



Continuous isomerization of olefins
by Lenard D Gustafson

A THESIS Submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree
of Master of Science in Chemical Engineering
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Abstract:

The purpose of this investigation was the evaluation of alumina activated with anhydrous hydrogen fluoride as an olefin isomerization catalyst.

Heptene, 1-octene, ethylhexene, and 1-pentene were isomerized in a continuous system removing the product from a continuous fractionating column. Isobutylene and cis-2-butene were passed over the isomerization catalyst and fractionated batchwise in a vacuum jacketed rectification column.

The products were analyzed by hydrogenating the pentanes, heptenes, and "octenes followed by a precision rectification of the resulting paraffins*. The butene isomers were analyzed by rectification. Infrared analysis was made of the pentenes and the hydrogenated heptenes and octenes.

The products from the isomerization were found to contain a mixture of several isomers, usually with a few predominating. The products from the 1-octene and ethylhexene isomerizations were found to be of essentially the same composition.

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Approved:



Head, Major Department



Chairman, Examining Committee



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ABSTRACT

The purpose of this investigation was the evaluation of alumina activated with anhydrous hydrogen fluoride as an olefin isomerization catalyst.

Heptene, 1-octene, ethylhexene, and 1-pentene were isomerized in a continuous system removing the product from a continuous fractionating column. Isobutylene and cis-2-butene were passed over the isomerization catalyst and fractionated batchwise in a vacuum jacketed rectification column.

The products were analyzed by hydrogenating the pentenes, heptenes, and octenes followed by a precision rectification of the resulting paraffins. The butene isomers were analyzed by rectification. Infrared analysis was made of the pentenes and the hydrogenated heptenes and octenes.

The products from the isomerization were found to contain a mixture of several isomers, usually with a few predominating. The products from the 1-octene and ethylhexene isomerizations were found to be of essentially the same composition.

I INTRODUCTION

The purpose of this investigation was to continue an investigation started by Luke (5) to evaluate alumina activated with anhydrous hydrogen fluoride as an isomerization catalyst to convert olefins to their branched chain isomers. Luke investigated the isomerization of hexene-1. This investigation was made on the isomerization of heptenes, octenes, pentenes, and butenes. Essentially the same apparatus and methods were used in this investigation as were used by Luke. Oblad & Messenger (7) carried out an investigation on the isomerization of straight chain olefin with hydrogen fluoride activated alumina.

The isomerization of olefins occurs in either of two ways: a shifting of the double bond along the carbon chain or by chain breaking as illustrated by Naragon (6). The mechanisms by which isomerization may take place are illustrated by Egloff, Hulla, and Komarewsky (3). Comparison of the octane numbers of the straight chain olefins with those of the branched chain type shows that if improved octane number is desired it is desirable to convert the straight chain olefins found in olefinic gasolines into their higher octane number branched chain isomers. Berg, Sumner, and Montgomery (1) found that the octane number of olefinic gasolines was improved by treating at 380-420°C. with alumina activated with anhydrous hydrogen chloride. Many of the branched chain olefin isomers have a lower boiling point and a higher octane number than the straight chain and other low octane number isomers (2); therefore, through the isomerization and fractionation of the low octane

olefins a product of a much higher octane number may be produced.

The isomerization of the lower olefins (butenes, pentenes) has been studied in considerable detail (3). It was found that the following catalysts favored the shifting of the double bond: zinc chloride, benzene-sulfonic acid and perchloric acid, pure phosphoric acid with or without diatomaceous earth, bauxite, silica, titania, difficultly reducible metal oxides, neutral borates, neutral phosphates, neutral silicates, aluminum phosphate on pumice, and aluminum sulfate. The n-butenes were isomerized to isobutene in presence of steam using such catalysts as aluminum sulphate, Glukhov clay, "floridin" or phosphoric acid dried either on charcoal or "silicate" related to Chamotte (3).

It has been found that the action of an isomerization catalyst on olefins has a tendency to produce cracking and polymerization; this tendency was noted by Luke (5) in his investigation of the isomerization of Hexene-1. Kindschy (4) reported that alumina activated with anhydrous hydrogen fluoride when used as a catalyst for dealkylating alkyl-benzenes acted also as an alkylation agent. Alkylation decreased with increase in temperature while dealkylation increased with increase in temperature.

The olefins which were used in this study were chosen because of their presence in cracked gasolines and Fischer-Tropsch naphtha. It was the desired purpose of this investigation to find the composition of the products formed from the isomerization and to note the change in octane numbers over the original charges. Favorable operating conditions were also to be determined in order to obtain maximum isomerization without excessive cracking.

II EQUIPMENT, METHODS AND MATERIALS

A. Equipment

The equipment used in this investigation consisted of the reaction system shown in Figure 1. In addition, the following equipment was required: potentiometer, a precision rectification column, Corad distilling head (constant reflux type), distillation flasks, two glass stem thermometers, Harvard triple beam balance, a refractometer, eight autotransformers, Parr hydrogenation bomb with heating jacket and rocker powered by an electric motor, a catalytic reaction system for the dehydration of heptanol and ethylhexanol, an Oldershaw vacuum jacketed rectification column, a dry ice cooled distilling head, and a flow meter.

The catalytic reactor consisted of a 24 inch length of three inch standard mild steel pipe. This pipe was capped at the lower end and fitted with a flanged head for easy removal. The thermowells consisted of 1/8-inch standard pipe extending into the catalyst bed. The catalyst bed extended from just below the bottom thermowell to the top thermowell. Iron-constantan thermocouples were used in conjunction with a Leeds and Northrup potentiometer with built in cold junction.

The reactor was wrapped with asbestos tape around which 75 feet of Nichrome wire was placed. Following additional asbestos winding two 33 feet lengths of Nichrome wire were added to supply additional heating. This Nichrome wire had a resistance of 1.079 ohms per foot. More asbestos tape was wrapped around the heating wires and then the reactor was further insulated with a one inch layer of magnesia.

The feed system consisted of a 1000 cc. graduated separatory funnel attached to a Merkle-Korff type bellows pump. Feed was admitted directly to the top of the reactor through 1/8-inch flexible copper tubing. A water cooled condenser followed by an 8 inch test tube acting as a water and tar trap was attached to the bottom of the reactor. Overflow from this trap passed into the continuous column through a side arm between the upper and lower section of the column.

The continuous column was constructed of three concentric glass tubes. The innermost tube was 33 mm inside diameter and was packed with 1/8-inch Fenske stainless steel helices. Nichrome resistance wire was wrapped around this inner column. The other two sections of tubing were placed around this inner column dividing it into two sections. Calibration of the column indicated the upper section to calibrate about 30 theoretical plates and the lower section about 14 theoretical plates. Details of the column construction are shown in Figure 1. On the top of the column was mounted an adjustable reflux head with a cold finger condenser as well as a wall condenser. The stillpot was of the continuous type with a side arm for takeoff, the overflow being recycled to the feed chamber through the use of a Merkle-Korff type bellows pump. This stillpot was welded solidly to the lower section of the column. The bottoms recycle was cooled by passing through another water cooled condenser.

Overhead from the column was first passed into a water cooled receiver where the liquid product was removed. Any non-condensable

vapors passing through this receiver were passed through a dry ice trap and a "Precision" wet test meter.

The precision rectification column used to fractionate the hydrogenated product was a batch column fitted with a Corad head and packed with 48 inches of 1/8-inch Fenske stainless steel helices. This column calibrated 30 theoretical plates.

The Parr hydrogenation bomb was of 250 cc. capacity fitted with a pressure gage which read from 0-10,000 pounds per square inch. The bomb fitted into an insulated jacket, with built-in heating coils, supported by an electric rocker. An iron-constantan thermocouple fitted in the bottom of the bomb and led to a Brown Potentiometer. Heat was supplied to the jacket through an autotransformer.

The reactor used to dehydrate the heptanol and ethylhexanol was of similar construction to that used in the isomerization unit except that only two heating wires of 33 and 75 feet Nichrome wire were used. Nine hundred ml. of Harshaw 1/8-inch activated alumina pellets were used as a catalyst. The alcohol was introduced to the reactor from a 1000 cc. graduated separatory funnel by means of a bellows pump. A water condenser was fitted to the bottom of the reactor in order to condense the vapors.

The Oldershaw column used with the butenes was fitted with a distilling head containing a mixture of dry ice and isopropanol in order to condense the low-boiling butene isomers. A 1000 ml. round bottomed flask was fitted to the bottom of the column. A flow meter was const-

ructed out of 14 mm. pyrex tubing arranged as a simple manometer across a small orifice about 1 mm. in diameter. In order to measure flow rates, this manometer was filled with water and calibrated with isobutylene passed through a "Precision" wet test meter connected in series with it.

The same system was used for condensing the product from the Oldershaw column as was used for condensing the light vapors which passed through the water receiver in the head as illustrated in Figure 1. The light butene isomers necessitated condensation of all products at temperatures which could not be reached by the use of cold water; therefore a dry ice-isopropanol mixture was required.

E. Methods

1. Preparation of Catalyst:

The reactor was filled with Berl saddles to a point about 1/8-inch below the bottom thermowell. Fifteen hundred ml. of Harshaw 1/8-inch activated alumina pellets were placed in the reactor over the Berl saddles. The reactor was then completely filled with additional Berl saddles which acted as a preheat section.

The catalyst was first dried by heating to 250°C. and holding that temperature for two hours. The reactor was then capped with a calcium chloride drying tube and allowed to cool to room temperature. Anhydrous hydrogen fluoride was passed through the reactor at room temperature for an hour, then the reactor was heated to 400°C. and held there for an hour while the hydrogen fluoride was still passing through. The catalyst was then purged with nitrogen to sweep out any excess hydrogen fluoride. During activation any excess hydrogen fluoride that flowed through the reactor was bubbled through kerosene and out through a blow-down line.

2. Isomerization:(a). Heptene, pentenes and octenes:

The reactor was heated until the temperature of the preheat section (top thermowell) reached 350°C., then the reactor was purged with nitrogen. By this time, the temperature of the preheat section having reached 375°C., the feed line was connected to the reactor and the feed introduced by starting the pump which was connected to the feed chamber. Two hundred to three hundred ml. of feed was usually kept in the chamber. The column

heats, as well as the stillpot heater, were turned on after enough material had collected in the stillpot to reach the side arm leading to the recycle pump. The recycle pump was started at this time. The system then was allowed to run until material was condensing in the head and the column and the reactor temperatures were constant showing that equilibrium conditions had been reached. The temperatures of the reactor generally ranged about 300°C. in the preheat section and 375°C. in the middle and bottom thermowell. These values are recorded in Table I. The column, head, and stillpot temperatures varied with the charging stock and are recorded in Table I.

Material balances for the system were determined after first lining out the system as described above. After noting the feed level in the 1000 ml. graduated feed chamber, a weighed amount of charge, usually 100 grams, was added. At the same time, the reading on the gas meter was noted and a new condenser was inserted in the dry ice trap. When the feed level in the graduated separatory returned to the original feed level (the level before the weighed amount of olefin charge was added), the total product collected in the water cooled receiver and the dry ice trap was weighed. The density of the gas was estimated at one gram per liter. The sum of the weights was then compared with that originally added. The unit was kept in continuous operation by merely adding more feed to the chamber.

To shut down the system, the reactor was purged with nitrogen for fifteen minutes. The oily material was blown out and collected in a suction flask which acted as a receiver. The effluent gases were withdrawn through a side arm on the receiving bottle. The reactor was then capped with a

calcium chloride drying tube on one end and the other was completely shut off from contact with air.

(b). Butenes:

Since the butene isomers are gases at normal temperatures it was necessary to devise a new system for feeding and removing the olefins to and from the reactor. The equipment available made it impossible to construct a continuous system without incurring considerable loss of vapors. The butane cylinder was connected to the flow meter (manometer type) by a neoprene tube and thence to the top of the reactor by another neoprene tube. The reactor was heated and purged in the same manner as for other olefins, and the temperature in the preheat section allowed to reach 380°C. before starting the butene flow. The reactor product was collected in the round bottomed flask attached to the bottom of the vacuum jacketed column. This flask was partially immersed in a bath of dry ice and isopropanol in order to condense the product. The water condenser preceding the stillpot cooled the vapors partially in order to prevent excessive contact of hot vapors with the cold stillpot. The head was cooled with a mixture of dry ice and isopropanol to prevent escape of any condensible vapors which passed through the stillpot and up the column. A "Precision" wet test meter was connected to the by-pass line on the condenser to measure the flow of non-condensable gases. After passing about 500 ml. of charge through the reactor the system was closed down as before and the stillpot on the vacuum column sealed off from the reactor and the atmosphere by stoppering the sidearm through which the product entered the stillpot.

3. Analysis of Product:

The product was hydrogenated in order to simplify the identification of products by distillation. Hydrogenation decreases the number of possible isomers but still shows the degree of chain branching.

Hydrogenation of all the isomers except those from the butene isomerization was carried out by placing 100 ml. of olefin product in the 250 cc. Parr hydrogenation bomb with 5-10 ml. of Universal Oil Products Company hydrogenation catalyst. The bomb was then pressurized by connecting with high pressure tubing to a hydrogen cylinder at a pressure of 1400-1800 pounds per square inch. The valve on the bomb was closed, the tubing disconnected and the bomb placed in the rocker and the thermocouple inserted. The rocker was started and heat was applied to the bomb by means of the heating jacket. When the temperature reached 100°C. (usually requiring about 10-15 minutes) the heat was turned off. The temperature continued to increase to 150°C due to lag, then the pressure dropped until constant indicating the reaction was complete. The bomb was allowed to rock until the temperature decreased to 100°C., or lower to insure complete reaction. The bomb was cooled to room temperature by removing it from the rocker and heating jacket and placing it in cold water. Next, the hydrogen was slowly bled off in a hood by means of the valve on the bomb and then the head was removed. The liquid product in the bomb was poured out leaving the catalyst in the bomb. Another charge of olefin was added and the process repeated. It was noted that the pressure drop for the pentene hydrogenation was about 8/5 of the pressure drop for

the octene hydrogenation which agrees with their molecular weight ratio.

The accumulated hydrogenated product from each type of isomerization was then weighed and placed in a one liter distillation flask with about 100 grams of chaser. Benzene was used as chaser for the hydrogenated pentenes, and diethylbenzene was used as chaser for the hydrogenated heptenes and octenes. The precision fractionation was carried out batch-wise. The column was run at total reflux and flooded to wet the packing. This was done by merely applying enough heat to the stillpot. After flooding, the heat was reduced. The reflux was set at 30:1 by means of the Corad head and the stopcock on the head was opened to allow the product to be withdrawn. Cuts were taken from the overhead, the size of which depended upon the range of temperature increase during the cut. When at a plateau, the cuts were large, while during a midfraction, the cuts were small. This was done to define the distillation curve more clearly. The refractive index of each cut was taken. The results are plotted in Figures 2-6.

4. Catalyst Burn-Off and Reactivation:

As the catalyst was used, a deposit of carbonaceous material and tar was laid down upon its surface thus reducing the activity of the catalyst and necessitating periodic burn-offs. The catalyst was burned off after 15-20 hours use.

Burn-off was accomplished by passing air through the reactor while maintaining the temperature below the sintering point of the catalyst (570°C.). The air for burn-off was regulated by a needle valve as only

a small stream of air could be allowed to pass over the catalyst. The oil and carbon ignited readily and heated the reactor very rapidly to the catalyst sintering point unless great care was taken in the control of the admission of the air.

It was found that reactivation of the catalyst with hydrogen fluoride was unnecessary during the 300 hours of use since no loss of activity was noted during this time.

5. Preparation of Olefins From Alcohols:

The heptene and ethylhexene were prepared from the dehydration of 2-heptanol and 2-ethylhexanol respectively. The dehydration reactor containing the alumina catalyst was first heated to 400°C. and the alcohol introduced at the rate of 15 ml. per minute. The effluent from the reactor was condensed and collected. The water was decanted off and the remainder collected in a large distillation flask. The olefins were separated from the remaining water and unreacted alcohol by fractionation in a precision column. The heptene cut was made between 88 and 90°C. at a pressure of 640 mm, and the ethylhexene cut made from 113-114°C. at 635 mm. A refractive index of 1.4036 was found for the heptene product and 1.4173 for the ethylhexene product. All refractive indices were taken at 20°C.

C. Materials

<u>Material</u>	<u>Source</u>
One-eighth inch Activated Alumina Pellets	Harshaw Chemical Co.
Anhydrous Hydrogen Fluoride	Matheson Company
Hydrogenation Catalyst	Universal Oil Products Company
Hydrogen	Air Reduction Co.
2-Heptanol	Carbide & Carbon Chemicals Corporation
Pentene-1	Phillips Petroleum Company
1-Octene	Humphrey Wilkinson Company
2-Ethylhexanol	Carbide & Carbon Chemicals Corporation
Isobutylene	Phillips Petroleum Company
cis-Butene-2	Matheson Company

III RESULTS

Heptene Isomerization

This isomerization was carried out on the product from the dehydration of 2-heptanol. The heptene prepared in this manner had a refractive index of 1.4036, and a boiling point of 89 °C. at 640 mm. These values indicated the heptene to be a mixture of 1-heptene and 2-heptene. The conditions of the isomerization are shown in Table I. In removing the overhead product from this isomerization in the continuous column a reflux ratio of 3:1 was used. The composition of the overhead could be varied by changing the reflux ratio in the head, a more volatile product being obtained at a higher reflux ratio.

Analysis of the hydrogenated overhead product from the heptene isomerization was made in a precision rectification column. Figure 2 shows the fractionation curve of this hydrogenated product. Before hydrogenation, the olefinic product had a refractive index of 1.3873. Examination of the fractionation curve from the hydrogenated product showed two distinct plateaus. The largest plateau covered 50 per cent of the charge by weight. The refractive index for this plateau ranged from 1.3872-1.3892 and had a boiling point of

about 84 °C. at 630 mm. The smaller plateau covered about 10 per cent of the charge; its refractive index ranged from 1.3824-1.3830 and had a boiling point of about 75 °C. at 630 mm. Infrared analysis by the Analytical Group of the Phillips Petroleum Company of Bartlesville, Oklahoma, showed the smaller plateau to be predominately 2, 4-dimethylpentane, while the larger plateau had the following composition:

2,3-dimethylpentane	20.1 volume %
3-methylhexane	30.8 volume %
2-methylhexane	51.2 volume %

Analysis by the infrared method of the complete hydrogenated charge is shown in Table II. The research octane number of the hydrogenated product was 60.6 as compared with an octane number of 0 for n-Heptane, which would have been formed by the hydrogenation of the heptene product had no chain branching isomerization taken place.

Pentene Isomerization:

The charge used for this isomerization was 1-pentene. It was necessary to use special cooling and precautions with this isomerization in order to save the low boiling pentene isomers. As soon as the pentene product was removed from the continuous column it was placed in a stoppered bottle and kept cold in a refrigerator. This isomerization was divided into two parts, allowing comparison of overhead and

bottoms product. In the first the product was removed as overhead from the continuous column using a reflux ratio of 5:1, and in the second, the product was removed from the bottom of the continuous column while the overhead was recycled. The reflux ratio used in the head while removing bottoms product was about 1:1. The products from these isomerizations were separately hydrogenated and analyzed. The operating conditions for the isomerization runs are shown in Table I. The pentene overhead product had a refractive index of 1.375 while the refractive index of the pentene bottoms products was about 1.383. The hydrogenated products were analyzed by making a precision rectification of the separate products. The results from these fractionations, as shown in Figures 3 and 4, indicated an iso-structure of about 45% for the overhead and 35% for the bottoms.

The olefinic products from the pentene isomerization were analyzed by Phillips, and the results of this infrared analysis are shown in Table II. It can be seen that the isomerization of 1-pentene produced a product containing all possible isomers. The Research octane number of the hydrogenated overhead and bottoms product as reported by Phillips indicated the overhead product to have an octane number of 80 and the bottoms product to have an octane number of

77. Hydrogenation of 1-Pentene without isomerization would produce n-Pentane having an octane number of 61.7. The increase in octane number as the result of the isomerization amounted to almost 20 points.

Octene Isomerization:

It was found when isomerizing octenes that cracking took place easier than with the shorter chain olefins. A slight change in the reflux ratio used in the head caused a large variation in the temperature of the product being withdrawn as overhead. In this isomerization 1-octene and ethylhexene were used as the charge materials. The ethylhexene was prepared by the dehydration of 2-ethylhexanol. The product from this dehydration had a boiling point of 113-114 °C. at 635 mm and a refractive index of 1.4173. This indicated that the ethylhexene produced in this manner was a mixture of the various ethylhexenes. The temperatures and conditions for the isomerization of each of these olefins were held as near constant as possible as indicated in Table I in order to compare the isomerization of the two separate charges. A reflux ratio of 4:1 was used in the head of the continuous column. The products of the two isomerizations were both removed at a head temperature of about 96-97 °C. and the refractive index

of the 1-octene product was 1.4033 as compared with 1.4045 for the ethylhexene product. The variation in the refractive index may be attributed to the evaporation of the lights in the product which immediately changes the refractive index. These cracked products formed from the octene isomerization appeared to be in the butene range as indicated by their rapid evaporation. Hydrogenation and precision rectification of the octene isomerization products were made and their fractionation curves are shown in Figures 5 and 6. Comparison of these two plots indicate that the products of both isomerizations have essentially the same composition. The hydrogenated products of both isomerizations were sent to Phillips for analysis; however, because of the large number of isomers and the presence of unsaturates it was impossible to make an accurate infrared analysis. The octane numbers determined by the ASTM method showed the hydrogenated product from the 1-octene isomerization to have an octane number of 70.4, and the hydrogenated ethylhexene product had an octane number of 71.3. These octane numbers supported the foregoing observation that the products of both isomerizations were of essentially the same composition.

Butene Isomerization:

The butene isomerization was carried out batchwise as

it was not feasible to operate a continuous system without incurring excessive losses. Isobutylene and cis-2-butene were used as the charges for the butene isomerization runs. The rectification of the products of these isomerizations was performed in an Oldershaw vacuum jacketed column, and the resulting fractionation curves are shown in Figure 7.

Analysis of these curves indicated that isomerization had taken place, but that the products were not of the same composition. This indicates that the isomerization of the butenes is more difficult than with the longer chain olefins. Also, no recycling was used in these isomerizations and there was less chance for equilibrium conditions to be reached. The conditions of these isomerizations are shown in Table I.

The product from the isomerization of cis-2-butene was analyzed by infrared methods by the Analytical Group of the Phillips Petroleum Company. A small amount of C₃ and C₅ was removed by fractionation and the remaining C₄ fraction yielded the following analysis: Propane 0.2 vol.%, isobutane 1.8%, trans-2-butene 42.7%, 1-butene 19.5%, isobutylene 1.7%, n-butane 0.0%, cis-2-butene 30.0%, C₅ and heavier 4.1%.

IV SUMMARY

1. Alumina activated with anhydrous hydrogen fluoride may be used as an isomerization catalyst in the temperature range of 360-380 °C. converting butenes, pentenes, heptenes and octenes into a mixture of their straight and branched chain isomers.

2. No one isomer predominates exclusively and the infrared analysis of the pentenes showed all isomers to be present.

3. In the octene isomerization it was shown that the ethylhexene and 1-octene isomerization products were of essentially the same composition.

4. By isomerizing continuously a straight chain olefin having a low octane number, a mixture of isomers having a higher octane rating can be produced.

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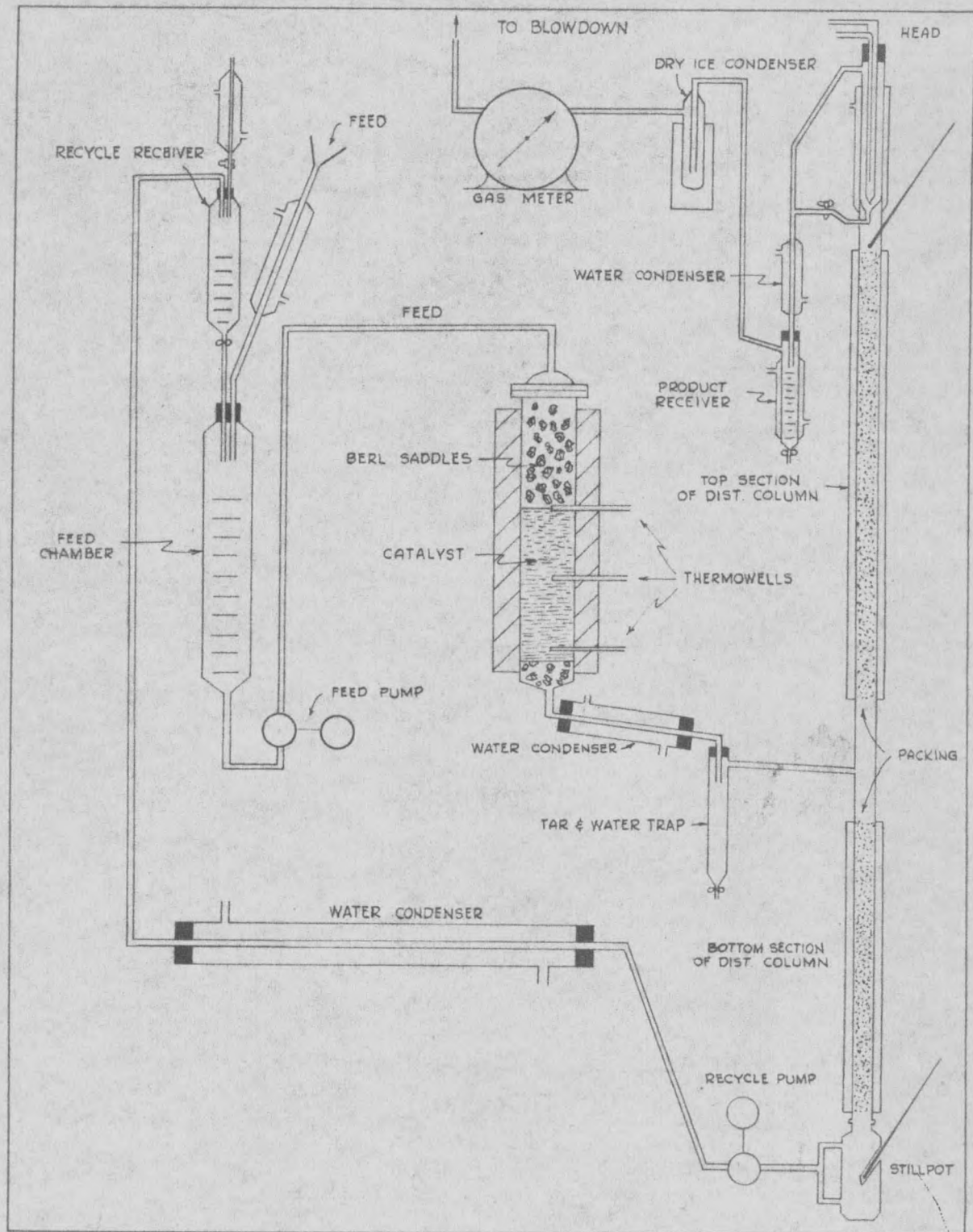


Figure 1. - Diagram of Equipment

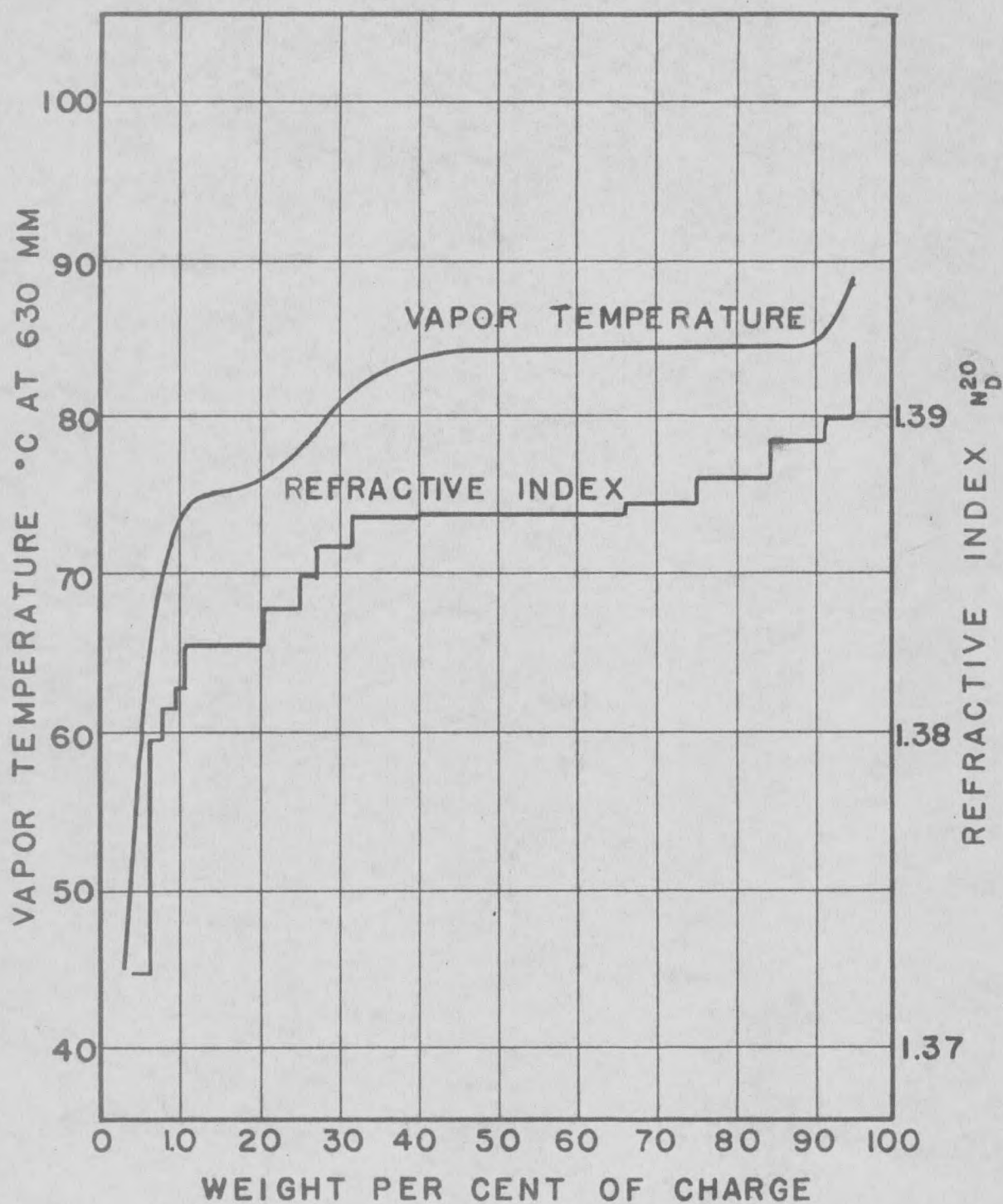


Figure 2 - Analysis of Hydrogenated Heptene Overhead Product.

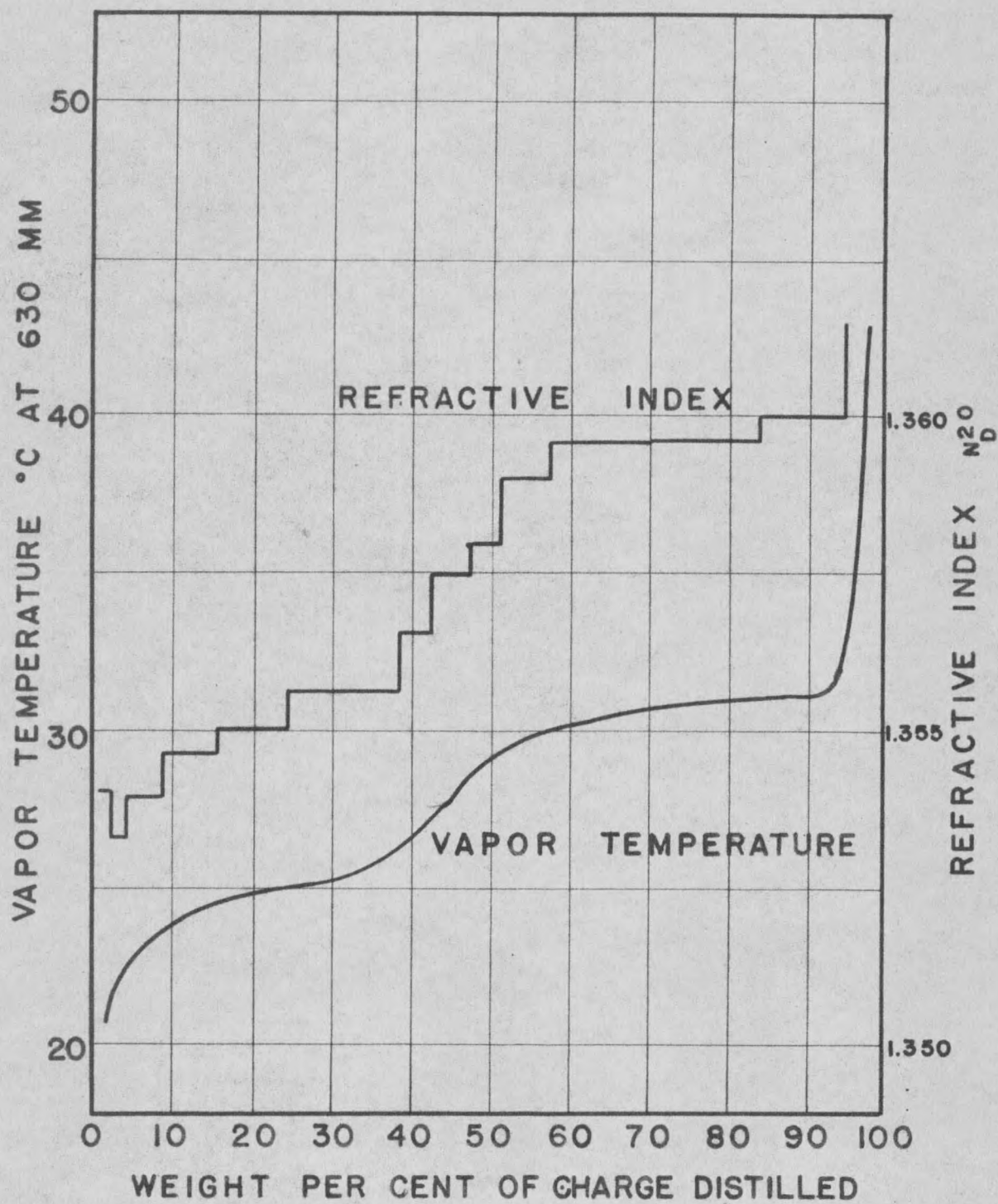


Figure 3 - Analysis of Hydrogenated Pentene
Overhead Product

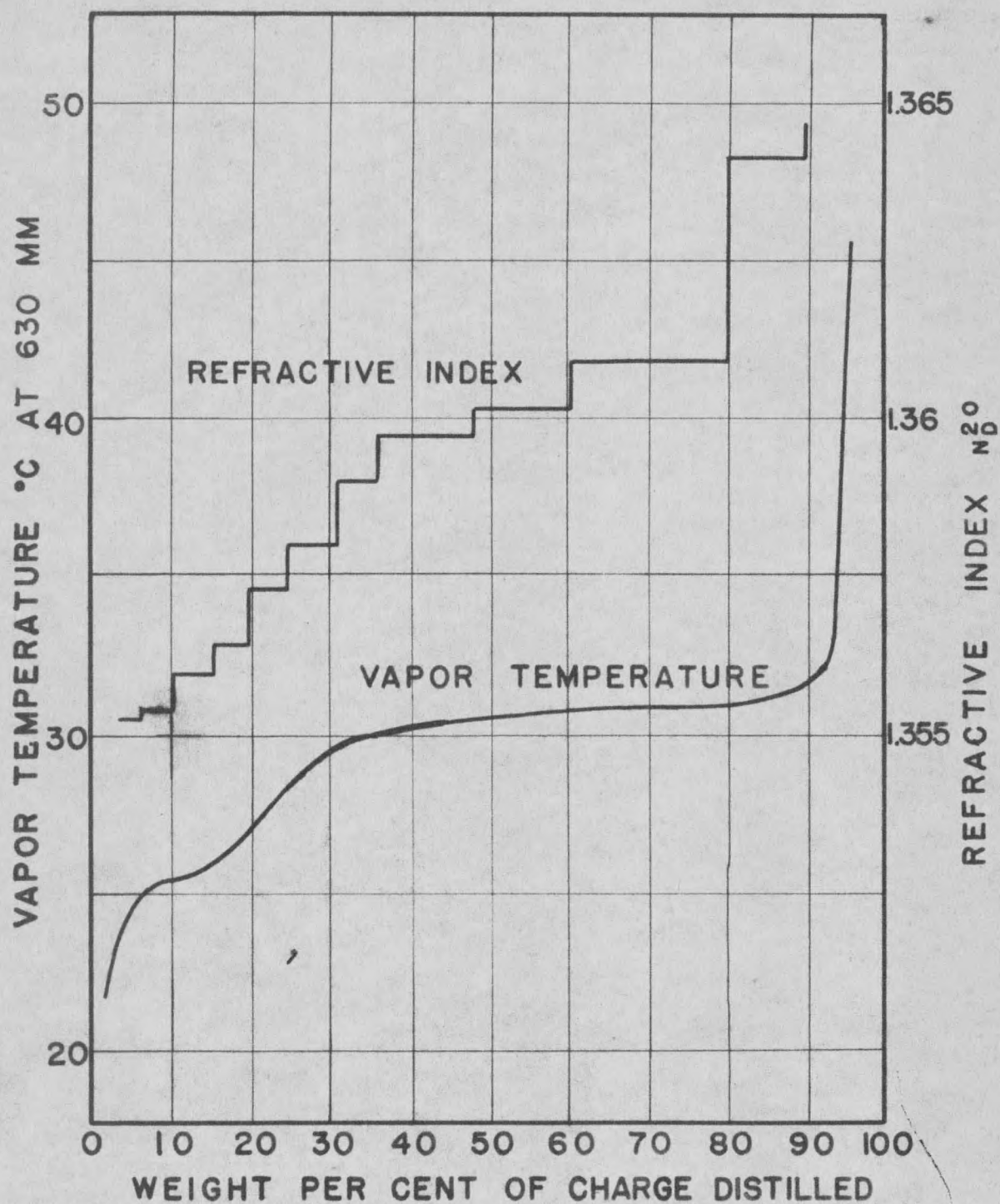


Figure 4 - Analysis of Hydrogenated Pentene
Bottoms Product

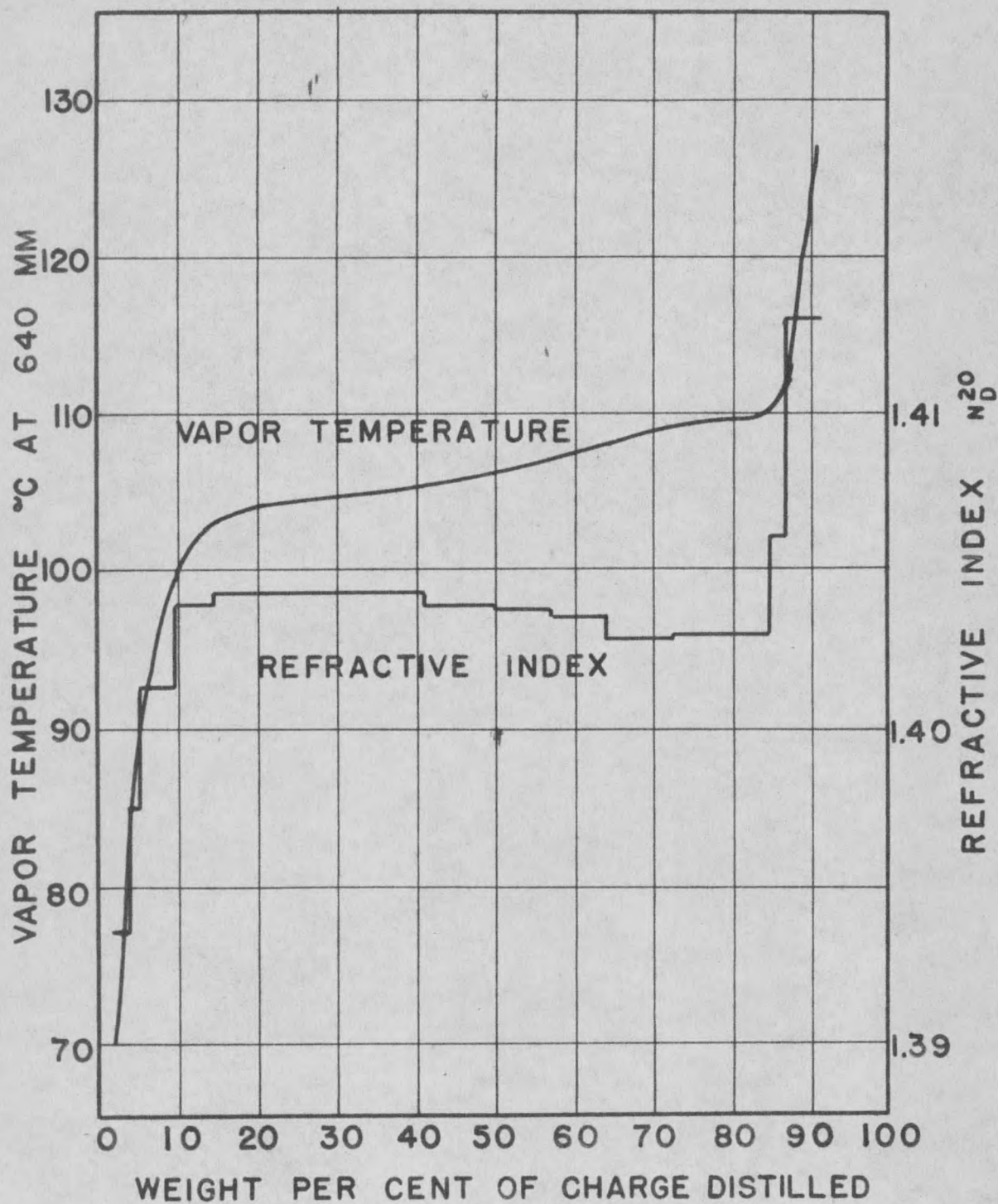


Figure 5 - Analysis of Hydrogenated 1-Octene Overhead Product.

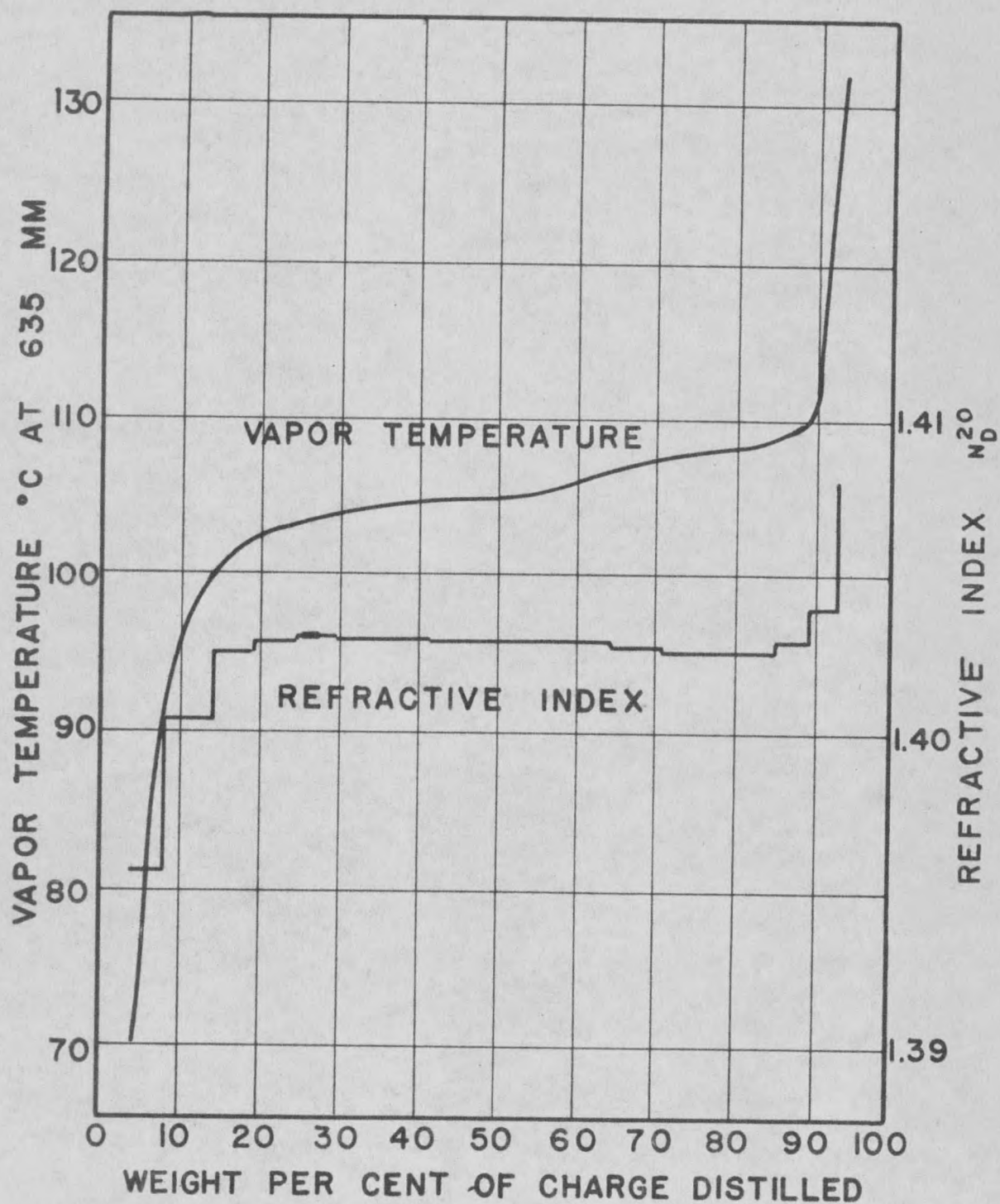


Figure 6 - Analysis of Hydrogenated Ethyl-Hexene
Overhead Product

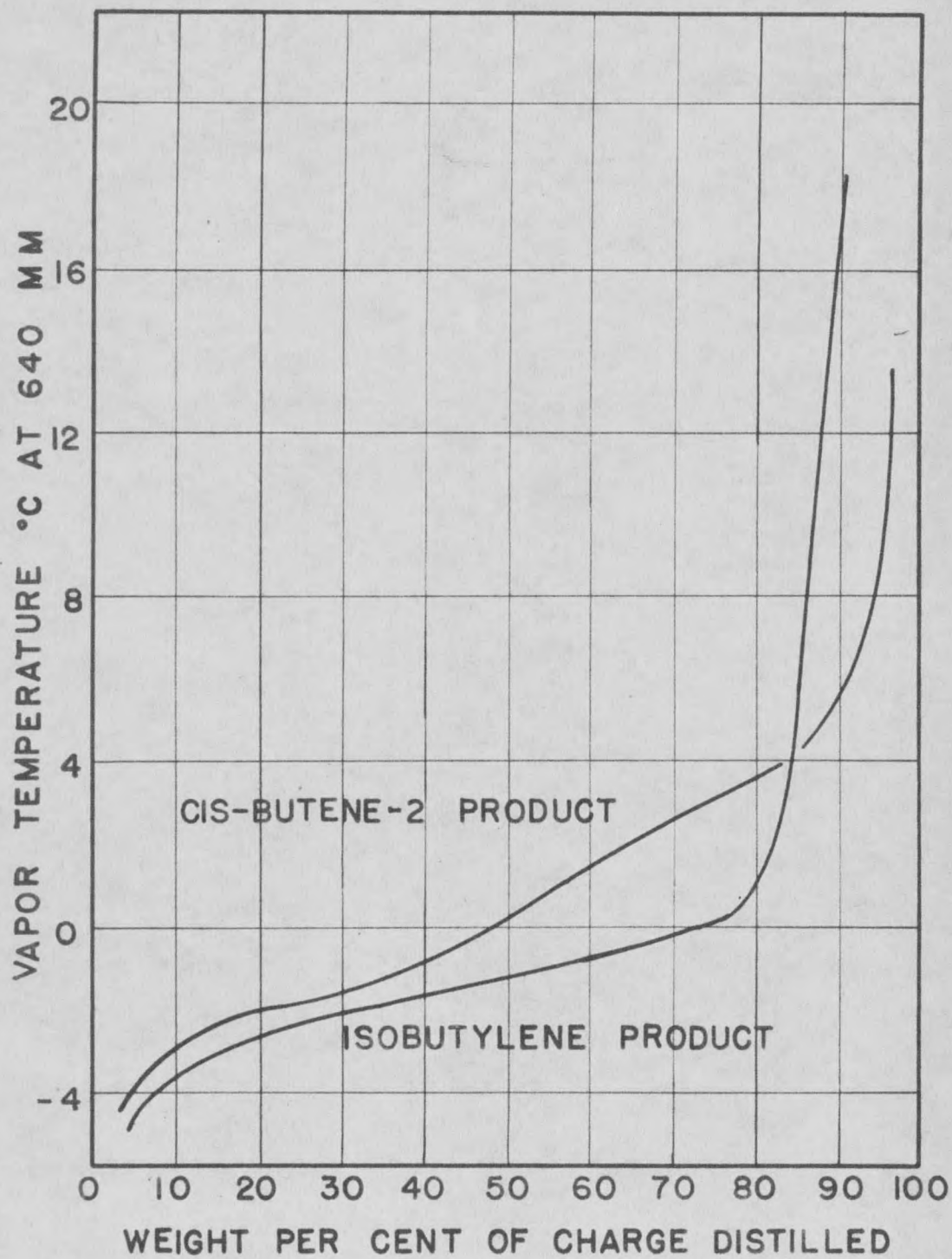


Figure 7 - Analysis of Butene Products

TABLE I

Material Balances

Charge:	Heptene	Pentene (overhead)	Pentene (bottoms)	1-Octene	Ethyl- Hexene	Iso- Butylene	Cis-2- Butene
Charge Weight, grams:	100	100	100	300	300	320	200
Charge Volume, ml:	140	154	154	420	420	530	530
Time of Run, minutes:	48	60	22	137	126	34	22
Feed Rate, ml./minute:	12	15	17	16	16	15.6	15
Catalyst Volume, ml:	1500	1500	1500	1500	1500	1500	1500
Average Reactor Temperatures, °C:							
Upper (preheat) Section:	290	295	270	325	320	370	375
Middle Section:	373	375	350	375	375	380	380
Lower Section:	371	375	363	374	371	325	320
Average Column Temperatures, 640 mm: °C.							
Head; °C:	74.9	26.6	29.5	96	97.5	---	---
Section above Feed Plate:	84.0	30.0	33.0	102	113	---	---
Section below Feed Plate:	92.0	36.5	38.8	119	122	---	---
Stillpot:	102.2	43.0	35.0	127	125	---	---
Product Weight, grams:							
Liquid Column Overhead:	91.0	95.6	96.5	291.4	292.8	---	---
Liquid Condensed in Trap:	4.0	2.0	1.8	5.1	3.9	---	---
Non-condensable Gases:	0.3	0.2	0.3	1.0	1.0	---	---
Total Weight Recovered; grams:	95.3	97.8	98.6	297.5	297.7	---	---

TABLE I (Continued)

	Heptene	Pentene (overhead)	Pentene (bottoms)	1-Octene	Ethyl- Hexene
Total Volume Recovered, ml:	137	150	152	418	418
Weight Per Cent Recovery:	95.3 %	97.8 %	98.6 %	99.1 %	99.2 %
Volume Per Cent Recovery:	97.9 %	97.0 %	98.5 %	99.5 %	99.5 %

TABLE II

Liquid Product Analysis

Heptene Product after Hydrogenation:

2,3-Dimethylpentane	13.3	volume %
2,4-Dimethylpentane	20.8	volume %
3-Methylhexane	28.6	volume %
2-Methylhexane	33.4	volume %

Pentene (overhead):

2-Methyl-1-Butene	16.0	volume %
3-Methyl-1-Butene		
1-Pentene	26.0	volume %
Isopentane	2.9	volume %
2-Methyl-2-Butene	21.5	volume %
2-Pentene	32.1	volume %
n-Pentane	1.5	volume %

Pentene (bottoms):

2-Methyl-2-Butene	33.7	volume %
2-Pentene	62.2	volume %
n-Pentane	4.1	volume %



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