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(54) Title: COMPOSITIONS INCLUDING 1,1,1,2,3,4,4,5,5,5-DECAFLUOROPENTANE

(57) Abstract

Compositions of 1,1,1,2,3,4,4,5,5,5-decafluoropentane, bis(fluoromethyl) ether, 2,2,4,4-tetrafluorooxetane, 2,2,3,3-tetrafluorooxetane, 1,1,1,2-tetrafluoro-2-(fluoromethoxy)ethane, 1-(difluoromethoxy)-1,2,2-trifluoroethane, 1-(difluoromethoxy)-1,1,2-trifluoroethane, acetone, cyclopentane, ethyl acetate, ethyl formate, methyl *tert*-butyl ether, methyl acetate, methyl formate, propylene oxide, 2,2-dimethylbutane, n-pentane or n-propanol are useful as cleaning agents, expansion agents for polyolefins and polyurethanes, aerosol propellants, refrigerants, heat transfer media, gaseous dielectrics, fire extinguishing agents, power cycle working fluids, polymerization media, particulate removal fluids, carrier fluids, buffing abrasive agents, and displacement drying agents.

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TITLE

COMPOSITIONS INCLUDING 1,1,1,2,3,4,4,5,5,5-DECAFLUOROPENTANE

FIELD OF THE INVENTION

This invention relates to compositions that include 1,1,1,2,3,4,4,5,5,5-decafluoropentane. These compositions are useful as refrigerants, cleaning agents, expansion agents for polyolefins and polyurethanes, aerosol propellants, heat transfer media, gaseous dielectrics, fire extinguishing agents, power cycle working fluids, polymerization media, particulate removal fluids, carrier fluids, buffing abrasive agents, and displacement drying agents.

BACKGROUND OF THE INVENTION

Fluorinated hydrocarbons have many uses, one of which is as a refrigerant. Such refrigerants include trichlorofluoromethane (CFC-11) dichlorodifluoromethane (CFC-12) and chlorodifluoromethane (HCFC-22).

In recent years it has been pointed out that certain kinds of fluorinated hydrocarbon refrigerants released into the atmosphere may adversely affect the stratospheric ozone layer. Although this proposition has not yet been completely established, there is a movement toward the control of the use and the production of certain chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) under an international agreement.

Accordingly, there is a demand for the development of refrigerants that have a lower ozone depletion potential than existing refrigerants while still achieving an acceptable performance in refrigeration applications.

In refrigeration applications, a refrigerant is often lost during operation through leaks in shaft seals, hose connections, soldered joints and broken lines. In addition, the refrigerant may be released to the atmosphere during maintenance procedures on refrigeration equipment. If the refrigerant is not a pure component or an azeotropic or azeotrope-like composition, the refrigerant composition may change when leaked or discharged to the atmosphere from the refrigeration equipment, which may cause the refrigerant to become flammable or to have poor refrigeration performance.

Accordingly, it is desirable, if possible, to use as a refrigerant a single compound or an azeotropic or azeotrope-like composition of more than one

compound.

It is also desirable to find replacements for CFCs and HCFCs for use as a cleaning agent or solvent to clean, for example, electronic circuit boards. It is preferred that the cleaning agents be azeotropic or azeotrope-like because in vapor degreasing operations the cleaning agent is generally redistilled and reused for final rinse cleaning.

Replacements for CFCs and HCFCs may also useful as blowing agents in the manufacture of closed-cell polyurethane, phenolic and thermoplastic foams, as propellants in aerosols, as heat transfer media, gaseous dielectrics, fire extinguishing agents, power cycle working fluids such as for heat pumps, inert media for polymerization reactions, fluids for removing particulates from metal surfaces, as carrier fluids that may be used, for example, to place a fine film of lubricant on metal parts, as buffing abrasive agents to remove buffing abrasive compounds from polished surfaces such as metal, as displacement drying agents for removing water, such as from jewelry or metal parts, as resist developers in conventional circuit manufacturing techniques including chlorine-type developing agents, or as strippers for photoresists when used with, for example, a chlorohydrocarbon such as 1,1,1-trichloroethane or trichloroethylene.

SUMMARY OF THE INVENTION

The present invention relates to the following compositions: 1,1,1,2,3,4,4,5,5,5-decafluoropentane and bis(fluoromethyl) ether, 2,2,4,4-tetrafluorooxetane, 2,2,3,3-tetrafluorooxetane, 1,1,1,2-tetrafluoro-2-(fluoromethoxy)ethane, 1-(difluoromethoxy)-1,2,2-trifluoroethane, 1-(difluoromethoxy)-1,1,2-trifluoroethane, acetone, cyclopentane, ethyl acetate, ethyl formate, methyl *tert*-butyl ether, methyl acetate, methyl formate, propylene oxide, 2,2-dimethylbutane, n-pentane or n-propanol. These compositions are useful as refrigerants, cleaning agents, expansion agents for polyolefins and polyurethanes, aerosol propellants, heat transfer media, gaseous dielectrics, fire extinguishing agents, power cycle working fluids, polymerization media, particulate removal fluids, carrier fluids, buffing abrasive agents, and displacement drying agents. Further, the invention relates to the discovery of binary azeotropic or azeotrope-like compositions comprising effective amounts of these components to form an azeotropic or azeotrope-like composition.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a graph of the vapor/liquid equilibrium curve for mixtures of 4310mee and 152E at 25°C;

Figure 2 is a graph of the vapor/liquid equilibrium curve for mixtures of 4310mee and 245eaE at 25°C;

Figure 3 is a graph of the vapor/liquid equilibrium curve for mixtures of 4310mee and acetone at 25°C;

Figure 4 is a graph of the vapor/liquid equilibrium curve for mixtures of 4310mee and cyclopropane at 25°C;

Figure 5 is a graph of the vapor/liquid equilibrium curve for mixtures of 4310mee and ethyl acetate at 25°C;

Figure 6 is a graph of the vapor/liquid equilibrium curve for mixtures of 4310mee and ethyl formate at 25°C;

Figure 7 is a graph of the vapor/liquid equilibrium curve for mixtures of 4310mee and methyl acetate at 25°C;

Figure 8 is a graph of the vapor/liquid equilibrium curve for mixtures of 4310mee and methyl formate at 25°C;

Figure 9 is a graph of the vapor/liquid equilibrium curve for mixtures of 4310mee and propylene oxide at 25°C;

Figure 10 is a graph of the vapor/liquid equilibrium curve for mixtures of 4310mee and 2,2-dimethylbutane at 25°C;

Figure 11 is a graph of the vapor/liquid equilibrium curve for mixtures of 4310mee and n-pentane at 25°C;

Figure 12 is a graph of the vapor/liquid equilibrium curve for mixtures of 4310mee and n-propanol at 25°C; and

Figure 13 is a graph of the vapor/liquid equilibrium curve for mixtures of 4310mee and MTBE at 18.46°C.

DETAILED DESCRIPTION

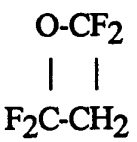
The present invention relates to the discovery of compositions of 1,1,1,2,3,4,4,5,5,5-decafluoropentane (HFC-4310mee) and bis(fluoromethyl) ether (152E), 2,2,4,4-tetrafluorooxetane (c234fEαβ), 2,2,3,3-tetrafluorooxetane (c234fEβγ), 1,1,1,2-tetrafluoro-2-(fluoromethoxy)ethane (245ebEβγ), 1-(difluoromethoxy)-1,2,2-trifluoroethane (245eaE), 1-(difluoromethoxy)-1,1,2-trifluoroethane (245caEαβ), acetone, cyclopentane, ethyl acetate, ethyl formate, methyl *tert*-butyl ether (MTBE), methyl acetate, methyl formate, propylene oxide,

2,2-dimethylbutane, n-pentane or n-propanol. 1-99 wt.% of each of the components in the above compositions can be used as refrigerants.

The present invention also relates to the discovery of azeotropic or azeotrope-like compositions of effective amounts of 4310mee and 152E, c234fEαβ, c234fEβγ, 245ebEβγ, 245eaE, 245caEαβ, acetone, cyclopentane, ethyl acetate, ethyl formate, MTBE, methyl acetate, methyl formate, propylene oxide, 2,2-dimethylbutane, n-pentane, or n-propanol to form an azeotropic or azeotrope-like composition.

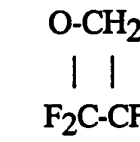
The components of the compositions of this invention include the following.

1. 1,1,1,2,3,4,4,5,5,5-decafluoropentane (HFC-4310mee, or $CF_3CFHCFHCF_2CF_3$) boiling point = 50.0C,
2. Bis(fluoromethyl) ether (152E, CH_2FOCH_2F), having a boiling point = 33C,
3. 2,2,4,4-tetrafluorooxetane (c234fEαβ, or $C_3H_2F_4O$, having a structure of



boiling point = 21.2°C),

4. 2,2,3,3-tetrafluorooxetane (c234fEβγ, or $C_3H_2F_4O$, having a structure of



boiling point =28°C),

5. 1,1,1,2-tetrafluoro-2-(fluoromethoxy)ethane, (245ebEβγ, or $CH_2FOCHFCF_3$, boiling point = 43°C)
6. 1-(difluoromethoxy)-1,2,2-trifluoroethane (245eaE, or $CHF_2OCHFCHF_2$, boiling point = 53°C),
7. 1-(difluoromethoxy)-1,1,2-trifluoroethane (245caEαβ, or $CHF_2OCF_2CH_2F$, boiling point = 40°C),
8. acetone, CH_3COCH_3, boiling point = 56.2C,
9. cyclopentane, C_5H_{10}, boiling point = 49.2C,
10. ethyl acetate, $CH_3COOC_2H_5$, boiling point = 77C,
11. ethyl formate, $HCOOC_2H_5$, boiling point = 53-54C,
12. methyl *tert*-butyl ether, $(CH_3)_3C(OCH_3)$, or MTBE, boiling point = 55.2C,
13. methyl acetate, CH_3COOCH_3, boiling point = 56.9C,
14. methyl formate, $HCOOCH_3$, boiling point = 31.5C,

15. propylene oxide, C3H6O, boiling point = 34.23C,
16. 2,2-dimethylbutane, $CH_3CH_2C(CH3)_3$, boiling point = 49.74C,
17. n-pentane, $CH_3CH_2CH_2CH_2CH_3$, boiling point = 35.07C,
18. n-propanol, $CH_3CH_2CH_2OH$, boiling point = 97.2C.

152E, CAS Reg. No. [462-51-1], has been prepared by reacting poly(oxymethylene) with sulfur tetrafluoride as reported by Hasek, et. al. in J. Am. Chem. Soc. Vol. 82, pages 543-551 (1960).

c234fEαβ may be prepared by direct fluorination of trimethylene oxide (cyclo-$CH_2CH_2CH_2O$-) using techniques described by Lagow and Margrave in Progress in Inorganic Chemistry, Vol. 26, pp. 161-210 (1979) or by Adcock and Cherry in Ind. Eng. Chem. Res., Vol. 26, pp. 208-215 (1987). The direct fluorination is carried out to the desired level of fluorine incorporation into the starting material, and products receovered by fractional distillation.

c234fEβγ (CAS Reg. No. 765-63-9) has been prepared by Weinmayr (J. Org. Chem., Vol. 28, pp. 492-494 (1963)) as a by-product from the reaction of TFE with formaldehyde in HF.

245caEαβ (CAS Reg. No. 69948-24-9), HFOC-245caEαβ, has been prepared by hydrogenation of 2-chloro-1,1,2-trifluoroethyl difluoromethyl ether at 200°C over a palladium catalyst as reported by Bagnall, et. al. in J. Fluorine Chem. Vol. 13, pages 123-140 (1979).

245eaE (CAS Reg. No. 60113-74-8), HFOC-245eaE, has been prepared by hydrogenation of 1,2-dichloro-1,2,2-trifluoroethyl difluoromethyl ether at a temperature range of 200-250C using a palladium on charcoal catalyst as disclosed by Bell, et. al. U. S. Patent 4, 149, 018.

245ebEβγ (CAS Reg. No. 56885-27-9), HFOC-245ebEβγ has been prepared by fluorination of 1,1,1,2-tetrafluoro-2-(chloromethoxy)ethane using HF and a chromium oxyfluoride catalyst as disclosed by Siegemund, et. al. in Ger. Offen. 2,520,962.

By "azeotropic" composition is meant a constant boiling liquid admixture of two or more substances that behaves as a single substance. One way to characterize an azeotropic composition is that the vapor produced by partial evaporation or distillation of the liquid has the same composition as the liquid from which it was evaporated or distilled, that is, the admixture distills/refluxes without compositional change. Constant boiling compositions are characterized as azeotropic because they exhibit either a maximum or minimum boiling point, as

compared with that of the non-azeotropic mixtures of the same components.

By "azeotrope-like" composition is meant a constant boiling, or substantially constant boiling, liquid admixture of two or more substances that behaves as a single substance. One way to characterize an azeotrope-like composition is that the vapor produced by partial evaporation or distillation of the liquid has substantially the same composition as the liquid from which it was evaporated or distilled, that is, the admixture distills/refluxes without substantial composition change. Another way to characterize an azeotrope-like composition is that the bubble point vapor pressure and the dew point vapor pressure of the composition at a particular temperature are substantially the same.

It is recognized in the art that a composition is azeotrope-like if, after 50 weight percent of the composition is removed such as by evaporation or boiling off, the difference in vapor pressure between the original composition and the composition remaining after 50 weight percent of the original composition has been removed is less than 10 percent, when measured in absolute units. By absolute units, it is meant measurements of pressure and, for example, psia, atmospheres, bars, torr, dynes per square centimeter, millimeters of mercury, inches of water and other equivalent terms well known in the art. If an azeotrope is present, there is no difference in vapor pressure between the original composition and the composition remaining after 50 weight percent of the original composition has been removed.

Therefore, included in this invention are compositions of effective amounts of 4310mee and 152E, c234fEαβ, c234fEβγ, 245ebEβγ, 245eaE, 245caEαβ, acetone, cyclopentane, ethyl acetate, ethyl formate, MTBE, methyl acetate, methyl formate, propylene oxide, 2,2-dimethylbutane, n-pentane or n-propanol, such that after 50 weight percent of an original composition is evaporated or boiled off to produce a remaining composition, the difference in the vapor pressure between the original composition and the remaining composition is 10 percent or less.

For compositions that are azeotropic, there is usually some range of compositions around the azeotrope point that, for a maximum boiling azeotrope, have boiling points at a particular pressure higher than the pure components of the composition at that pressure and have vapor pressures at a particular temperature lower than the pure components of the composition at that temperature, and that, for a minimum boiling azeotrope, have boiling points at a particular pressure lower than the pure components of the composition at that pressure and have vapor pressures at a particular temperature higher than the pure components of the composition at that temperature. Boiling temperatures and vapor pressures above

or below that of the pure components are caused by unexpected intermolecular forces between and among the molecules of the compositions, which can be a combination of repulsive and attractive forces such as van der Waals forces and hydrogen bonding.

The range of compositions that have a maximum or minimum boiling point at a particular pressure, or a maximum or minimum vapor pressure at a particular temperature, may or may not be coextensive with the range of compositions that have a change in vapor pressure of less than about 10% when 50 weight percent of the composition is evaporated. In those cases where the range of compositions that have maximum or minimum boiling temperatures at a particular pressure, or maximum or minimum vapor pressures at a particular temperature, are broader than the range of compositions that have a change in vapor pressure of less than about 10% when 50 weight percent of the composition is evaporated, the unexpected intermolecular forces are nonetheless believed important in that the refrigerant compositions having those forces that are not substantially constant boiling may exhibit unexpected increases in the capacity or efficiency versus the components of the refrigerant composition.

The components of the compositions of this invention have the following vapor pressures at 25°C.

Component	Psia	kPa
4310mee	4.36	30
152E	11.00	76
c234fEαβ	16.75	115
c234fEβγ	13.26	91
245ebEβγ	7.63	53
245eaE	5.22	36
245caEαβ	8.51	59
acetone	4.45	31
cyclopentane	6.14	42
ethyl acetate	1.87	13
ethyl formate	4.69	32
MTBE	4.59	32
methyl acetate	4.18	29
methyl formate	10.68	74
propylene oxide	10.43	72
2,2-dimethylbutane	6.17	43
n-pentane	10.29	71
n-propanol	0.403	2.8

Substantially constant boiling, azeotropic or azeotrope-like compositions of this invention comprise the following (all compositions are measured at 25°C):

COMPONENTS	WEIGHT RANGES (wt.%/wt/%)	PREFERRED (wt.%/wt.%)
4310mee/152E	1-70/30-99	40-70/30-60
4310mee/c234fEαβ	1-41/59-99	1-41/59-99
4310mee/c234fEβγ	1-49/51-99	1-49/51-99
4310mee/245ebEβγ	1-99/1-99	15-99/1-85
4310mee/245eaE	1-99/1-99	40-99/1-60
4310mee/245caEαβ	1-99/1-99	10-80/20-90
4310mee/acetone	1-99/1-99	40-99/1-60
4310mee/cyclopentane	39-83/17-61	39-83/17-61
4310mee/ethyl acetate	65-99/1-35	65-99/1-35
4310mee/ethyl formate	53-89/11-47	53-89/11-47
4310mee/MTBE	1-99/1-99	40-99/1-60
4310mee/methyl acetate	50-89/11-50	50-89/11-50
4310mee/methyl formate	36-82/18-64	50-82/18-50
4310mee/propylene oxide	28-79/21-72	50-79/21-50
4310mee/2,2-dimethylbutane	39-82/18-61	50-82/18-50
4310mee/n-pentane	29-77/23-71	40-77/23-60
4310mee/n-propanol	85-99.3/0.7-15	85-99.3/0.7-15

For purposes of this invention, "effective amount" is defined as the amount of each component of the inventive compositions which, when combined, results in the formation of an azeotropic or azeotrope-like composition. This definition includes the amounts of each component, which amounts may vary depending on the pressure applied to the composition so long as the azeotropic or azeotrope-like compositions continue to exist at the different pressures, but with possible different boiling points.

Therefore, effective amount includes the amounts, such as may be expressed in weight percentages, of each component of the compositions of the instant invention which form azeotropic or azeotrope-like compositions at temperatures or pressures other than as described herein.

For the purposes of this discussion, azeotropic or constant-boiling is intended to mean also essentially azeotropic or essentially-constant boiling. In other

words, included within the meaning of these terms are not only the true azeotropes described above, but also other compositions containing the same components in different proportions, which are true azeotropes at other temperatures and pressures, as well as those equivalent compositions which are part of the same azeotropic system and are azeotrope-like in their properties. As is well recognized in this art, there is a range of compositions which contain the same components as the azeotrope, which will not only exhibit essentially equivalent properties for refrigeration and other applications, but which will also exhibit essentially equivalent properties to the true azeotropic composition in terms of constant boiling characteristics or tendency not to segregate or fractionate on boiling.

It is possible to characterize, in effect, a constant boiling admixture which may appear under many guises, depending upon the conditions chosen, by any of several criteria:

* The composition can be defined as an azeotrope of A, B, C (and D...) since the very term "azeotrope" is at once both definitive and limitative, and requires that effective amounts of A, B, C (and D...) for this unique composition of matter which is a constant boiling composition.
* It is well known by those skilled in the art, that, at different pressures, the composition of a given azeotrope will vary at least to some degree, and changes in pressure will also change, at least to some degree, the boiling point temperature. Thus, an azeotrope of A, B, C (and D...) represents a unique type of relationship but with a variable composition which depends on temperature and/or pressure. Therefore, compositional ranges, rather than fixed compositions, are often used to define azeotropes.
* The composition can be defined as a particular weight percent relationship or mole percent relationship of A, B, C (and D...), while recognizing that such specific values point out only one particular relationship and that in actuality, a series of such relationships, represented by A, B, C (and D...) actually exist for a given azeotrope, varied by the influence of pressure.
* An azeotrope of A, B, C (and D...) can be characterized by defining the compositions as an azeotrope characterized by a boiling point at a given pressure, thus giving identifying characteristics without unduly limiting the scope of the invention by a specific numerical

composition, which is limited by and is only as accurate as the analytical equipment available.

The azeotrope or azeotrope-like compositions of the present invention can be prepared by any convenient method including mixing or combining the desired amounts. A preferred method is to weigh the desired component amounts and thereafter combine them in an appropriate container.

Specific examples illustrating the invention are given below. Unless otherwise stated therein, all percentages are by weight. It is to be understood that these examples are merely illustrative and in no way are to be interpreted as limiting the scope of the invention.

EXAMPLE 1

Phase Study

A phase study shows the following compositions are azeotropic, all at 25°C.

Composition	Weight percents	Vapor Press. psia	kPa
4310mee/152E	36.3/63.7	12.07	83
4310mee/245eaE	33.6/66.4	5.38	37
4310mee/acetone	73.3/26.7	3.15	22
4310mee/cyclopentane	62.3/37.7	8.60	59
4310mee/ethyl acetate	90.3/9.7	4.67	32
4310mee/ethyl formate	70.6/29.4	7.34	51
4310mee/methyl acetate	73.8/26.2	7.04	49
4310mee/methyl formate	56.8/43.2	13.90	96
4310mee/propylene oxide	52.4/47.6	12.43	86
4310mee/2,2-dimethylbutane	62.1/37.9	9.24	64
4310mee/n-pentane	50.5/49.5	12.80	88
4310mee/n-propanol	99.3/0.7	4.38	30

EXAMPLE 2

Impact of Vapor Leakage on Vapor Pressure at 25°C

A vessel is charged with an initial composition at 25°C, and the vapor pressure of the composition is measured. The composition is allowed to leak from the vessel, while the temperature is held constant at 25°C, until 50 weight percent of the initial composition is removed, at which time the vapor pressure of the

composition remaining in the vessel is measured. The results are summarized below.

Refrigerant Composition	0 wt% evaporated psia	kPa	50 wt% evaporated psia	kPa	0% change in vapor pressure
4310mee/152E					
36.3/63.7	12.07	83	12.07	83	0.0
20/80	11.97	83	11.75	81	1.8
10/90	11.72	81	11.25	78	4.0
1/99	11.11	77	11.01	76	0.9
60/40	11.87	82	11.48	79	3.3
70/30	11.56	80	10.45	72	9.6
71/29	11.51	79	10.29	71	10.6
4310mee/c234fEαβ					
1/99	16.71	115	16.69	115	0.1
20/80	15.86	109	15.39	106	3.0
41/59	14.60	101	13.17	91	9.8
42/58	14.53	100	13.03	90	10.3
4310mee/c234fEβγ					
1/99	13.25	91	13.25	91	0.0
20/80	12.88	89	12.72	88	1.2
40/60	12.21	84	11.50	79	5.8
50/50	11.71	81	10.53	73	10.1
49/51	11.76	81	10.64	73	9.5
4310mee/245ebEβγ					
1/99	7.61	52	7.61	52	0.0
20/80	7.37	51	7.30	50	0.9
40/60	6.99	48	6.81	47	2.6
60/40	6.45	44	6.12	42	5.1
80/20	5.64	39	5.24	36	7.1
90/10	5.08	35	4.78	33	5.9
99/1	4.44	31	4.40	30	0.9
4310mee/245eaE					
33.6/66.4	5.38	37	5.38	37	0.0
20/80	5.36	37	5.35	37	0.2
1/99	5.23	36	5.23	36	0.0
60/40	5.27	36	5.24	36	0.6
80/20	5.00	34	4.89	34	2.2

	99/1	4.40	30	4.39	30	0.2
	4310mee/245caEαβ					
	1/99	8.49	59	8.48	58	0.1
	20/80	8.11	56	7.98	55	1.6
	40/60	7.59	52	7.29	50	4.0
	60/40	6.88	47	6.38	44	7.3
	80/20	5.87	40	5.32	37	9.4
	85/15	5.55	38	5.05	35	9.0
	99/1	4.45	31	4.40	30	1.1
	4310mee/acetone					
	73.3/26.7	3.15	22	3.15	22	0.0
	90/10	3.55	24	3.40	23	4.2
	99/1	4.25	29	4.20	29	1.2
	40/60	3.82	26	3.49	24	8.6
	30/70	4.08	28	3.74	26	8.3
	20/80	4.28	30	4.04	28	5.6
	1/99	4.45	31	4.45	31	0.0
	4310mee/cyclopentane					
	62.3/37.7	8.60	59	8.60	59	0.0
	80/20	8.44	58	8.01	55	5.1
	83/17	8.34	58	7.62	53	8.6
	84/16	8.30	57	7.44	51	10.4
	39/61	8.55	59	8.09	56	5.4
	38/62	8.54	59	7.58	52	11.2
	4310mee/ethyl acetate					
	90.3/9.7	4.67	32	4.67	32	0.0
	99/1	4.45	31	4.42	30	0.7
	65/35	4.42	30	4.03	28	8.8
	64/36	4.41	30	3.96	27	10.2
	4310mee/ethyl formate					
	70.6/29.4	7.34	51	7.34	51	0.0
	87/13	7.14	49	6.55	45	8.3
	88/12	7.09	49	6.37	44	10.2
	47/53	7.23	50	6.70	46	7.3
	46/54	7.26	50	6.51	45	10.3
	4310mee/MTBE					
	1/99	4.59	32	4.59	32	0.0
	20/80	4.57	32	4.56	31	0.2

	40/60	4.53	31	4.53	31	0.0
	60/40	4.47	31	4.47	31	0.0
	80/20	4.39	30	4.39	30	0.0
	99/1	4.28	30	4.28	30	0.0
	4310mee/methyl acetate					
	73.8/26.2	7.04	49	7.04	49	0.0
	89/11	6.83	47	6.20	43	9.2
	90/10	6.78	47	6.00	41	11.5
	50/50	6.97	48	6.43	44	7.7
	49/51	6.97	48	6.19	43	11.2
	4310mee/methyl formate					
	56.8/43.2	13.90	96	13.90	96	0.0
	80/20	13.77	95	12.96	89	5.9
	82/18	13.72	95	12.42	86	9.5
	83/17	13.69	94	12.02	83	12.2
	36/64	13.88	96	12.79	88	7.9
	35/65	13.88	96	10.75	74	22.6
	4310mee/propylene oxide					
	52.4/47.6	12.43	86	12.43	86	0.0
	80/20	12.05	83	10.77	74	10.6
	79/21	12.10	83	10.99	76	9.2
	28/72	12.33	85	11.18	77	9.3
	27/73	12.32	85	11.02	76	10.6
	4310mee/2,2-dimethylbutane					
	62.1/37.9	9.24	64	9.24	64	0.0
	82/18	9.09	63	8.29	57	8.8
	83/17	9.06	62	8.07	56	10.9
	39/61	9.20	63	8.38	58	8.9
	38/62	9.20	63	7.84	54	14.8
	4310mee/n-pentane					
	50.5/49.5	12.80	88	12.80	88	0.0
	70/30	12.70	88	12.36	85	2.7
	77/23	12.55	87	11.44	79	8.8
	78/22	12.52	86	11.20	77	10.5
	29/71	12.75	88	11.57	80	9.3
	28/72	12.74	88	11.21	77	12.0
	4310mee/n-propanol					
	99.3/0.7	4.38	30	4.38	30	0.0
	85/15	4.16	29	3.82	26	8.2

84/16	4.15	29	3.70	26	10.8

The results of this Example show that these compositions are azeotropic or azeotrope-like because when 50 wt.% of an original composition is removed, the vapor pressure of the remaining composition is within about 10% of the vapor pressure of the original composition, at a temperature of 25°C.

EXAMPLE 3

Impact of Vapor Leakage at 0°C

A leak test is performed on compositions of 4310mee and 152E, at the temperature of 0°C. The results are summarized below.

Refrigerant Composition	0 wt% evaporated psia	0 wt% evaporated kPa	50 wt% evaporated psia	50 wt% evaporated kPa	0% change in vapor pressure
4310mee/152E					
30.0/70.0	4.28	30	4.28	30	0.0
20/80	4.26	29	4.24	29	0.5
10/90	4.20	29	4.09	28	2.6
1/99	4.02	28	3.99	28	0.7
60/40	4.18	29	3.96	27	5.3
66/34	4.12	28	3.73	26	9.5
67/33	4.10	28	3.67	25	10.5

These results show that compositions of 4310mee and 152E are azeotropic or azeotrope-like at different temperatures, but that the weight percents of the components vary as the temperature is changed.

EXAMPLE 4

Refrigerant Performance

The following table shows the performance of various refrigerants. The data are based on the following conditions.

Evaporator temperature	40.0°F (4.4°C)
Condenser temperature	130.0°F (54.4°C)
Subcool	5.0°F (2.8°C)
Return gas temperature	60.0°F (15.6°C)

Compressor efficiency is 70%.

The refrigeration capacity is based on a compressor with a fixed displacement of 3.5 cubic feet per minute and 70% volumetric efficiency. Capacity is intended to mean the change in enthalpy of the refrigerant in the evaporator per pound of refrigerant circulated, i.e. the heat removed by the refrigerant in the evaporator per time. Coefficient of performance (COP) is intended to mean the ratio of the capacity to compressor work. It is a measure of refrigerant energy efficiency.

Refrig. Comp.	Evap. Press. Psia	Evap. Press. kPa	Cond. Press. Psia	Cond. Press. kPa	Comp. Dis. Temp. °F	Comp. Dis. Temp. °C	COP	Capacity BTU/min	Capacity kw
4310mee/152E									
1.0/99.0	4.5	31	30.0	207	211.2	99.6	3.28	28.3	0.5
36.3/63.7	5.5	38	35.5	245	183.4	84.1	3.15	31.9	0.6
99.0/1.0	2.2	15	16.8	116	131.8	55.4	2.89	12.2	0.2
4310mee/c234fEαβ									
1.0/99.0	7.6	52	41.5	286	158.6	70.3	3.06	38.2	0.7
41.0/59.0	6.0	41	37.0	255	150.5	65.8	2.90	30.2	0.5
99.0/1.0	2.1	14	16.1	111	131.5	55.3	2.82	11.3	0.2
4310mee/c234fEβγ									
1.0/99.0	5.8	40	33.6	232	160.9	71.6	3.10	30.7	0.5
49.0/51.0	4.8	33	31.2	215	148.4	64.7	2.91	25.2	0.4
99.0/1.0	2.0	14	16.0	110	131.7	55.4	2.80	11.2	0.2
4310mee/245ebEβγ									
1.0/99.0	3.0	21	21.7	150	164.5	73.6	3.10	17.8	0.3
50.0/50.0	3.1	21	22.3	154	147.0	63.9	2.95	17.3	0.3
99.0/1.0	2.0	14	15.7	108	131.7	55.4	2.78	10.9	0.2
4310mee/245eaE									
1.0/99.0	1.9	13	15.6	108	173.8	78.8	3.18	12.5	0.2
33.6/66.4	2.4	17	18.6	128	158.4	70.2	3.06	14.6	0.3
99.0/1.0	2.0	14	15.7	108	131.8	55.4	2.77	10.8	0.2
4310mee/245caEαβ									
1.0/99.0	3.4	23	24.0	165	163.3	72.9	3.09	19.8	0.3

	50.0/50.0	3.3	23	23.5	162	146.8	63.8	2.94	18.3	0.3
	99.0/1.0	2.0	14	15.7	108	131.8	55.4	2.78	10.9	0.2
	4310mee/acetone									
	1.0/99.0	2.0	14	14.2	98	217.1	102.8	3.64	14.4	0.3
	73.3/26.7	3.1	21	23.9	165	168.1	75.6	2.94	18.2	0.3
	99.0/1.0	2.2	15	16.7	115	132.5	55.8	2.86	12.0	0.2
	4310mee/cyclopentane									
	1.0/99.0	2.6	18	17.2	119	159.2	70.7	3.16	15.2	0.3
	62.3/37.7	3.7	26	23.4	161	144.3	62.4	2.95	19.3	0.3
	99.0/1.0	2.1	14	16.2	112	131.8	55.4	2.81	11.4	0.2
	4310mee/ethyl acetate									
	1.0/99.0	0.8	6	7.0	48	188.9	87.2	3.65	6.4	0.1
	90.3/9.7	2.3	16	17.7	122	137.8	58.8	2.86	12.9	0.2
	99.0/1.0	2.0	14	15.8	109	132.1	55.6	2.78	11.0	0.2
	4310mee/ethyl formate									
	1.0/99.0	2.0	14	15.3	105	200.3	93.5	3.68	15.1	0.3
	70.6/29.4	3.1	21	27.1	187	165.3	74.1	2.73	18.0	0.3
	99.0/1.0	2.1	14	16.6	114	132.1	55.6	2.85	11.9	0.2
	4310mee/MTBE									
	1.0/99.0	2.0	14	14.2	98	148.7	64.8	3.06	11.7	0.2
	50.0/50.0	2.4	17	17.3	119	142.6	61.4	2.92	13.4	0.2
	99.0/1.0	2.1	14	16.3	112	132.6	55.9	2.79	11.5	0.2
	4310mee/methyl acetate									
	1.0/99.0	1.9	13	13.8	95	215.3	101.8	3.60	13.6	0.2
	73.8/26.2	3.6	25	24.9	172	156.2	69.0	3.00	20.3	0.4
	99.0/1.0	2.1	14	16.4	113	132.2	55.7	2.84	11.7	0.2
	4310mee/methyl formate									
	1.0/99.0	4.5	31	31.3	216	243.0	117.2	3.46	31.1	0.5
	56.8/43.2	6.6	46	42.6	294	184.7	84.8	3.12	37.8	0.7
	99.0/1.0	2.3	16	17.6	121	132.2	55.7	2.96	13.2	0.2
	4310mee/propylene oxide									
	1.0/99.0	4.5	31	31.3	216	243.0	117.2	3.46	31.1	0.5
	56.8/43.2	6.6	46	42.6	294	184.7	84.8	3.12	37.8	0.7
	99.0/1.0	2.3	16	17.6	121	132.2	55.7	2.96	13.2	0.2
	4310mee/2,2-dimethylbutane									
	1.0/99.0	2.7	19	16.8	116	137.6	58.7	2.94	13.8	0.2

	62.1/37.9	2.5	17	17.3	119	134.9	57.2	2.86	13.4	0.2
	99.0/1.0	2.0	14	15.6	108	131.6	55.3	2.77	10.8	0.2
	4310mee/n-pentane									
	1.0/99.0	4.4	30	26.4	182	155.7	68.7	3.07	23.4	0.4
	50.5/49.5	4.0	28	25.6	177	147.7	64.3	2.97	21.4	0.4
	99.0/1.0	2.0	14	16.0	110	132.0	55.6	2.79	11.2	0.2
	4310mee/n-propanol									
	85.0/15.0	0.6	4	10.9	75	180.3	82.4	2.64	4.7	0.1
	99.3/0.7	2.0	14	15.7	108	132.5	55.8	2.78	10.8	0.2

EXAMPLE 5

This Example is directed to measurements of the liquid/vapor equilibrium curves for the mixtures in Figures 1-12.

Turning to Figure 1, the upper curve represents the composition of the liquid, and the lower curve represents the composition of the vapor.

The data for the compositions of the liquid in Figure 1 are obtained as follows. A stainless steel cylinder is evacuated, and a weighed amount of 4310mee is added to the cylinder. The cylinder is cooled to reduce the vapor pressure of 4310mee, and then a weighed amount of 152E is added to the cylinder. The cylinder is agitated to mix the 4310mee and 152E, and then the cylinder is placed in a constant temperature bath until the temperature comes to equilibrium at 25°C, at which time the vapor pressure of the 4310mee and 152E in the cylinder is measured. Additional samples of liquid are measured the same way, and the results are plotted in Figure 1.

The curve which shows the composition of the vapor is calculated using an ideal gas equation of state.

Vapor/liquid equilibrium data are obtained in the same way for the mixtures shown in Figures 2-12.

The data in Figures 1-2 and 4-12 show that at 25°C, there are ranges of compositions that have vapor pressures higher than the vapor pressures of the pure components of the composition at that same temperature. As stated earlier, the higher than expected pressures of these compositions may result in an unexpected increase in the refrigeration capacity and efficiency for these compositions verus the pure components of the compositions.

The data in Figures 3 show that at 25°C, there are ranges of compositions that have vapor pressures below the vapor pressures of the pure

components of the composition at that same temperature. These minimum vapor pressure compositions are useful in refrigeration, and may show an improved efficiency when compared to the pure components of the composition.

EXAMPLE 6

This Example is directed to measurements of the liquid/vapor equilibrium curve for mixtures of 4310mee and MTBE. The liquid/vapor equilibrium data for these mixtures are shown in Figure 13. The upper curve represents the liquid composition, and the lower curve represents the vapor composition.

The procedure for measuring the composition of the liquid for mixtures of 4310mee and MTBE in Figure 13 was as follows. A stainless steel cylinder was evacuated, and a weighed amount of 4310mee was added to the cylinder. The cylinder was cooled to reduce the vapor pressure of 4310mee, and then a weighed amount of MTBE was added to the cylinder. The cylinder was agitated to mix the 4310mee and MTBE, and then the cylinder was placed in a constant temperature bath until the temperature came to equilibrium at 18.46°C, at which time the vapor pressure of the content of the cylinder was measured. Samples of the liquid in the cylinder were taken and analyzed, and the results are plotted in Figure 13 as asterisks, with a best fit curve having been drawn through the asterisks.

This procedure was repeated for various mixtures of 4310mee/MTBE as indicated in Figure 13.

The curve which shows the composition of the vapor is calculated using an ideal gas equation of state.

The data in Figure 13 show that at 18.46°C, there are ranges of compositions that have vapor pressures higher than the vapor pressures of the pure components of the composition at that same temperature.

The novel compositions of this invention, including the azeotropic or azeotrope-like compositions, may be used to produce refrigeration by condensing the compositions and thereafter evaporating the condensate in the vicinity of a body to be cooled. The novel compositions may also be used to produce heat by condensing the refrigerant in the vicinity of the body to be heated and thereafter evaporating the refrigerant.

The novel compositions of the invention are particularly suitable for replacing refrigerants that may affect the ozone layer, including R-11, R-12, R-22, R-114 and R-502.

In addition to refrigeration applications, the novel constant boiling or substantially constant boiling compositions of the invention are also useful as aerosol propellants, heat transfer media, gaseous dielectrics, fire extinguishing agents, expansion agents for polyolefins and polyurethanes and power cycle working fluids.

ADDITIONAL COMPOUNDS

Other components, such as aliphatic hydrocarbons having a boiling point of -60 to +60°C, hydrofluorocarbonalkanes having a boiling point of -60 to +60°C, hydrofluoropropanes having a boiling point of between -60 to +60°C, hydrocarbon esters having a boiling point between -60 to +60°C, hydrochlorofluorocarbons having a boiling point between -60 to +60°C, hydrofluorocarbons having a boiling point of -60 to +60°C, hydrochlorocarbons having a boiling point between -60 to +60°C, chlorocarbons and perfluorinated compounds, can be added to the azeotropic or azeotrope-like compositions described above without substantially changing the properties thereof, including the constant boiling behavior, of the compositions.

Additives such as lubricants, corrosion inhibitors, surfactants, stabilizers, dyes and other appropriate materials may be added to the novel compositions of the invention for a variety of purposes provides they do not have an adverse influence on the composition for its intended application. Preferred lubricants include esters having a molecular weight greater than 250.

CLAIMS

1. A composition of 1,1,1,2,3,4,4,5,5,5-decafluoropentane and bis(fluoromethyl) ether, 2,2,4,4-tetrafluorooxetane, 2,2,3,3-tetrafluorooxetane, 1,1,1,2-tetrafluoro-2-(fluoromethoxy)ethane, 1-(difluoromethoxy)-1,2,2-trifluoroethane, 1-(difluoromethoxy)-1,1,2-trifluoroethane, acetone, cyclopentane, ethyl acetate, ethyl formate, methyl *tert*-butyl ether, methyl acetate, methyl formate, propylene oxide, 2,2-dimethylbutane, n-pentane or n-propanol.

2. Effective amounts of the following compounds to form an azeotropic or azeotrope-like composition: 1,1,1,2,3,4,4,5,5,5-decafluoropentane and bis(fluoromethyl) ether, 2,2,4,4-tetrafluorooxetane, 2,2,3,3-tetrafluorooxetane, 1,1,1,2-tetrafluoro-2-(fluoromethoxy)ethane, 1-(difluoromethoxy)-1,2,2-trifluoroethane, 1-(difluoromethoxy)-1,1,2-trifluoroethane, acetone, cyclopentane, ethyl acetate, ethyl formate, methyl *tert*-butyl ether, methyl acetate, methyl formate, propylene oxide, 2,2-dimethylbutane, n-pentane or n-propanol.

3. The azeotropic or azeotrope-like composition of Claim 2, said composition comprising: 1-70 weight percent 1,1,1,2,3,4,4,5,5,5-decafluoropentane and 30-99 weight percent bis(fluoromethyl) ether; 1-41 weight percent 1,1,1,2,3,4,4,5,5,5-decafluoropentane and 59-99 weight percent 2,2,4,4-tetrafluorooxetane; 1-49 weight percent 1,1,1,2,3,4,4,5,5,5-decafluoropentane and 51-99 weight percent 2,2,3,3-tetrafluorooxetane; 1-99 weight percent 1,1,1,2,3,4,4,5,5,5-decafluoropentane and 1-99 weight percent 1,1,1,2-tetrafluoro-2-(fluoromethoxy)ethane; 1-99 weight percent 1,1,1,2,3,4,4,5,5,5-decafluoropentane and 1-99 weight percent 1-(difluoromethoxy)-1,2,2-trifluoroethane; 1-99 weight percent 1,1,1,2,3,4,4,5,5,5-decafluoropentane and 1-99 weight percent 1-(difluoromethoxy)-1,1,2-trifluoroethane; 1-99 weight percent 1,1,1,2,3,4,4,5,5,5-decafluoropentane and 1-99 weight percent acetone; 39-83 weight percent 1,1,1,2,3,4,4,5,5,5-decafluoropentane and 17-61 weight percent cyclopentane; 65-99 weight percent 1,1,1,2,3,4,4,5,5,5-decafluoropentane and 1-35 weight percent ethyl acetate; 53-89 weight percent 1,1,1,2,3,4,4,5,5,5-decafluoropentane and 11-47 weight percent ethyl formate; 1-99 weight percent 1,1,1,2,3,4,4,5,5,5-decafluoropentane and 1-99 weight percent methyl *tert*-butyl ether; 50-89 weight percent 1,1,1,2,3,4,4,5,5,5-decafluoropentane and 11-50 weight percent methyl acetate; 36-82 weight percent

1,1,1,2,3,4,4,5,5,5-decafluoropentane and 18-64 weight percent methyl formate; 28-79 weight percent 1,1,1,2,3,4,4,5,5,5-decafluoropentane and 21-72 weight percent propylene oxide; 39-82 weight percent 1,1,1,2,3,4,4,5,5,5-decafluoropentane and 18-61 weight percent 2,2-dimethylbutane; 29-77 weight percent 1,1,1,2,3,4,4,5,5,5-decafluoropentane and 23-71 weight percent n-pentane; and 85-99.3 weight percent 1,1,1,2,3,4,4,5,5,5-decafluoropentane and 0.7-15 weight percent n-propanol.

4. Effective amounts of 1,1,1,2,3,4,4,5,5,5-decafluoropentane and bis(fluoromethyl) ether, 1-(difluoromethoxy)-1,2,2-trifluoroethane, acetone, cyclopentane, ethyl acetate, ethyl formate, methyl acetate, methyl formate, propylene oxide, 2,2-dimethylbutane, n-pentane or n-propanol to form binary compositions having a vapor pressure higher or lower than that of the components of the binary composition.

5. A process for producing refrigeration, comprising condensing a composition of any of Claims 1-4, and thereafter evaporating said composition in the vicinity of the body to be cooled.

6. A process for producing heat comprising condensing a composition of any of Claims 1-4 in the vicinity of a body to be heated, and thereafter evaporating said composition.

FIG.1

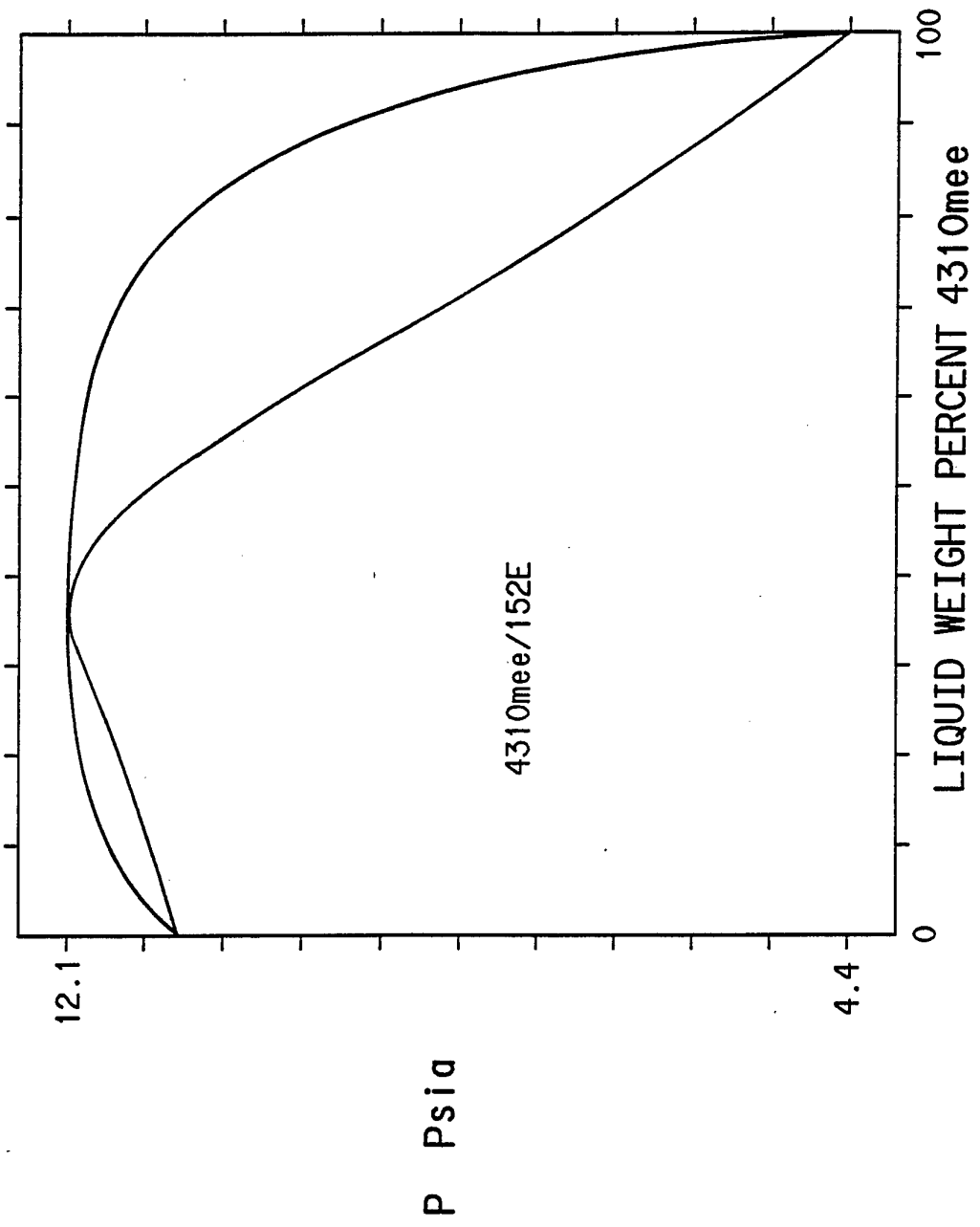

12.1
4.4
P Psia
0
100
LIQUID WEIGHT PERCENT 4310mee
4310mee/152E

FIG.2

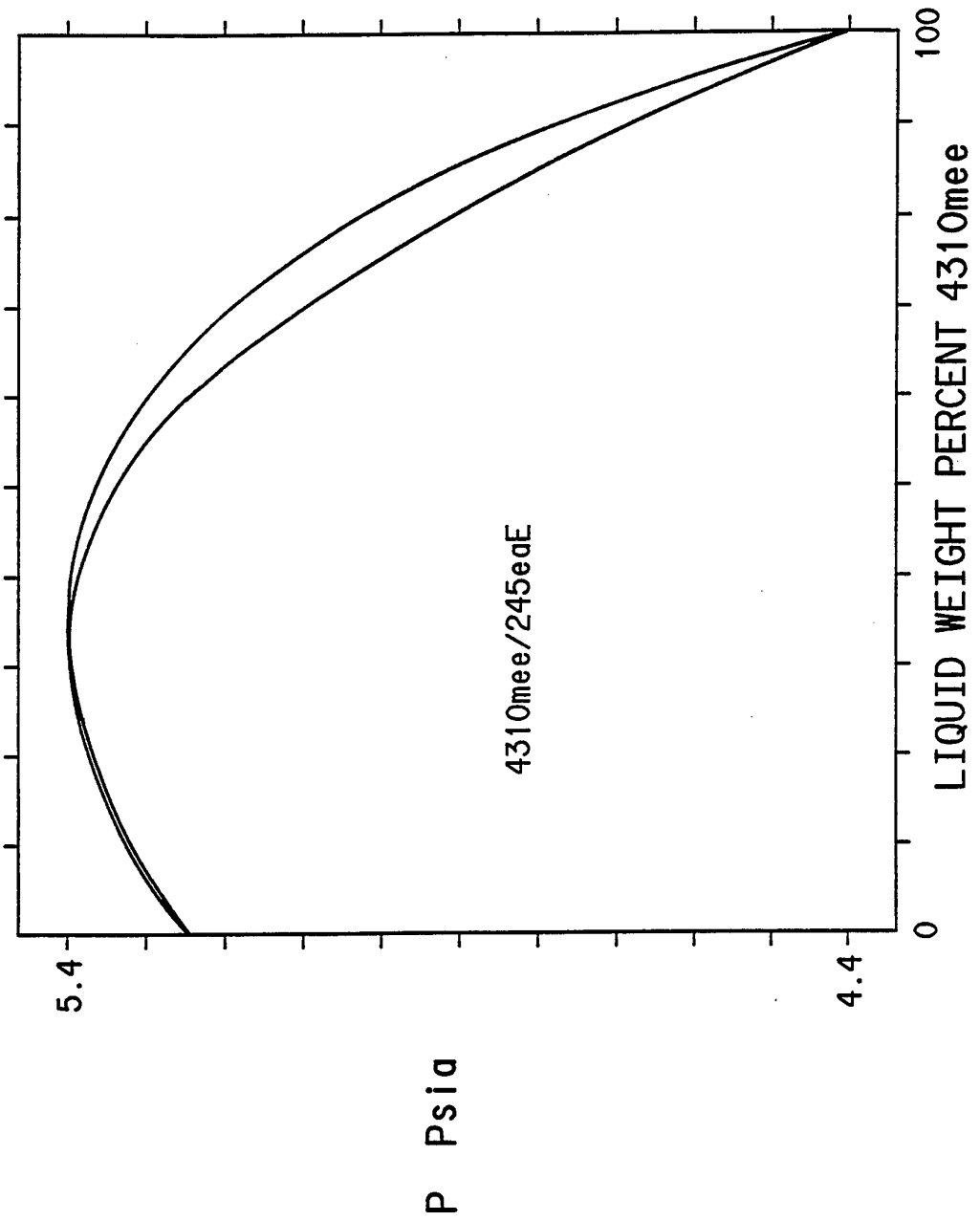

5.4
4.4
P Psia
0
100
LIQUID WEIGHT PERCENT 4310mee
4310mee/245eaE

FIG.3

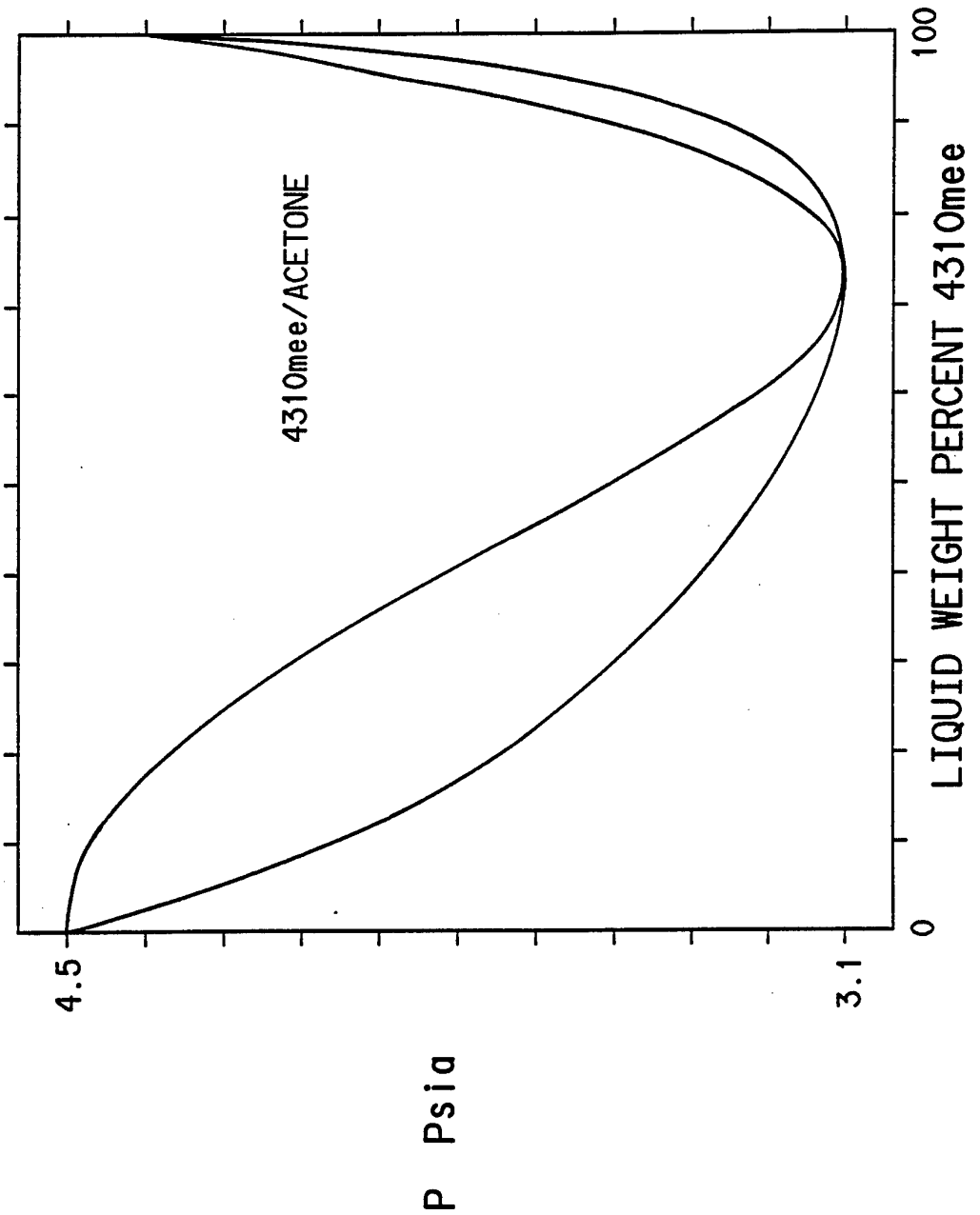

4310mee/ACETONE
LIQUID WEIGHT PERCENT 4310mee
0
100
4.5
3.1
P Psia

FIG.4

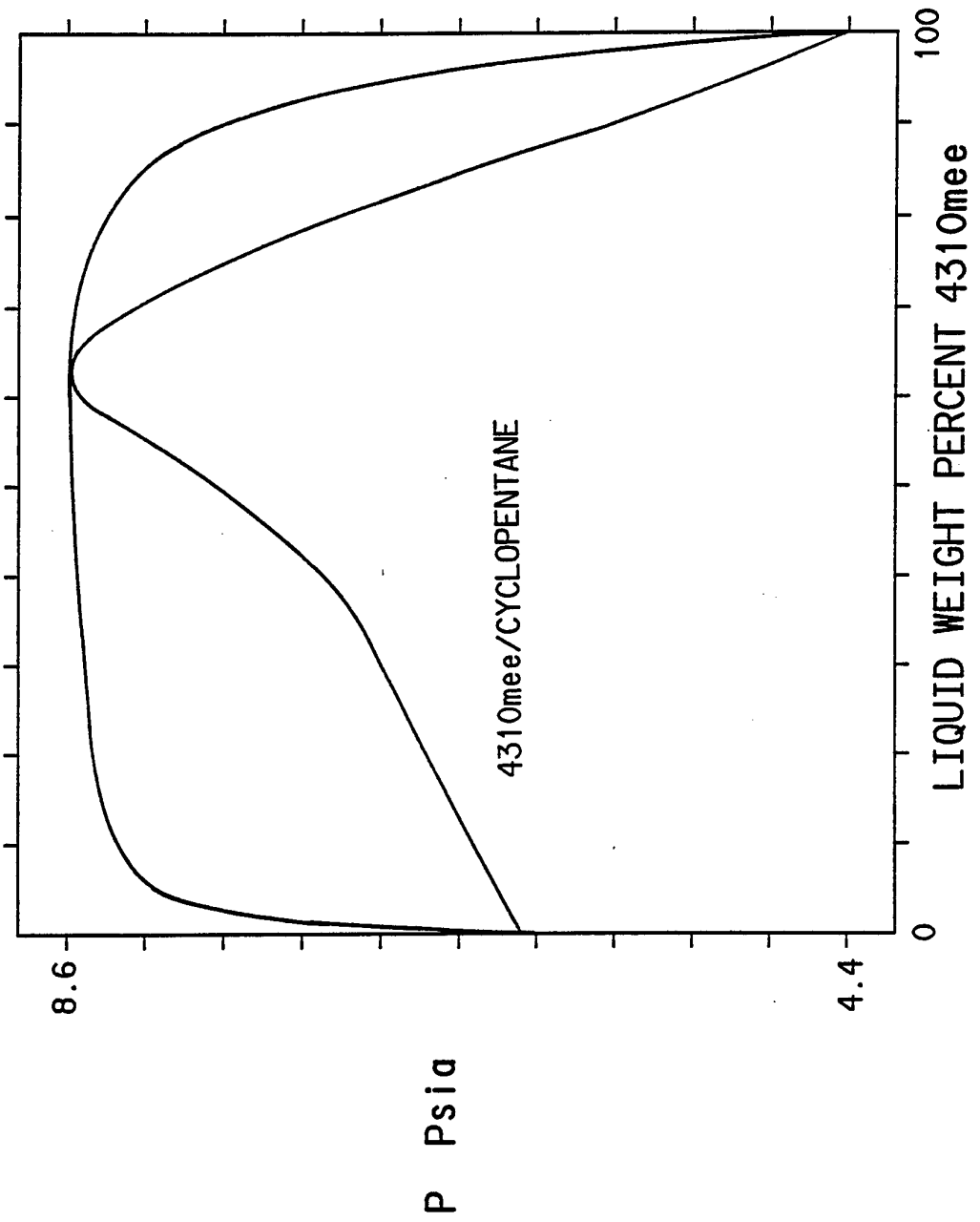

8.6
4.4
P Psia
0
100
LIQUID WEIGHT PERCENT 4310mee
4310mee/CYCLOPENTANE

FIG.5

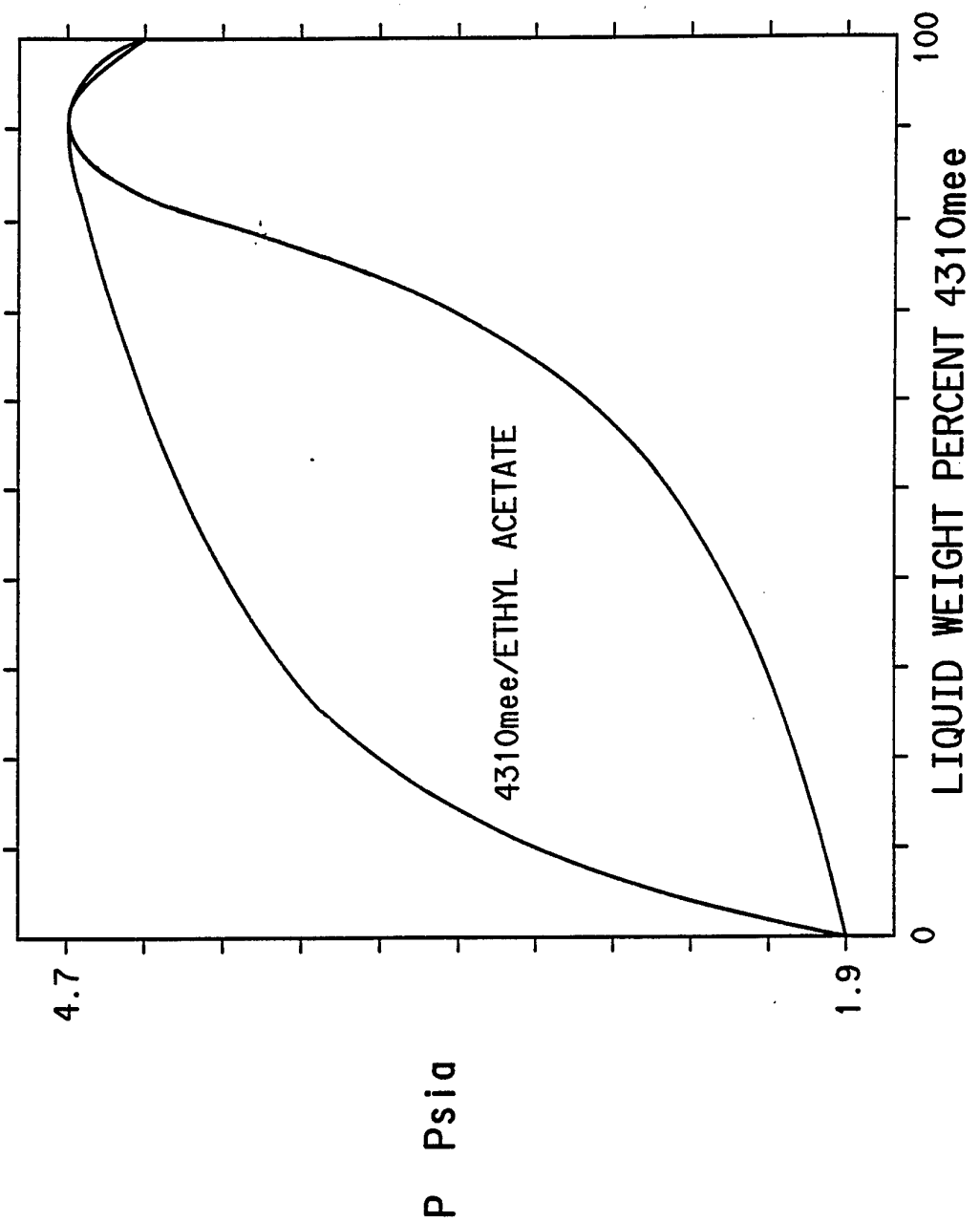

4.7
1.9
P Psia
0
100
LIQUID WEIGHT PERCENT 4310mee
4310mee/ETHYL ACETATE

FIG.6

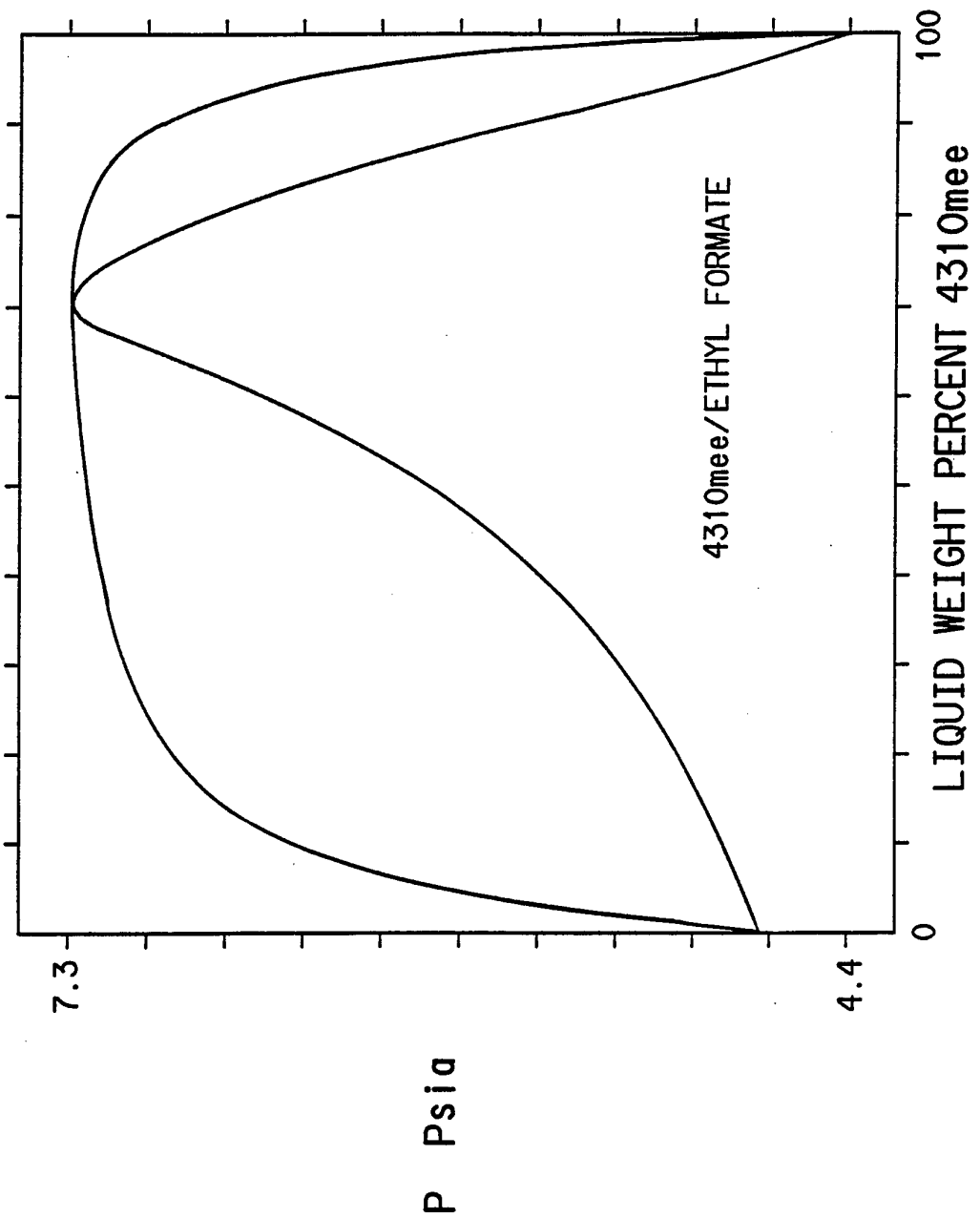

7.3
4.4
P Psia
0
100
LIQUID WEIGHT PERCENT 431Omee
431Omee/ETHYL FORMATE

FIG.7

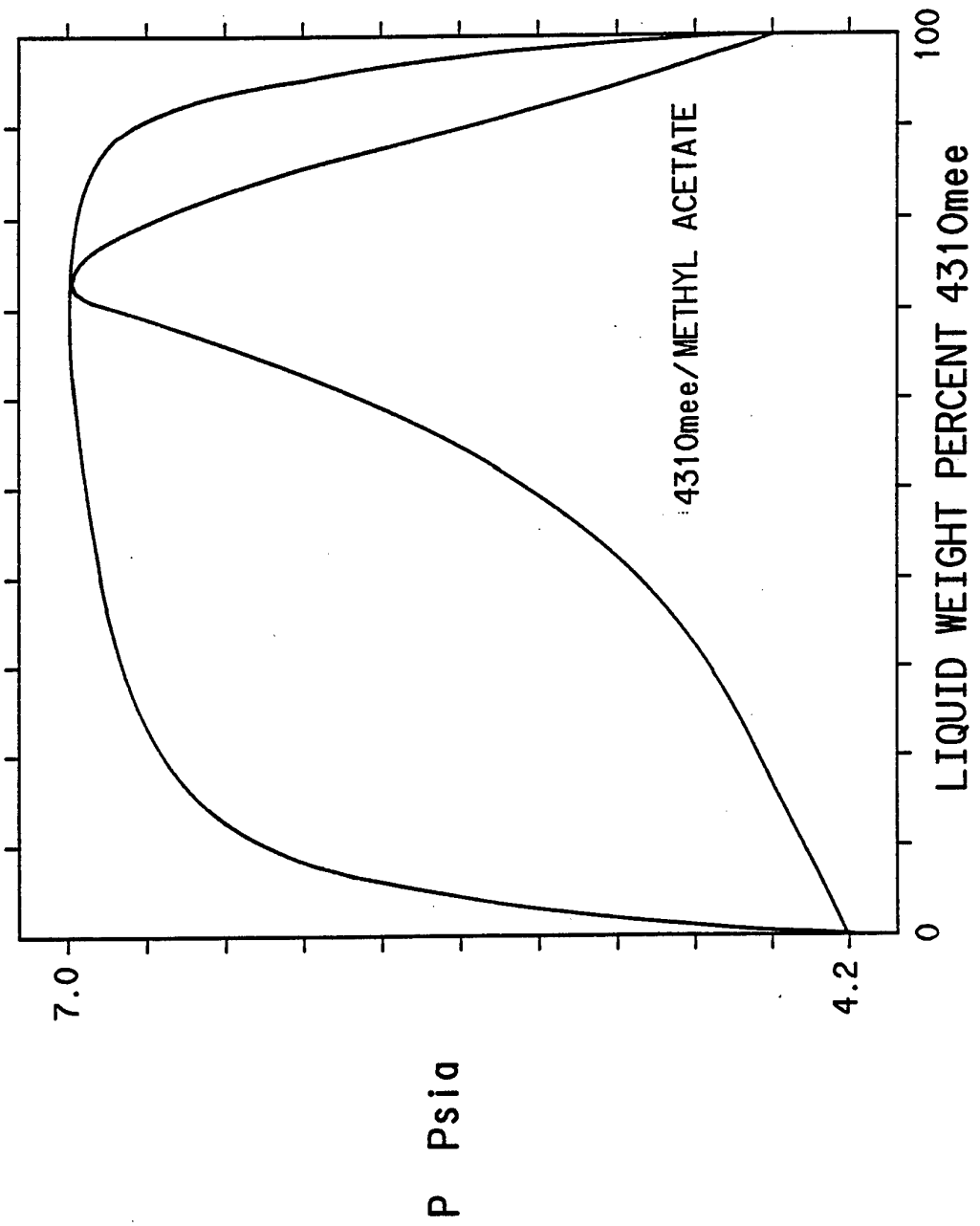

7.0
4.2
P Psia
0
100
LIQUID WEIGHT PERCENT 431Omee
431Omee/METHYL ACETATE

FIG.8

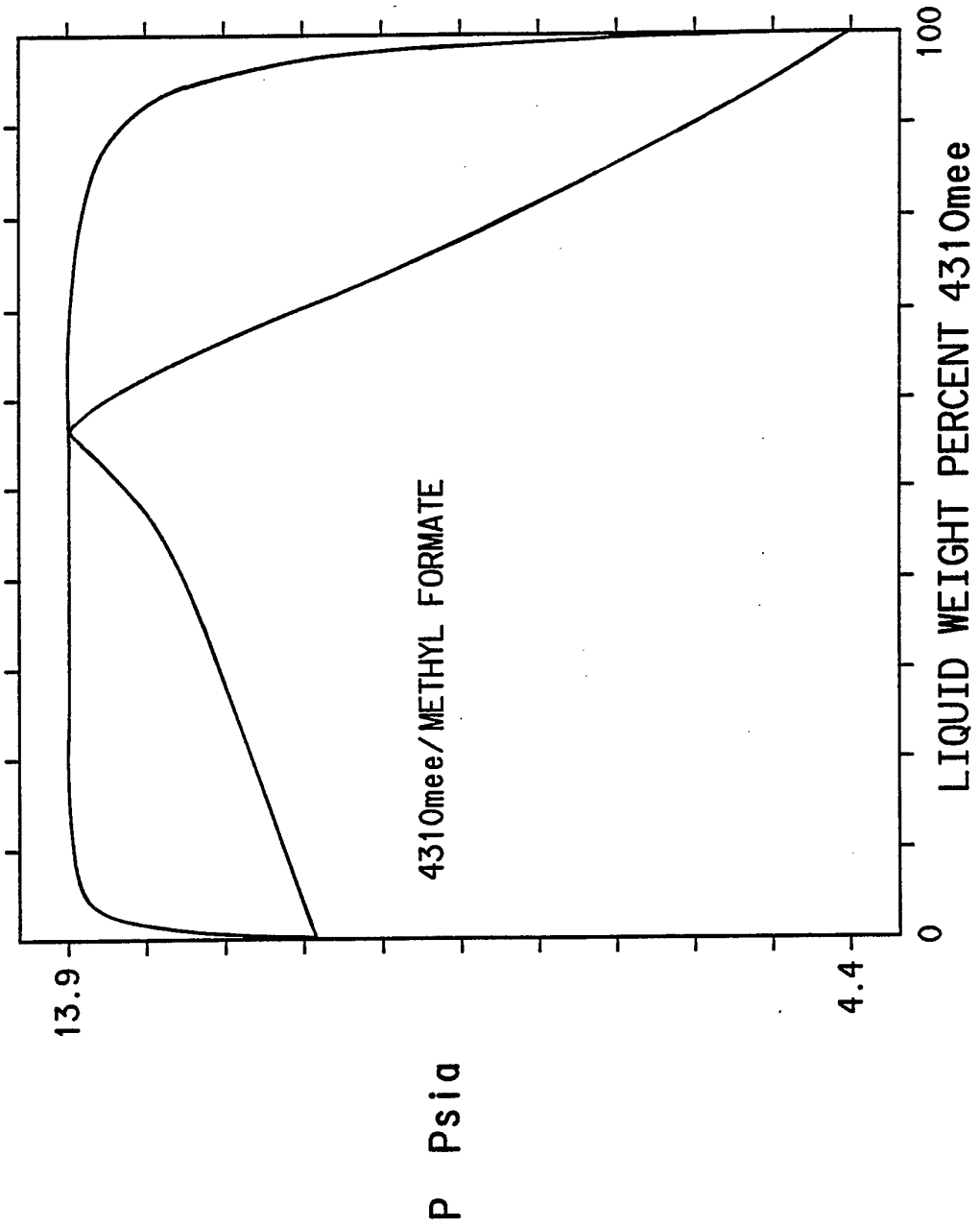

13.9
4.4
P Psia
0
100
LIQUID WEIGHT PERCENT 431Omee
431Omee/METHYL FORMATE

FIG.9

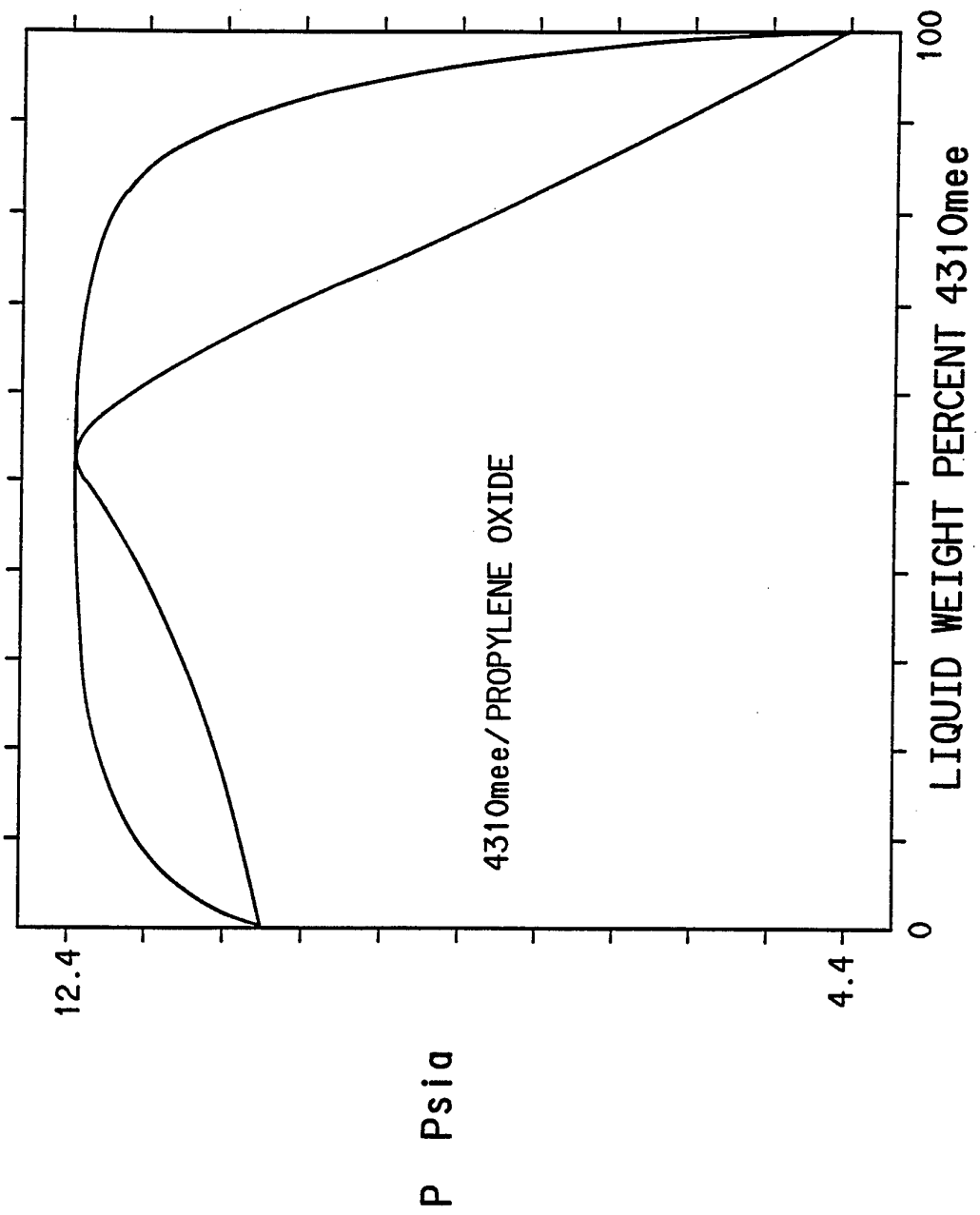

12.4
4.4
P Psia
0
100
LIQUID WEIGHT PERCENT 4310mee
4310mee/PROPYLENE OXIDE

FIG. 10

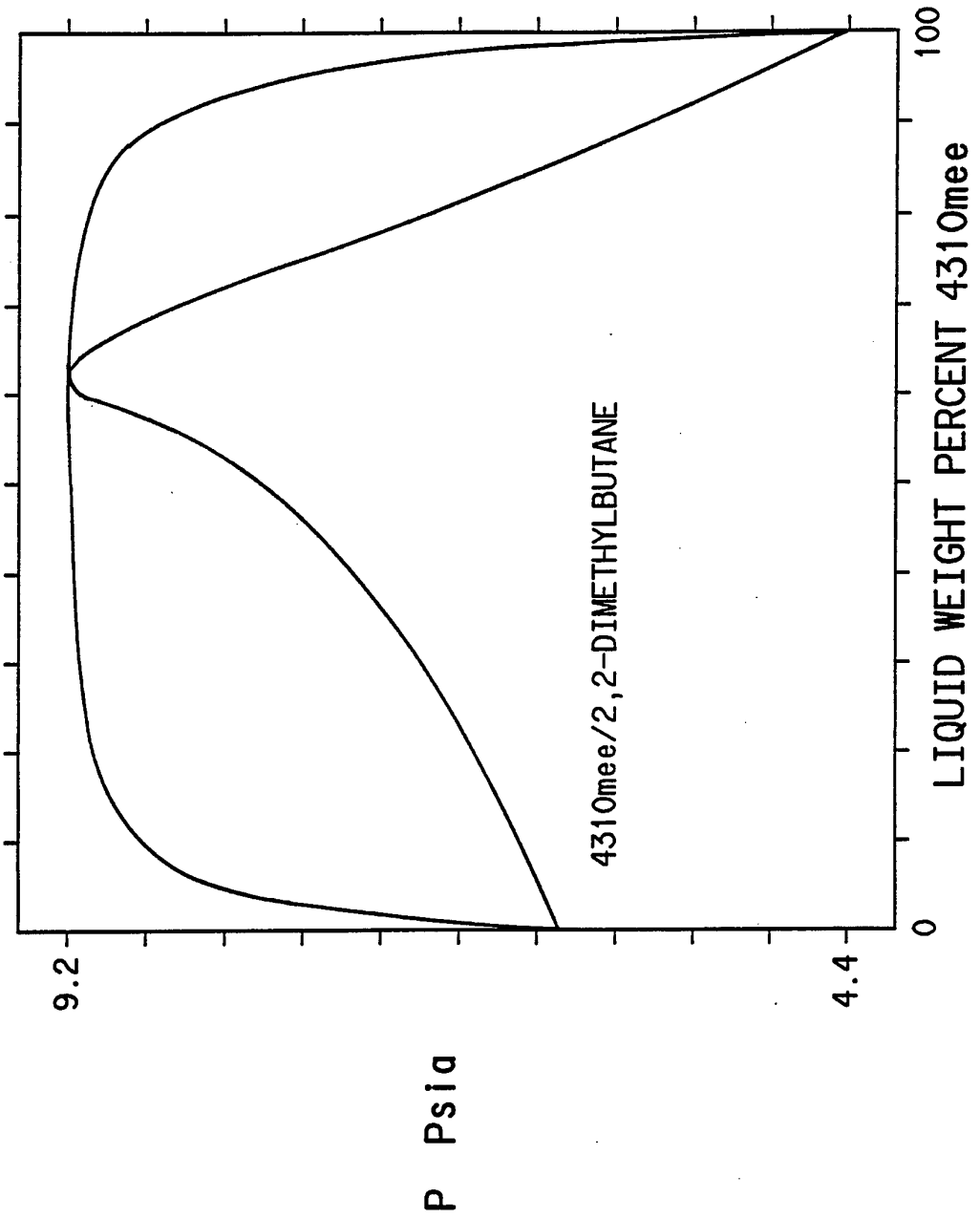

9.2
4.4
P Psia
0
100
LIQUID WEIGHT PERCENT 4310mee
4310mee/2,2-DIMETHYLBUTANE

FIG. 11

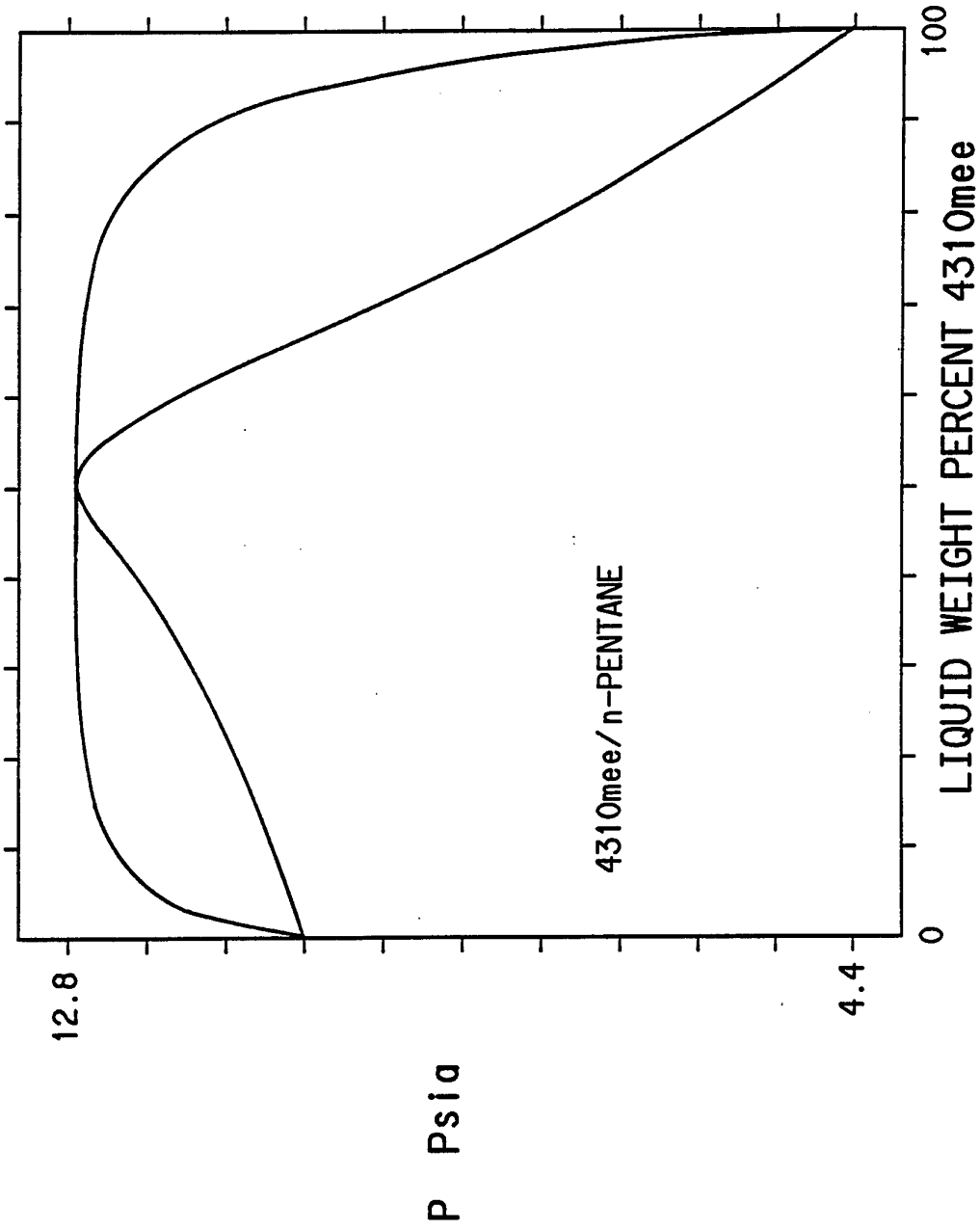

12.8
4.4
P Psia
0
100
LIQUID WEIGHT PERCENT 4310mee
4310mee/n-PENTANE

FIG. 12

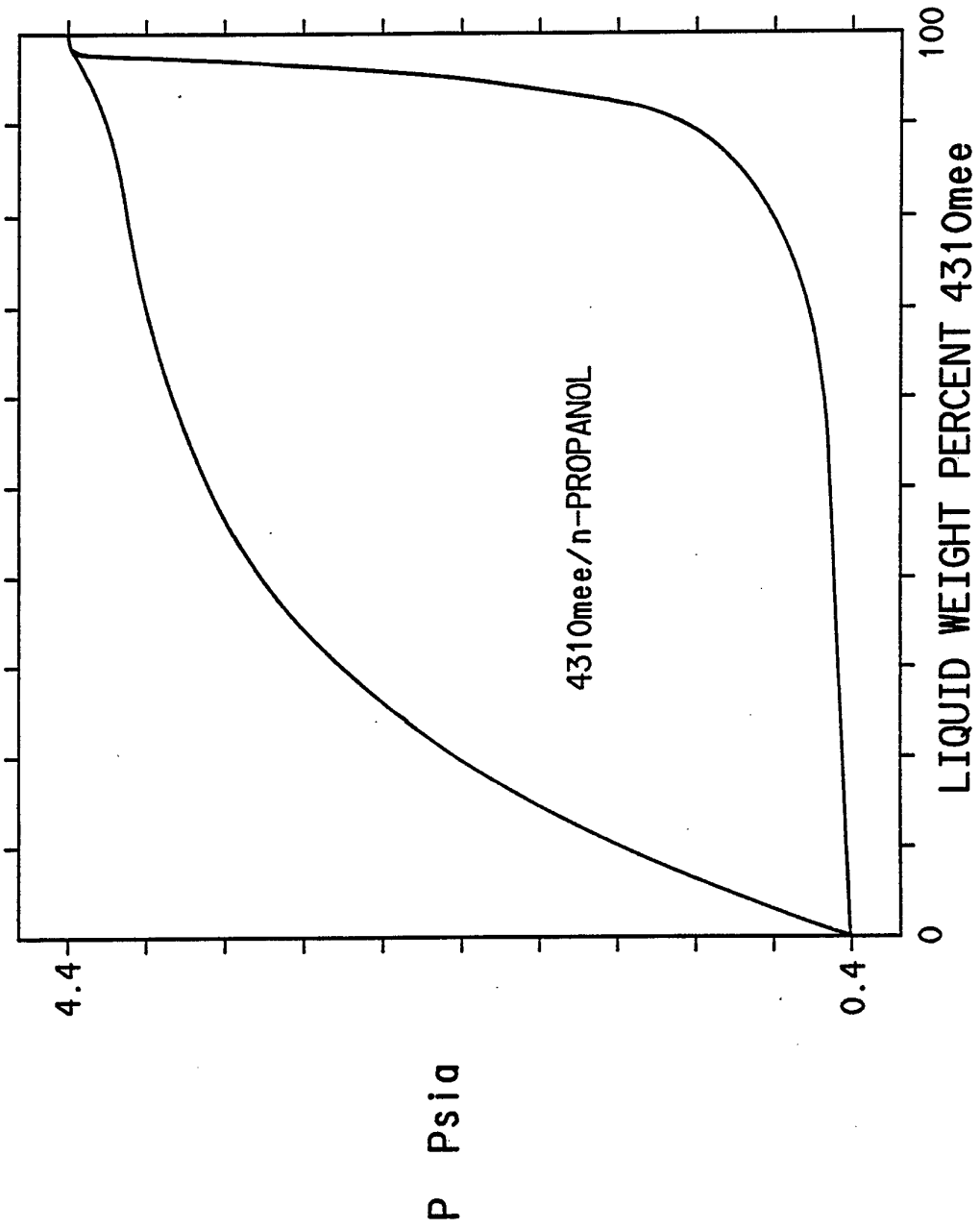
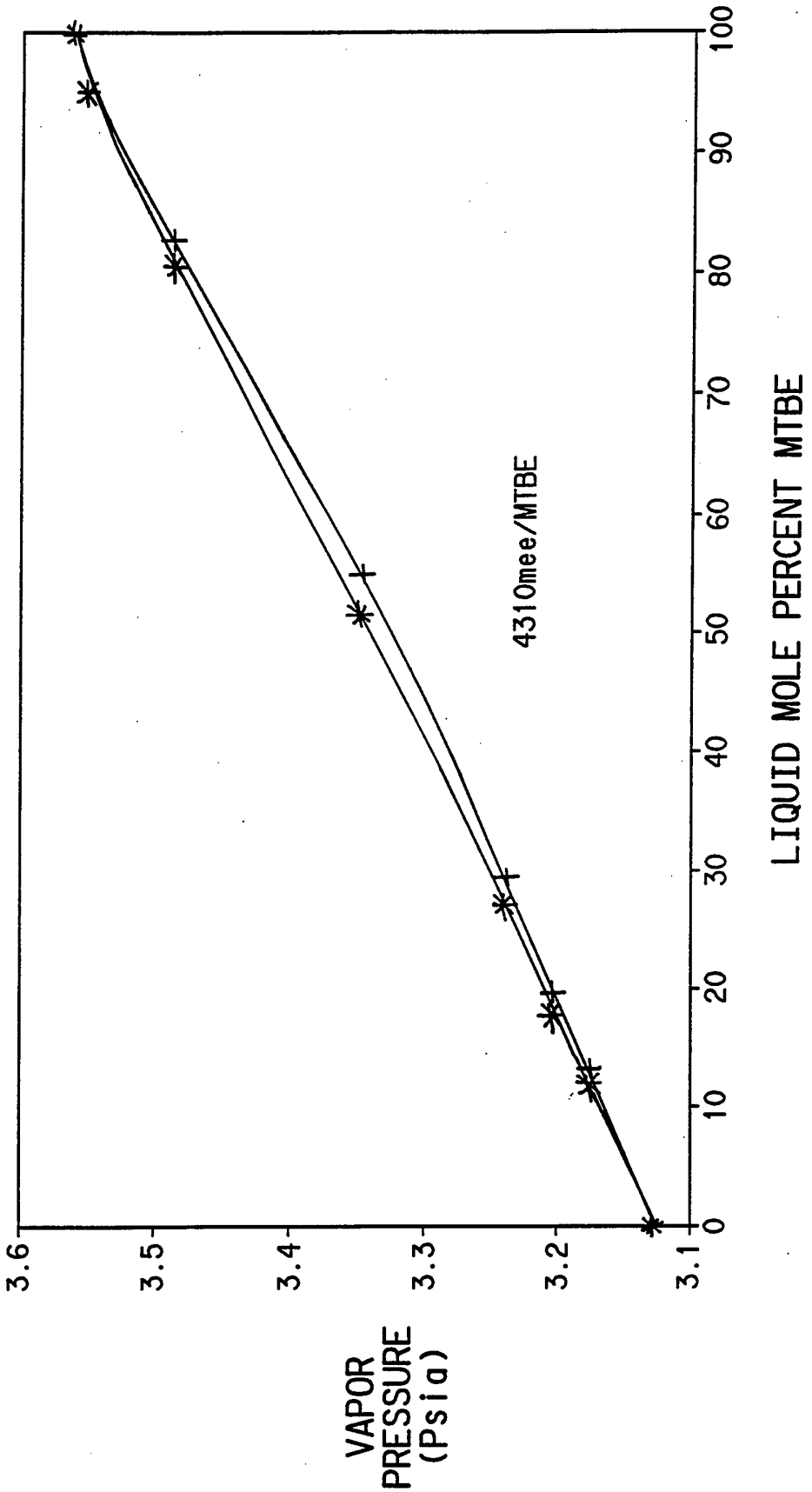

4.4
0.4
P Psia
0
100
LIQUID WEIGHT PERCENT 4310mee
4310mee/n-PROPANOL

FIG. 13


4310mee/MTBE
VAPOR PRESSURE (Psia)
3.6
3.5
3.4
3.3
3.2
3.1
0
10
20
30
40
50
60
70
80
90
100
LIQUID MOLE PERCENT MTBE

INTERNATIONAL SEARCH REPORT

Interna al Application No
PCT/US 94/09523

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 C09K5/04

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)
IPC 6 C09K C08J

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 practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US,A,5 064 559 (MERCHANT) 12 November 1991 see abstract; claims 1,8-10,14,15 ---	1-6
X	DATABASE WPI Section Ch, Week 9325, Derwent Publications Ltd., London, GB; Class A60, AN 93-200463 & JP,A,5 124 995 (MITSUI FLUOROCHEMICAL CO LTD) 21 May 1993 see abstract ---	1-6
X	DATABASE WPI Section Ch, Week 9325, Derwent Publications Ltd., London, GB; Class A60, AN 93-200456 & JP,A,5 124 988 (MITSUI FLUOROCHEMICAL CO LTD) 21 May 1993 see abstract --- -/--	1-6

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

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
2 December 1994	15. 12. 94

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, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Nicolas, H

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DATABASE WPI Section Ch, Week 9325, Derwent Publications Ltd., London, GB; Class A60, AN 93-200462 & JP,A,5 124 994 (MITSUI FLUOROCHEMICAL CO LTD) 21 May 1993 see abstract	1-6
X	DATABASE WPI Section Ch, Week 9328, Derwent Publications Ltd., London, GB; Class E19, AN 93-224471 & JP,A,5 148 498 (DAIKIN KOGYO KK) 15 June 1993 see abstract	1-6
P,X	DATABASE WPI Section Ch, Week 9408, Derwent Publications Ltd., London, GB; Class A97, AN 94-062265 & JP,A,6 017 093 (MITSUI FLUOROCHEMICAL CO LTD) 25 January 1994 see abstract	1-6

INTERNATIONAL SEARCH REPORT

Information on patent family members

Inten. ..nal Application No
PCT/US 94/09523

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		CN-A-	1060505	22-04-92
		EP-A-	0552225	28-07-93
		JP-T-	6501949	03-03-94
		WO-A-	9207112	30-04-92