a need for a self-lubricating polymer composition

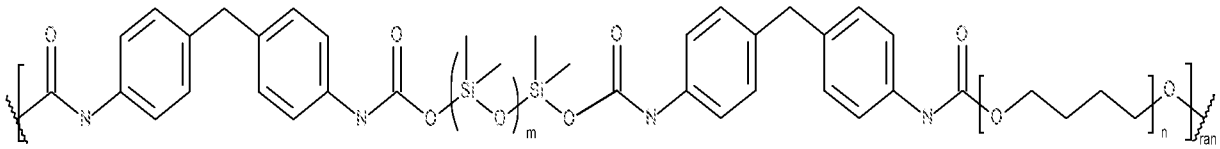
would also result in a consistent coating thickness and amount due to the lubricant being chemically-bounded to the resin, thereby mitigating concerns of variations of lubrication performance due to process variations. There is also a need for a functionalized lubricant which would eliminate migration concerns of the lubricant into the blood stream.

SUMMARY

[0005] One aspect is directed to a self-lubricating polyurethane composition comprising a areaction product of a diisocyanate and a diol mixture containing a short chain diol, a long chain polyether or polyester diol, and a lubricant. In one or more embodiments, the polyurethane has a lubricant chemically attached within the polyurethane resin. In one embodiment, the lubricant is incorporated into a backbone of the polyurethane resin. In one or more embodiments, the diisocyanate is selected from the group consisting of an aliphatic diisocyanate, alicyclic diisocyanate and an aromatic diisocyanate. In a more specific embodiment, the diisocyanate is selected from the group consisting of 4,4-diphenyl methane diisocyanate (MDI), toluene diisocyanate (TDI), isophorone diisocyanate (IPDI), and methylene bis (4-cyclohexyl isocyanate) (HMDI). In one or more embodiments, the short chain diol is selected from the group consisting of ethylene glycol, 1,3-propylene glycol, 1,4-butane diol, neopentyl glycol, and alicyclic glycols having up to 10 carbon atoms. In one or more embodiments, the polyester diol is a polyalkylene glycol. In one embodiment, the polyalkylene glycol is poly(tetramethylene ether) glycol. In one or more embodiments, the lubricant is a non-silicone diol, silicon diol, or fluorinated lubricant. In one embodiment, the silicon diol is polydimethylsiloxane diol. In a specific embodiment, the polydimethylsiloxane is present in an amount ranging from about 3 to 10 weight percent of the polyurethane composition. In one or more embodiments, the self-lubricating polyurethane composition includes an anti-microbial moiety covalently attached to the self-lubricating polyurethane. In one or more embodiments, the self-lubricating polyurethane composition includes an anti-thrombogenic moiety covalently attached to self-lubricating polyurethane. In one or more embodiments, the lubricant may be present in an amount ranging from about 1 to 10 weight percent of the polyurethane composition. In one or more embodiments, the lubricant is incorporated into a backbone formed by the diisocyanate and the diol mixture.

[0006] In one or more embodiments, the reaction further includes a catalyst selected from a group consisting of dibutyltin dilaurate, tertiary amines, and metallic compounds. In a specific embodiment, the tertiary amine is 1,4-diazabicyclo[2.2.2]octane). In a specific embodiment, the metallic compound is dibutyltin dilaurate or bismuth octanoate.

[0007] Another aspect is directed to a polyurethane of Formula I:



(I)

wherein the repeating unit of m is in the range from 5 to 2000; the repeating unit of n is in the range from 1 to 40 and the overall molecular weight of the polyurethane resins is between 15,000 g/mole to 130,000 g/mol.

[0008] Another aspect is directed to an article molded from the self-lubricated polyurethane composition disclosed herein. In one or more embodiments, the article is a component of a cannula, catheter, wedge, tipping, blood control actuator, or syringe. In a specific embodiment, the article is a stopper.

DETAILED DESCRIPTION OF THE INVENTION

[0009] Before describing several exemplary embodiments of the invention, it is to be understood that the invention is not limited to the details of construction or process steps set forth in the following description. The invention is capable of other embodiments and of being practiced or being carried out in various ways.

[0010] The present invention relates to a polyurethane resin having an incorporated lubricant structure which may be used to produce a self-lubricating medical device or component of a medical device. The resin of the present invention eliminates the required secondary lubrication step currently found in the manufacture of many medical device

components. Due to the lower surface energy of an incorporated lubricant, the incorporated lubricant has a propensity for migration to the surface both during the catheter fabrication process and as a function of time post-production.

[0011] In one or more embodiments of the present invention, a lubricant is attached chemically to a polyurethane resin. In one or more embodiments, existing lubricants, such as polydimethylsiloxane or fluorinated lubricants, may be used. The lubricants are chemically reacted to attach with or be incorporated into a desired polyurethane resin of interest. In one or more embodiments, the lubricant is covalently attached or incorporated into the backbone structure of the resin. The lubricant may be attached chemically to a desired polyurethane resin using several techniques. One technique to chemically attach the lubricant to the desired polyurethane is the modification of the urethane monomer prior to polymerization of the monomer into a polyurethane polymer. In one embodiment, isocyante monomers are reacted with polyols to create polyurethane. The isocyante monomers can be modified to contain a lubricating moiety and the reaction with polyols will continue to create self-lubricating polyurethane.

[0012] Another technique to chemically attach the lubricant to the desired polyurethane is to graft a lubricant onto the resin backbone of an existing resin using controlled chemistry such as ATRP, functional group reactions, or plasma modification of the resin surface followed by grafting of the lubricant onto the surface of the resin.

[0013] Another technique to chemically attach the lubricant to the desired polyurethane is to utilize the functional groups on the lubricating chemicals to co-polymerize it with the monomers into a co-polymer thereby adding the lubricating moiety directly into the backbone of the polymer. For example, a lubricant, such as PDMS, can be made with alcohol or "OH" functional groups, which is an essential reactive group to the polyurethane synthesis. The structure of PDMS with the -OH functional group will co-react with the isocyanate to incorporate PDMS chains into polyurethane creating the self-lubricating polymer.

[0014] It is intended that the chemical modification process to functionalize the lubricant onto the resin would still enable the resin to be suitable for use in Class II medical devices.

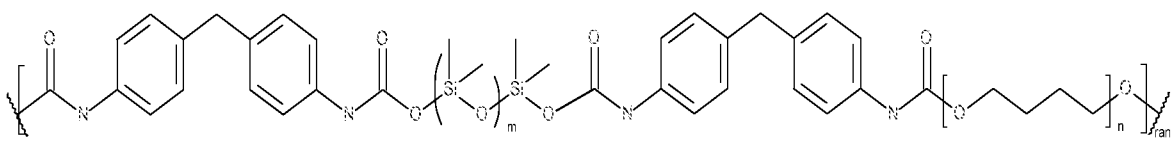
[0015] During and after the fabrication process of the medical device component, the lubricant blooms to the surface due to the lower surface energies of the silicone or fluorinated groups. Due to the chemical linkage of the lubricant to the polymer chain of the bulk material, an additional lubrication process step to obtain the lubrication performance required is eliminated.

[0016] In another aspect of the present invention, the synthesis technique may also be utilized to incorporate anti-microbial chemicals or anti-thrombogenic chemicals into a polymer resin composition of the present invention including a lubricant structure.

[0017] The resin of the present invention may be used in polymer based medical devices which require lubrication such as the injection syringe barrel and/or stopper. The resin of the present invention may also be used in syringes which are prefilled with saline or other solutions which further dissolve the lubricant off the surface of the syringe barrel and carry it into the patient's bloodstream.

[0018] Example 1- PDMS-polyurethane (self-lubricating urethane):

[0019] A series of polyurethane resins of Formula I as follows were prepared:



(I)

wherein the repeating unit of m is in the range from 5 to 2000. The repeating unit of n is in the range from 1 to 40. The overall molecular weight of the polyurethane resins is between 15,000 g/mole to 130,000 g/mol.

[0020] The polyurethane resins of Formula I were prepared from 400 g/mol to 77,000 g/mol of silicone fluid such as Gelest DMS-S31, polyols such as DuPont Tetrathane T-1000, 4,4-diphenyl methane diisocyanate (MDI), and 1,4 butanediol (BDO). The diols, i.e., DMS-S31, Tetrathane T-1000, and BDO were mixed, heated to 65 ± 3 °C. The MDI then was added and the mixture was stirred to prevent phase separation of the liquid mixture. After about 1 to 3 minutes, the temperature increased to about 80 °C. The liquid mixture then was poured into polytetrafluoroethylene lined trays and heated to 100 °C overnight to complete the polymerization. After cooling to ambient temperature, the resins were chipped and extruded into film for measurement of physical properties. The results are showed in Table 1. As a control, sample #1 "0% PDMS", was prepared in which the DMS-S31 fluid was omitted and replaced with a like quantity of polyols. The results are also included in Table 1.

Table 1. Molecular Weight

	Number Avg. MW (Mn, g/mol)	Weighted Avg. MW (Mw, g/mol)	Polydispersity (PDI = Mw/Mn)
0% PDMS	27,303	50,960	1.87
1% PDMS	34,007	67,837	1.99
2% PDMS	31,020	67,567	2.18
3% PDMS	48,640	110,300	2.27
4% PDMS	15,990	30,613	1.91
5% PDMS	15,887	28,647	1.80
6% PDMS	24,073	50,060	2.08
7% PDMS	24,510	41,273	1.68
10% PDMS	15,683	27,707	1.77

Table 2. Tensile Properties

	Avg. Tensile at break (Psi)	Std. dev.
0% PDMS	5887	1951
1% PDMS	5684	965
2% PDMS	6565	1645
3% PDMS	6396	800
4% PDMS	3574	457
5% PDMS	2650	582
6% PDMS	N/A	N/A
7% PDMS	2157	582
10% PDMS	1538	417

Table 3. Coefficient of Friction (CoF)

	Avg. Kinetic CoF
0% PDMS	0.295
0% PDMS dipped into 5% silicone catheter lube	0.214
1% PDMS	0.215
2% PDMS	0.174
3% PDMS	0.197
4% PDMS	0.202
5% PDMS	0.190
6% PDMS	0.204
7% PDMS	0.286
10% PDMS	0.190

Table 4. Thermal Analysis

	Tc (°C)	Tc Enthalpy (J/g)	Td (°C)
0% PDMS	161.5	16.7	305
1% PDMS	ND	ND	309
2% PDMS	ND	ND	308
3% PDMS	ND	ND	308
4% PDMS	ND	ND	306
5% PDMS	ND	ND	304
6% PDMS	ND	ND	307
7% PDMS	ND	ND	301
10% PDMS	ND	ND	309
ND is defined as "not detected".			

[0021] As shown in Tables 1-4,various Polyurethane/Polysiloxane resins were tested for various attributes such as number average molecular weight, weighted average molecular weight, polydispersity, average tensile at break, coefficient of friction and thermal analysis, the results are shown in Tables 1-4.

[0022] As shown from the results in Table 3, the addition of 3% by weight of co-polymer PDMS into the polyurethane synthesis, achieved the same if not lower coefficient of friction as currently lubricated polyurethane material. The current lubrication of polyurethane required an additional coating of 5% by weight addition of PDMS. This method of co-polymerizing lubrication functionality into polyurethane is more efficient at achieving lower coefficient of friction than simply coating an additional layer of PDMS.

[0023] As shown in Table 4, co-polymerization of PDMS into the resin backbone disrupted the crystallization of the hard segment but did not disturb the tensile properties.

[0024] Silicone diols, such as those disclosed in U.S. Patent No. 4, 647,643 are known products which can be prepared by synthetic methods reported in the art may be used as lubricants in the present invention. Non-silicone diols, for example fluorinated diols, such as those marketed as "Krytox" diols commercially available from Dupont may be used as lubricants in the present invention.

[0025] From consideration of the synthesis, those skilled in the art will appreciate that the silicone diol may include a mixture of functional R- groups such as a combination of ethylene and butylene groups.

[0026] A presently preferred silicone diol for use in the invention is a polydimethylsiloxane diol with molecular weight in range of 400 g/mole to 139,000 g/mol.

[0027] As a general rule, the polyurethanes of the present invention are easily prepared by forming a diol mixture containing the short chain diol, a long chain polyether or polyester diol and the silicone diol of formula and adding the diisocyanate to the diol mixture. Catalysts conventionally used in the synthesis of polyurethanes, such as dibutyltin dilaurate, tertiary amines (i.e. 1,4-diazabicyclo[2.2.2]octane), and metallic compounds (i.e. dibutyltin dilaurate or bismuth octanoate) may be used.

[0028] Polyether diols which can be used in the present invention include the polyalkylene glycols. Two polyether diols that are presently preferred for use in the present invention are poly(tetramethylene ether) glycols having molecular weights in the range of 650 to about 2000. Such polyols are commercially available as Polymeg 1000 (Quaker Oats Co., Chemical Division) and Terathane T-1000 (DuPont).

[0029] The diol included in the polyurethane resins of the invention may include ethylene glycol, 1,3-propylene glycol, 1,4-butane diol, neopentyl glycol, etc. Other diols which can be employed are alicyclic glycols having up to 10 carbon atoms, e.g., 1,4-cyclohexane diol, 1,4-dimethylol cyclohexane, etc.

[0030] Representative diisocyanates useful in the present invention include aromatic and alicyclic diisocyanates, such as 4,4-diphenyl methane diisocyanate (MDI), toluene diisocyanate (TDI), isophorone diisocyanate (IPDI), methylene bis (4-cyclohexyl isocyanate) (HMDI), etc. Of these, MDI and HMDI are presently preferred.

[0031] The diisocyanate and the diols are included in an amount of 1 to 10 weight percent of the product. In one or more embodiments, the diisocyanate range from 40% to 75% by weight. In one or more embodiments, silicone diol may be added in 1 to 10 weight %. In general, the ratio of OH to isocyanate functional group is about a 1:1 ratio.

[0032] The long chain polyether diol or the long chain polyether diol or a mixture of the two diols constitutes the balance of the polyurethane resin.

[0033] The polyurethane resins of the invention can be fabricated into film, tubing and other forms by conventional thermoplastic fabricating techniques including solution casting, extrusion molding, etc. The resin may have incorporated therein, as desired, conventional stabilizers and other additives. The amounts of these materials will vary depending upon the application of the polyurethane, but they are typically present in amounts ranging from about 0.2 to 50 weight percent of the polymer.

[0034] The polyurethane-polysiloxane resin may include polydimethylsilioxane (PDMS).

[0035] In one or more embodiments, it is envisioned that anti-microbial chemicals or anti-thrombogenic chemicals may be covalently bound to the resin.

[0036] The present invention also allows for the ability to injection mold catheters using a one shot mold without having to sacrifice optical clarity.

[0037] Reference throughout this specification to “one embodiment,” “certain embodiments,” “one or more embodiments” or "an embodiment" means that a particular feature, structure, material, or characteristic described in connection with the embodiment is included in at least one embodiment of the invention. Thus, the appearances of the phrases such as “in one or more embodiments,” “in certain embodiments,” “in one embodiment” or “in an embodiment” in various places throughout this specification are not necessarily referring to the same embodiment of the invention. Furthermore, the particular features, structures, materials, or characteristics may be combined in any suitable manner in one or more embodiments.

[0038] Although the invention herein has been described with reference to particular embodiments, it is to be understood that these embodiments are merely illustrative of the principles and applications of the present invention. It will be apparent to those skilled in the art that various modifications and variations can be made to the method and apparatus of the present invention without departing from the spirit and scope of the invention. Thus, it is intended that the present invention include modifications and variations that are within the scope of the appended claims and their equivalents.

What is claimed is:

1. A self-lubricating polyurethane comprising a reaction product of a diisocyanate and a diol mixture containing a short chain diol, a long chain polyether or polyester diol, and a lubricant.

2. The self-lubricating polyurethane of claim 1 wherein the diisocyanate is selected from the group consisting of an aliphatic diisocyanate, alicyclic diisocyanate and an aromatic diisocyanate.

3. The self-lubricating polyurethane of claim 2 wherein the diisocyanate is selected from the group consisting of 4,4-diphenyl methane diisocyanate (MDI), toluene diisocyanate (TDI), isophorone diisocyanate (IPDI), and methylene bis (4-cyclohexyl isocyanate) (HMDI).

4. The self-lubricating polyurethane of claim 1 wherein the short chain diol is selected from the group consisting of ethylene glycol, 1,3-propylene glycol, 1,4-butane diol, neopentyl glycol, and alicyclic glycols having up to 10 carbon atoms.

5. The self-lubricating polyurethane of claim 1 wherein the polyester diol is a polyalkylene glycol.

6. The self-lubricating polyurethane of claim 5 wherein the polyalkylene glycol is poly(tetramethylene ether) glycol.

7. The self-lubricating polyurethane of claim 1 wherein the lubricant is a non-silicone diol, silicon diol, or fluorinated lubricant.

8. The self-lubricating polyurethane of claim 7 wherein the silicone diol is polydimethylsiloxane diol.

9. The self-lubricating polyurethane of claim 8 wherein the polydimethylsiloxane diol is present in an amount ranging from about 3 to 10 weight percent of the polyurethane composition.

10. A medical article molded from the self-lubricating polyurethane composition of claim 1.

11. The medical article of claim 10, wherein the medical article is a component of a cannula, catheter, wedge, tipping, blood control actuator, stopper or syringe.

12. The self-lubricating polyurethane composition of claim 1 further comprising an anti-microbial moiety covalently attached to the self-lubricating polyurethane.

13. The self-lubricating polyurethane composition of claim 1 further comprising an anti-thrombogenic moiety covalently attached to self-lubricating polyurethane.

14. The self-lubricating polyurethane composition of claim 1 wherein the lubricant is present in an amount ranging from about 1 to 10 weight percent of the polyurethane composition.

15. The self-lubricating polyurethane of claim 1 wherein the reaction further includes a catalyst.

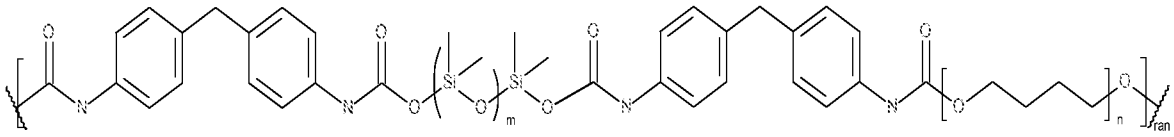
16. The self-lubricating polyurethane of claim 15 wherein the catalyst is selected from a group consisting of dibutyltin dilaurate, tertiary amines, and metallic compounds.

17. The self-lubricating polyurethane of claim 16 wherein the tertiary amine is 1,4-diazabicyclo[2.2.2]octane).

18. The self-lubricating polyurethane of claim 16 wherein the metallic compound is dibutyltin dilaurate or bismuth octanoate.

19. The self-lubricating polyurethane of claim 1 wherein the lubricant is incorporated into a backbone formed by the diisocyanate and the diol mixture.

20. A polyurethane resin of Formula I:



(I)

wherein the repeating unit of m is in the range from 5 to 2000; the repeating unit of n is in the range from 1 to 40 and the overall molecular weight of the polyurethane resins is between 15,000 g/mole to 130,000 g/mol.

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2015/041679

A. CLASSIFICATION OF SUBJECT MATTER
INV. C08G18/48 C08G18/61 C08G18/76 C08G18/32 C08G18/66
A61L29/06 A61L31/06 A61L31/14
ADD.
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C08G A61L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 647 643 A (ZDRAHALA RICHARD J [US] ET AL) 3 March 1987 (1987-03-03) cited in the application column 1, lines 5-8 column 2, lines 46-49 column 4, lines 20-57 column 5, lines 33-63 column 6, lines 23-26 examples 1-11, 13	1-19
X	WO 02/10244 A2 (3M INNOVATIVE PROPERTIES CO [US]) 7 February 2002 (2002-02-07) page 1, lines 5-8 page 7, lines 3-6 page 28, lines 1-4 example 1	1-19

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
30 September 2015	12/10/2015

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Lartigue, M

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Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2015/041679

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6 313 254 B1 (MEIJS GORDON FRANCIS [AU] ET AL) 6 November 2001 (2001-11-06) column 3, lines 35-59 examples 2, 7, 8, 15 column 8, lines 7-19 -----	1-8,10, 11,15, 16,19
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1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
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