MONSANTO
CHEMICALS — PLASTICS
®

HB-40

Monsanto Technical Bulletin No. P-104 July 1, 1952

Monsanto Chemical Company, Phosphate Division, St. Louis, Missouri

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HB-40, a relatively non-toxic, high-boiling, colorless liquid is especially of interest for plasticizing polystyrene, vinyl resins, ethyl cellulose and asphaltic materials and for softening many rubber compounds.

The product is reasonable in price and immediately available in commercial quantity.

Specific uses of HB-40 include:

Plasticizer for polystyrene casting resins
Plasticizer for polystyrene adhesives
Plasticizer for molding polyvinylcarbazole
Plasticizer for vinyl extrusions and adhesives
Plasticizer for ethyl cellulose injection moldings
Plasticizer for strip coatings for metals
Plasticizer for floor tile compositions
Plasticizer for asphalt base paints
Lubricant for tin plate
Diffusion pump oil
High-temperature lubricant
Heat-transfer medium

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I. INTRODUCTION

HB-40 is a partially hydrogenated mixture of isomeric terphenyls. The product is an almost colorless, oily liquid possessing a faint pleasant odor. It is relatively non-toxic to higher animals and does not seem to be injurious to foliage or plant life.

The principal commercial uses for HB-40 are in the plastics, coating and adhesive fields. Selected applications are described under the heading "Uses for HB-40".

II. PHYSICAL PROPERTIES OF HB-40

Appearance:	Practically colorless, oily liquid.
Color:	Less than 100 APHA
Odor:	Faint and pleasant.
Specific gravity:	1.004 ± 0.003 @ 25/15.6°C.
Pounds per gallon:	8.37 (average)
Refractive index:	1.5675 ± 0.0075 @ 25°C.
Viscosity:	144 ± 20 SUS @ 37.8°C. (100°F.) 39 ± 1 SUS @ 98.9°C. (210°F.) A. S. T. M. D-88
Pour Point:	Minus 25°C. ± 1 (−13°F. ± 2) A. S. T. M. D-97 — 39
Freezing characteristics:	The product shows a strong tendency to supercool. Some crystals are formed if the material is maintained at 0 to −5°C. for a long period of time. The crystals redissolve at about 5°C.
Coefficient of expansion:	0.000741 cc/cc/°C.
Distillation range (corrected):	Start 340-349°C. (645-660°F.) 10% 345-358°C. (653-676°F.) 50% 353-360°C. (667-680°F.) 90% 362-389°C. (684-732°F.) 95% 371-396°C. (700-745°F.) A. S. T. M. D-20
Flash point:	174°C. ± 6 (345°F. ± 10) A. S. T. M. D92-24
Flame point:	196°C. ± 6 (385°F. ± 10) A. S. T. M. D92-24

Vapor pressure:

Temperature °C.	mm. Hg.
150	2
200	15
250	69
300	230
350	625
362	760

Evaporation Loss at 100°C. for 6 hours:	0.033%
Stability to heat:	Appears stable at the boiling point in the absence of air.
Stability to acid and alkali:	Does not appear to undergo significant changes in composition when boiled with 10 percent aqueous solutions of sulfuric acid or sodium hydroxide.

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III. ELECTRICAL PROPERTIES OF HB-40

Dielectric Constant:	2.6-2.7 at 60 and 1000 cycles and 25°C.
	2.4-2.55 at 60 and 1000 cycles and 100°C.
Power factor:	less than 0.5% at 1000 cycles and 100°C.
	less than 1.0% at 60 cycles and 100°C.
	less than 0.1% at 1000 cycles and 25°C.
	less than 0.5% at 60 cycles and 25°C.
DC Volume Resistivity:	greater than 1×10^{12} ohm cm at 100°C.
	greater than 50×10^{12} ohm cm at 25°C.
Dielectric strength:	greater than 35 kv at 60 cycles and 25°C.

IV. SOLUBILITY AND COMPATIBILITY OF HB-40

HB-40 is not soluble in water, but is miscible at 25°C. with many solvents and oils, of which the following are typical:

Solvent or Oil	Solubility
Abalyn	Miscible
Acetone	Miscible
Benzene	Miscible
Carbon tetrachloride	Miscible
Castor oil	Miscible
Diethyl ether	Miscible
Ethyl acetate	Miscible
Ethyl alcohol	6 ml. of HB-40 will dissolve in 100 ml. of alcohol @ 25°C.
Linseed oil	Miscible
Mineral oil	Miscible
Petroleum oil	Miscible
Skellysolve B	Miscible
Solvent naphtha	Miscible
Turpentine	Miscible

The solubility of waxes and resins in HB-40 is given in the following tabulations:

Solute	Grams/100 grams HB-40	Temp. °C.
Acrawax C	<2.0	100
Aroplaz 905	<2.0	100
Beeswax	2.0	45
Candelilla	5.0	46
Carnauba	2.0	50
Cerese AA	2.0	51
Ceresin Yellow	5.0	60
Coumar MH 2½	>10.0	25
Dallawax No. 70	2.0	66
Dallawax No. 89	5.0	42
Loba B	<2.0	100
Montan	5.0	56
Naphthalene	30.0	35
Nonaethylene glycol hexaricinoleate	>50.0	25
Petrosene	2.0	55
Piccolite S-85	>5.0	25
Polypale	>10.0	25
Santowax M	>10.0	25
Santowax O	>30.0	25
Santowax OSA	5.0	44
Santowax P	5.0	61
Santowax R	5.0	38
Santowax R	25.0	100
Stroba	2.0	100
S & W Fused Congol	<2.0	100
Velsicol	2.0	45

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HB-40 is compatible with a number of resins or plastics materials, of which the following are typical:

Plastics	Parts HB-40/100 Parts Plastics
Butvar, low or high PVOH (polyvinyl butyral)	50
Cellulose nitrate 20-30 sec., 11% N.	10
Chlorinated rubber	100*
Ethyl cellulose (Dow Standard)	100
Formvar, type E (polyvinyl formal)	30
Polymethyl methacrylate	20
Polystyrene	100*
Vinylite VYNW	30

*Forms a sticky product; may be even more compatible.

It is important to point out that HB-40 is compatible with Gilsonite and asphaltic compounds, polyvinyl carbazole, Vistanex, Geon and similar plastics. In general, it is compatible with most aliphatic and aromatic hydrocarbons.

V. PLASTICIZING PROPERTIES

Low Temperature Flexibility:

The low temperature behavior of HB-40 in Butvar and ethylcellulose as compared with the similar value for other plasticizers is indicated in the following tabulation:

Plasticizer (50 Parts)	Resin (100 Parts)	Flex. Temp. °C.	Brittle Point °C.
Dibutyl sebacate	Butvar	about −60	below −70
Santicizer B-16	Butvar	−29.0	−33
Dimethyl phthalate	Butvar	−27.5	−39
HB-40	Butvar	−14.5	−8
Tricresyl phosphate	Butvar	−8.5	−7
Dibutyl sebacate	Ethylcellulose	below −50	−65
Santicizer B-16	Ethylcellulose	−37	−31
Dimethyl phthalate	Ethylcellulose	−33.5	−35
Tricresyl phosphate	Ethylcellulose	−26.5	−21
HB-40	Ethylcellulose	−23.5	−21

Volatility:

Test sheets for volatility determinations were 1x3 inches with gauge varying from 0.019 to 0.025 inches and were placed on a metal foil. A 24 hour time interval was found sufficient to give the proper volatility relationships. The circulating oven used in these tests had an air flow of about 150-200 ft/min. and a temperature of 105°C. was used. The following comparative tabulation indicates the volatility of the various plasticizers from Butvar and ethylcellulose sheets using 50 parts of plasticizer and 100 parts of resin.

Plasticizer	Percent Plasticizer Lost From Butvar	Percent Plasticizer Lost From Ethylcellulose
Dimethyl phthalate	93.4	81.4
HB-40	55.3	51.7
Santicizer M-17	39.7	44.4
Dibutyl sebacate	27.5	31.8
Santicizer B-16	16.9	12.7
Tricresyl phosphate	2.4	5.1

Water Absorption:

Samples 1x3 inches by 0.019-0.025 inches were conditioned at 50°C. for 24 hours, weighed and placed in beakers of distilled water for 24 hours at 25°C., then weighed and finally reconditioned at 50°C. for 24 hours and reweighed. Comparative water absorption values for various plasticizers used at a level of 50 parts in 100 parts of Butvar and ethylcellulose are given as follows:

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Plasticizers	Percent Weight Loss	
	Butvar	Ethylcellulose
Dimethyl phthalate	3.31	9.5
Santicizer M-17	1.23	4.8
HB-40	0.53	0.31
Santicizer B-16	0.15	0.08
Tricresyl phosphate	0.03	0.24
Dibutyl sebacate	0.0	0.13

Tensile Strength and Elongation:

All tensile strength measurements were made on a Scott IP-4 tilt table using a one inch jaw separator; 200 r.p.m. and a fifty pound weight. The samples were ⅜ inches wide and 0.020 to 0.025 inch gauge. The following is a comparative tabulation of the tensile strength and elongation values for HB-40 and various other plasticizers used at a level of 50 parts in 100 parts of Butvar and ethylcellulose:

Plasticizer	Resin	Tensile Strength p.s.i. at 25° C.	Percent Elongation
HB-40	Butvar	1800	230
Santicizer M-17	Butvar	1720	280
Tricresyl phosphate	Butvar	1300	235
Santicizer B-16	Butvar	800	350
Dimethyl phthalate	Butvar	620	345
Dibutyl sebacate	Butvar	560	380
HB-40	Ethylcellulose	2310	80
Santicizer M-17	Ethylcellulose	2070	84
Tricresyl phosphate	Ethylcellulose	2550	82
Santicizer B-16	Ethylcellulose	1420	77
Dimethyl phthalate	Ethylcellulose	1080	70
Dibutyl sebacate	Ethycellulose	830	80

Effect on Rubber:

HB-40 has a pronounced swelling action on many rubber compounds. This is illustrated by the following results of a 68 hour test conducted at room temperature:

Name of Rubber Composition	Source	Percent Swelling Length	Thickness
Buna S	Monsanto Chemical Co.	17.5	15.2
Hycar OR	Monsanto Chemical Co.	1.2	1.2
Koroseal	B. F. Goodrich Co.	0	0
Neoprene	Gates Engineering Co.	11.2	7.5
Paranite	Manhattan Rubber Co.	0	0
Perbunan	Monsanto Chemical Co.	13.6	8.5

The following are presumably compositions of natural rubber:

D173K215	Goodyear Tire & Rubber	10.8	8.9
T-50-P-58	Goodyear Tire & Rubber	4.5	7.9
9215	Goodyear Tire & Rubber	26.3	24.3

Color Stability:

To determine the color stability of HB-40 with reference to several other plasticizers, the following tests were made using the Gardner Standards for comparing the colors. For color after heating, 5 ml. of the plasticizer was placed in a Pyrex tube and heated in an oil bath for 2 hours at 250°C. For color changes after exposure to light 5 ml. of plasticizer was placed in a quartz test tube and exposed to a G. E. Sunlamp for 50 hours. The bulb was 6 inches above the turntable and the bottom of the test tube was 5.5 inches from the center of the turn table and at a 45 degree angle.

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Plasticizer	Original Color	Color after Heating	Color after Light
Dimethyl phthalate.	o	o	o
Dibutyl sebacate	o	1	o
Santicizer B-16	o	1	o
Dibutyl phthalate	o	2	o
Santicizer M-17	o	2	1
Tricresyl phosphate	o	5	7-8
HB-40	o	11	7-8
Santicizer 8	3	13-14	13-14

VI. TOXICOLOGY

Information submitted from a reliable source indicates that HB-40 is practically non-toxic. Rats and rabbits survived acute doses of 25 grams per kilo. Chronic experiments with six grams per kilo. ingested daily for four months produced no toxicity.

Preliminary results of experimental work with HB-40 in the horticultural field indicate a low order of phytotoxicity. HB-40 does not seem injurious to plant leaves.

VII. USES FOR HB-40

Plasticizer Field (General Comments):

In the plastics field HB-40 is particularly of interest for use with polystyrene, vinyl resins, ethylcellulose and asphaltic compounds. It is also of interest as a "softener" or swelling agent for rubber type compounds.

HB-40 plasticizer imparts good tensile strength, good elongation and good moisture resistant qualities to these plastics. Moreover, the plasticizer has good electrical properties which is very important when these plastics are used in the electrical field.

The low temperature characteristics of HB-40 are about average and its volatility is somewhat higher than average, but substantially lower than that of a number of widely used plasticizers. HB-40 does not have the outstanding resistance to discoloration possessed by several other commercial plasticizers when exposed to elevated temperatures and ultraviolet rays. However, in the case of certain plastics where HB-40 is used in combination with other plasticizers, it is known that the plastics possess good light stability.

The very low order of toxicity of HB-40, and its availability at relatively low cost are also important factors in the commercial use of this plasticizer.

With reference to the above named plastics, the properties of HB-40 indicate that the material is especially of interest for casting resins, plastics emulsions, including adhesives, plastics paint coatings and plastics extrusions.

It is also indicated that HB-40 should be used as a co-plasticizer or as an extender for primary plasticizers selected to give outstanding low temperature and low volatility characteristics.

HB-40 for Polystyrene Casting Resins:

HB-40 is highly compatible with polystyrene and imparts the type of plasticizing action desired in the use of polystyrene and related plastics for casting resin purposes. This is illustrated by the National Bureau of Standards Casting Resin, which is an outgrowth of wartime research on such devices as the radio proximity fuse. A representative formula is as follows:

Compounds	Percent by Weight
2,5-dichlorostyrene	33.0
Poly 2,5-dichlorostyrene	21.5
Styrene monomer	21.0
Polystyrene	11.00
HB-40	13.0
Solution containing 60% divinylbenzene	0.5
	100.0

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The following are some of the measured mechanical and electrical properties of the N. B. S. Casting Resin, cured at 50°C., employing 0.1 percent of benzoyl peroxide catalyst:

Compressive strength, p. s. i.	17,100
Izod impact, ft.-lb./in. of notch	0.228
Coefficient of thermal expansion per °C.	11×10^{-5} (approx.)
Water absorption (24 hr. immersion)	0.01%
Volumetric shrinkage or polymerization	8.0%
Density of monomer	1.13
Heat distortion, °C.	68-70
Power factor (at 100 megacycles and 50% R. H.)	0.0004-0.0008
Dielectric constant (at 100 megacycles and 50% R. H.)	2.5
Dielectric strength (1/8 in. sample; volts/mil)	610-660
Volume resistivity (megohm-cm.)	$> 10^{17}$

The liquid resin may be stored at 0°C. for a few months without a catalyst, and for a few weeks with a catalyst, before the viscosity increases to a point where pouring is difficult. At room temperature, the catalyzed casting resin gradually increases in viscosity and must be used in a day or two. The cured polymer may be drilled or turned on a lathe.

HB-40 Plasticizer for Polystyrene Emulsion Adhesives:

Emulsified HB-40 is added to the extent of about 30-35 percent to styrene monomer which is then emulsified in water using oil base emulsifying agents such as triethanolamine oleate or stearate. The emulsified styrene monomer and HB-40 combination is then polymerized using selected peroxide catalysts to produce the desired adhesive emulsion. The polymerization reaction is carried out in an autoclave under carefully controlled conditions so that the emulsion will not break. Dibutyl phthalate may be used in combination with HB-40 as a co-plasticizer in this process.

HB-40 — Polystyrene Adhesive Formulations:

Combinations of HB-40, Aroclors, Lustron A (polystyrene), ethylcellulose, Santowax and other selected resins and plastics make good adhesives.

a. LABEL ADHESIVES:

A satisfactory adhesive for brush application to labels when quick drying and non-wrinkling are required consists of:

Ingredients	Percent by Weight
Lustrex, LM-3	15
HB-40	10
Aroclor 5460	15
Ethylenedichloride-butylchloride mixture	10
Acetone	50

For mechanical application when slower drying and non-wrinkling are required, it is suggested to use a 50-50 mixture of acetone and toluene instead of acetone alone, as described in the above formula.

b. PRESSURE SENSITIVE ADHESIVE FORMULAE:

	Ingredients	Percent by Weight
Formula 1	Lustrex, LM-3	28
	Aroclor 1254	35
	HB-40	35
	Ethylcellulose N-100	2
Formula 2	Lustrex, LM-3	28
	Aroclor 5460	35
	HB-40	35
	Ethylcellulose N-100	2

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HB-40 Plasticizer for Molding Polyvinylcarbazole:

Polyvinylcarbazole is a thermoplastic material possessing electrical qualities comparable to polystyrene.

The material has a heat distortion point at about 150°C. and is too brittle for practical molding operations.

Relatively small amounts of HB-40 lower the molding temperature to practical values and improve the properties of the finished plastics.

The product has a very small temperature coefficient and a dielectric constant about 3.0. Its dielectric strength is high up to temperatures of about 150°C.

Made under the tradename Polectron, the material is being used in specialized electrical applications including the impregnation of some electrical condensers. Polectron polymer plasticized with 50% to 100% of HB-40 is used in various plastics applications.

HB-40 Plasticizer for Vinyl Extrusions:

HB-40 is especially recommended for Geon and similar vinyl plastics extrusions. In this operation it is desirable to use HB-40 at a level of about 25 percent based on the total weight of the plasticizers. When HB-40 is used in combination with dioctyl phthalate or certain other selected plasticizers, the volatility characteristics of the plasticizer combinations are entirely satisfactory for vinyl extrusion work. The finished plastics possess good light stability qualities. HB-40 plasticizes Vinylite without seeming to soften it excessively. The finished plastics has a dry feel instead of a greasy feel.

HB-40 Plasticizer for Vinyl and Vistanex Resin Adhesive Tapes:

HB-40 is attractive for use as a co-plasticizer in making vinyl and Vistanex resin base adhesive tapes. Used in combination with tricresyl phosphate, dibutyl phthalate or Santicizer B-16, HB-40 offers interesting properties at a saving in cost. When used as the only plasticizer for these compositions, HB-40 gives properties similar to those derived from tricresyl phosphate and dibutyl phthalate.

Vinyl Acetate Adhesives:

HB-40 with dibutyl phthalate or with combinations of Aroclor 1260 and dibutyl phthalate makes excellent co-plasticizer mixtures for polyvinyl acetate base adhesives.

HB-40 for Ethylcellulose Injection Molding:

HB-40 has proved satisfactory as a plasticizer for the injection molding of ethylcellulose. Although HB-40 is not more outstanding for this purpose than certain other plasticizers, nevertheless its good efficiency at lower costs makes it more attractive. The practice is to use about 15 percent of HB-40 in the ethylcellulose molding powder.

Strip Coating for Metals:

The following formulation containing HB-40 plasticizer and ethylcellulose is a good strip coating for metals:

Ingredients	Percent by Weight
Ethylcellulose N-100	25
HB-40	14
Aroclor 5460	20
Paraffin	31
Staybelite Ester No. 10	10
Age Rite Alba (stabilizer)	1
	101

Synthetic Rubber Latex:

HB-40 used at a level of 15 to 30 percent improves the miscibility of synthetic rubber latex with mineral oil to a marked degree.

This suggests the use of HB-40 in other commercial applications where improvement in the miscibility of petroleum hydrocarbons with rubber compounds and plastics materials is desired.

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HB-40 Non-Plasticizer Lubricant for Cellulose Acetate:

In the manufacture of cigarette cases, rattles and toys from cellulose acetate sheets, it is desirable to have a non-plasticizing lubricant to prevent the acetate sheets from sticking together during the hot-stamping operation. Because of its lack of plasticizing action on cellulose acetate, HB-40 is ideal for this purpose.

Floor-Tile:

HB-40 plasticizer is especially good for a variety of resinous materials used in making floor-tile. This includes asphaltic materials, certain oil-proof resins, vinyls, coumar resins, Piccolite, Polypale resins, Aroclors and rosin derivatives.

Asphalt Base Paints:

HB-40 works well as a plasticizer for maintenance paints with asphalt or Gilsonite bases.

The addition of about 2 percent of HB-40 to a high melting asphalt compound for molding purposes gives a very high gloss.

HB-40 for Enamel Finishes:

HB-40 imparts considerable flow to enamel films and increases gloss. It is quite effective as an anti-skinning agent, but in this connection it tends to retard the drying of alkyd enamels. HB-40 apparently has no deleterious effect relative to after yellowing or the water resistance of enamel paints. The product is valuable for use in four hour enamels to ease brushing, increase flow and prevent skinning without imparting odor.

HB-40 Lubrication for Tin Plate:

As a tin plate lubricant in place of oils, such as palm oil, HB-40 offers improvements particularly where phenolic coatings are applied. The enamel adhesion is good and HB-40 does not impart objectionable taste or toxicological problems which are important factors in cans intended for food products.

Diffusion Pump Oil:

Processed HB-40, i. e., after removal of about 10 percent of the lowest boiling fraction, is a good oil for use in diffusion pumps. It is possible to reach a pressure as low as 10^{-4} mm. and the oil may be operated in conventional type units with a pressure on the vapor column of over 5 mm. of mercury without decomposition.

Unprocessed HB-40 appears to be suitable for use in booster-type vacuum pumps.

HB-40 High-Temperature Lubricant:

HB-40 is used as high-temperature lubricant for chain drives on bakery ovens. Its lubricity, non-toxic qualities and lack of odor make HB-40 particularly attractive for uses of this type.

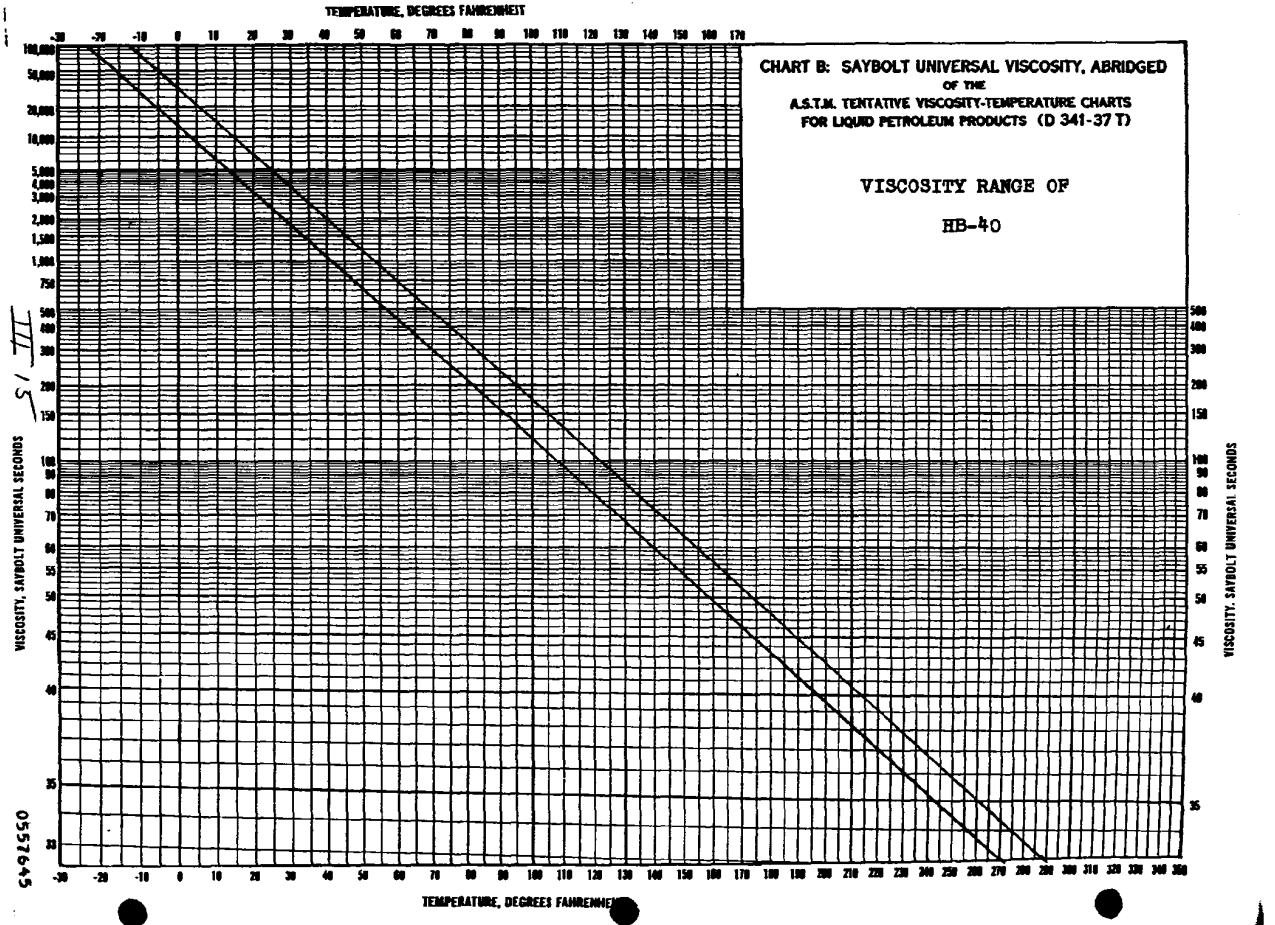
Heat-Transfer Medium:

HB-40 is a very satisfactory liquid for melting-point baths, particularly where temperatures exceeding 300°C. are not desired.

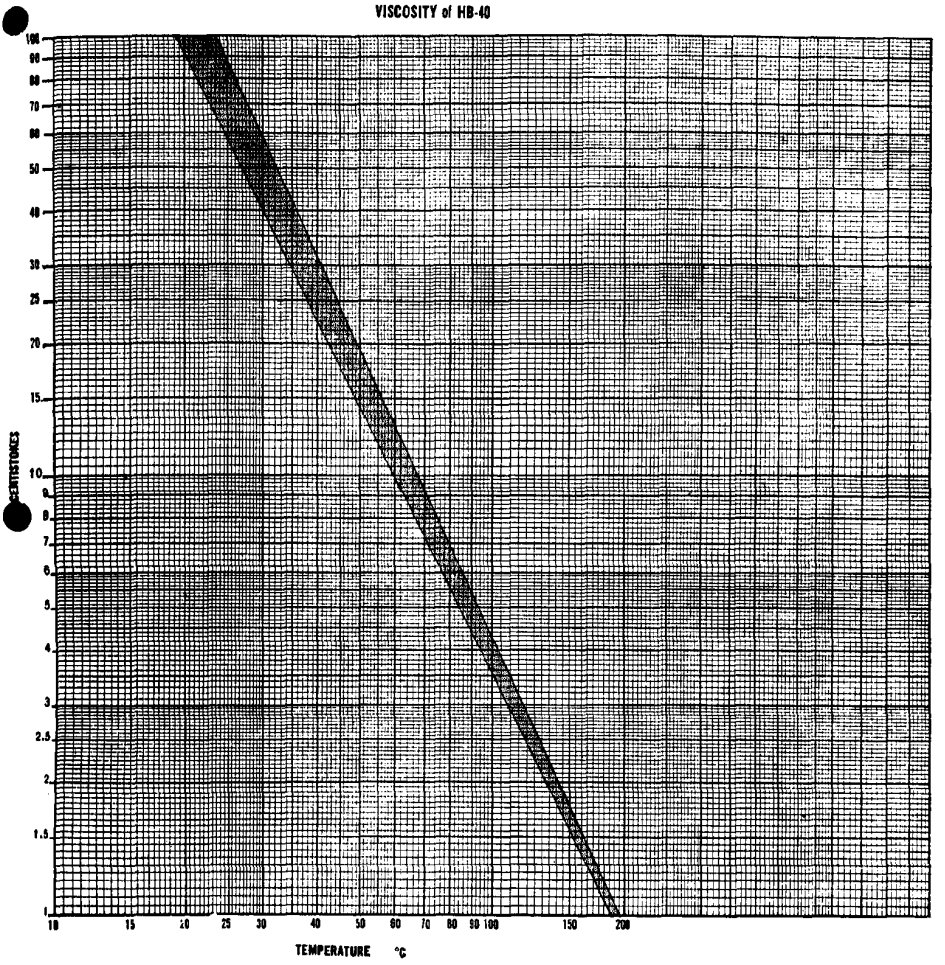
It is also of interest as an actuating medium for thermostatic controls provided that the operating temperatures are not beyond the range in which HB-40 can be used satisfactorily.

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