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USE OF ALCOHOL FROM FARM PRODUCTS IN MOTOR FUEL

LETTER

FROM

THE SECRETARY OF AGRICULTURE

TRANSMITTING

IN RESPONSE TO SENATE RESOLUTION NO. 65, SUBMITTED BY SENATOR SHIPSTEAD, A REPORT PERTAINING TO THE PRACTICABILITY AND ADVANTAGES TO AGRICULTURE OF USING ALCOHOL MANUFACTURED FROM CORN AND OTHER FARM PRODUCTS IN MOTOR FUEL

May 1 (calendar day, May 8), 1933.—Ordered to lie on the table and to be printed

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LETTER OF TRANSMITTAL

Department of Agriculture,
Washington, May 3, 1933.

The President of the Senate.

Sir: Pursuant to the request made in Senate Resolution 65, Seventy-third Congress, I am transmitting herewith a report pertaining to the practicability and advantages to agriculture of using alcohol manufactured from corn and other farm products in motor fuel, prepared by the Bureaus of Agricultural Economics, Chemistry and Soils, and Agricultural Engineering of this Department.

Sincerely yours,

Henry A. Wallace,
Secretary.

LETTER OF SUBMITTAL

WASHINGTON, D.C., *May 3, 1933*.

The SECRETARY OF AGRICULTURE.

DEAR MR. SECRETARY: The Senate of the United States under date of May 2, 1933, passed the following resolution:

Resolved, That the Secretary of Agriculture is hereby requested to investigate, through the agencies of the Bureaus of Agricultural Economics, Chemistry and Soils, and Agricultural Engineering, of the Department of Agriculture, the practicability and advantages to agriculture of using alcohol manufactured from corn and other farm products, in motor fuel, and to report thereon to the Senate as soon as possible.

A report complying with this resolution is herewith submitted.

Sincerely yours,

NILS A. OLSEN,
Chief, Bureau of Agricultural Economics.
HENRY G. KNIGHT,
Chief, Bureau of Chemistry and Soils.
S. H. MCCRORY,
Chief, Bureau of Agricultural Engineering.

USE OF ALCOHOL FROM FARM PRODUCTS IN MOTOR FUEL

SUMMARY

The depression has intensified interest in the possibility of developing new uses for farm products. The development of the internal-combustion engine has displaced horse and mule power and reduced the feed requirements for power animals to the extent of the production of about 35,000,000 acres. Finding an additional outlet for some part of this production, for which the demand has disappeared, would contribute to an improvement of the agricultural situation.

Experience in the United States and in many foreign countries has demonstrated that alcohol, manufactured from farm products, can be used successfully as motor fuel in a blend with gasoline. Anhydrous (99.5 percent) alcohol can be mixed with gasoline in any proportion, but the maintenance of a blend requires reasonable care to prevent the addition of water, or the use of a blending agent. Alcohol, added to gasoline, raises the antiknock rating; improves combustion, thus tending to prevent carbon formation; and in general makes for smoother engine operation. On the other hand, the solvent effects of alcohol may cause some difficulty, and as the percent of alcohol increases materially its lower heat unit value may require increased fuel consumption, especially in low-compression motors. Most engines now in use appear to be able to handle a 10 percent alcohol-gasoline mixture without adjustments and without much change in mileage per gallon of fuel.

Corn would provide an abundant supply of suitable raw material for the production of alcohol. Other farm products, such as wheat, rice, and potatoes, could be utilized when there were large supplies available at low prices. In fact, the manufacture of alcohol could be used as a material aid in taking care of surpluses and stabilizing the markets for farm products.

Using large economically operated units, the cost of anhydrous alcohol made from 25-cent corn would be about 27 cents; from 50-cent corn, about 39 cents; and from 75-cent corn, about 52 cents per gallon. The manufacturing cost from corn by ordinary processes would vary from about 7 to 11 cents per gallon, depending upon the size of the plant. Denaturing and distributing, together with some allowance for profit, would add about 9 cents per gallon to the manufacturing costs.

Blending alcohol with gasoline at present prices would increase the cost of a gallon of motor fuel. With corn at 50 cents per bushel and gasoline at 13 cents per gallon, the use of 2 percent anhydrous alcohol would add about one half cent; and the use of 10 percent would add about 2⅗ cents per gallon to the cost of motor fuel. This would, of course, increase the cost of motor power to farmers as well as to the public generally, but not without offsetting benefits.

Requiring the use of alcohol in motor fuel would in the first place tend to reduce the consumption of gasoline which may be offset by increased consumer purchasing power resulting from general business recovery. The oil industry is now in a chaotic situation. The production of crude oil and gasoline continues at a high level, in the face of reduced demand. Consequently, the prices of gasoline and all the byproducts of the crude-oil industry are now at a low level.

A great reduction in the buying power of the farmer is an important factor in the depression. Farmers have been compelled to reduce their purchases of automobiles, trucks, and tractors, and curtail the use of these machines. They have, in many cases, even been forced to return to the use of the horse and mule instead of the tractor, automobile, and truck. The reduced buying power of farmers has affected the sales of other things and contributed to unemployment generally. Any material improvement in the income of the farmer, therefore, might increase the sales of automotive machinery and of gasoline, to the extent of offsetting, in part at least, the increase in the costs of this fuel.

A new industrial outlet for large quantities of corn and barley would materially increase the prices of these products. Raising the price of corn and barley would increase to some extent the prices of all other feed grains and even wheat. Hog production would be reduced, resulting in higher prices and some increase in income. Cotton growers would increase corn acreage and grow a little less cotton. Corn acreage generally would increase to some extent and tend to reduce the acreage of wheat as well as cotton. Dairy and cattle feeding on corn in the Corn Belt might be reduced, but the increased production of distillers' grain would provide relatively cheap high-protein feeds for the dairy industry. All of these shifts would tend to improve the farm organization of the country and stabilize income on a higher level.

The present capacity of distilleries in the United States is sufficient to supply alcohol only to the equivalent of about 1½ percent of the motor fuel used annually. Even the existing plants would have to be overhauled, and in many cases additional equipment would be required, to manufacture alcohol from grain. Adopting a policy of increasing the use of alcohol would require provision for increasing plant capacity. The maintenance of a 2 percent blend would require additional capacity to produce at least 100,000,000 gallons per year. A 5 percent blend would require about 550,000,000, and a 10 percent blend 1,300,000,000 gallons additional capacity.

Furthermore, overhauling the existing plants and the building of new plants would contribute materially to increased employment. These operations would increase the demand for equipment machinery, building materials, freight tonnage, construction labor, and finally even fuel, for operating the plants.

The prompt development of manufacturing capacity sufficient to provide alcohol for blending to the extent of 5 or 10 percent in motor fuel would require some extraordinary measures, either to induce private capital to undertake the building of plants or to furnish capital through some Government agency. One of the problems to be met is that of insuring the future of the industry. Doubtless private capital could be obtained for the construction of plants sufficient to manufacture alcohol required for a 10 percent blend, if continuous operation on a profitable basis could be insured for a number of years, and especially if it were reasonably certain that the demand would increase and that there would be opportunity for the industry to expand.

Under present conditions some special measures would have to be undertaken to secure or insure the use of any considerable quantity of alcohol in motor fuel. It would be hazardous for private capital to enter upon an extensive construction program without substantial assurance that some Government policy of maintaining the industry would be carried through. An important factor in the cost of manufacturing is the cost of the plant. The continuous operation of the plant through a period of years tends to reduce costs. Private capital cannot enter into the business and sell alcohol on a low cost basis without assurance of a high rate of operation through a period of years. Viewing the proposition as a part of a general reconstruction program, the Government may properly advance funds for the reconstruction of plants and the development of new plants. Furthermore, the manufacture and use of industrial alcohol to stabilize the market for farm products by using larger quantities when materials are abundant and cheap, and curtailing operations when crops are short and prices high, may be properly considered a public enterprise to be operated by or under the close supervision of the Government. Such a policy could be followed to protect the consumer against being compelled to pay excessive costs of manufacturing or excessive profits on account of the hazards of the industry, as well as to provide an outlet for surplus farm products and help to establish and maintain a more satisfactory position of agriculture in the national economy.

The development of a farm-product alcohol industry should not be considered solely an emergency measure. If undertaken, it may be to the interest of both the users of motor fuel and the farmer to adopt it as a long-time program. The fact that there is now a surplus of crude oil and gasoline must not lead us to the belief that the oil resources of the country are inexhaustible. However, the manufacture of petroleum substitutes from other than farm products may be developed on a low-cost basis. On the other hand, a well-planned agricultural program or policy will maintain the renewable resources of the country indefinitely. Undoubtedly the costs of processing farm products into alcohol may be reduced to some extent and the demand for the by-products of this processing may increase. This consideration of a long-time program might warrant the adoption of a definite Government policy for encouraging, and at least protecting, the development of the industry and the use of alcohol in motor fuel, either by private capital under private management or by Government loans and Government operation or regulation.

If a policy of encouraging or requiring the use of alcohol in motor fuel were adopted by the United States, some special measures to this end would be necessary. Doubtless some alcohol would be used in motor fuel upon its own merits, but the relatively high cost of production handicaps its present use. In some foreign countries with a high import duty or other tax levied upon gasoline, alcohol is produced and mixed with the gasoline without adding materially to the cost of the fuel. In a few cases the blend is sold on its own merits, either at the same or a slightly higher price. In most countries, however, in which alcohol is now being used in motor fuel, special measures have been resorted to, to encourage its use.

A preferential tax could be utilized to encourage the development of the new industry and the use of the product in motor fuel. Apparently the best method of applying such a tax would be merely to require producers or distributors of motor fuel to use alcohol to the extent of some specified percentage of the total quantity of motor fuel distributed. This would simplify administration and permit the distributor to make the most economical use of the alcohol and sell both straight gasoline and blends in accordance with technological considerations and public preference. The tax levied upon the disdistributor of motor fuel should be only slightly in excess of the additional cost of the fuel on account of the use of alcohol. The extent of the use of alcohol in motor fuel could be effected by variations in the tax rate, as long as the alcohol costs more per gallon than the gasoline. The public should be protected against marked advances or too high costs of motor fuel on account of very high prices for farm products. This could be accomplished either by absolute Government control of the production and price of alcohol or by keeping the tax rate low enough so that when the cost of alcohol increased above some rate considered reasonable, the distributor could pay the tax and distribute relatively more gasoline, rather than buy all the alcohol required to blend a specified percentage of all motor fuel.

BEHAVIOR OF ALCOHOL-GASOLINE FUELS

In reviewing available information on the performance of alcohol and alcohol-gasoline mixtures as fuel for internal combustion engines, no significant difference appears to be evident other than what might be attributed to experimental error, when burning mixtures up to 10 percent of absolute alcohol and regular gasoline. The heat value of gasoline is approximately 19,200 and of alcohol 11,600 British thermal units per pound, or 114,850 and 78,900 British thermal units per gallon, respectively. On this basis, a gallon of 10 percent mixture of absolute alcohol and regular gasoline contains about 97 percent of the heat units contained in a gallon of gasoline. The 3 percent reduction in heat units available, however, would be practically offset by the denser charge due to the cooling effect of the alcohol. The maximum power, therefore, in a given engine designed for gasoline, would be about the same when using either plain gasoline or the blend. Fuel consumption increases in a given engine with the increase in the percent of alcohol until on alcohol alone the fuel consumption becomes approximately 50 percent greater than on gasoline. If, however, the compression be raised, the fuel economy of alcohol could be made to approach that of gasoline.

Observations and tests made by the Bureau of Agricultural Engineering, United States Department of Agriculture, on the behavior of alcohol-gasoline mixtures in internal combustion engines, including trucks and tractors, indicate that absolute alcohol can be mixed with regular gasoline at room temperature in any proportions. These results agree with findings of other Government agencies. Tests with mixtures of 10 and 20 percent absolute alcohol compared to that on straight gasoline, indicated very little difference in maximum horsepower developed, fuel economy, or acceleration.

It was found that the octane rating (antiknock value) of regular gasoline is improved by the addition of alcohol. When 10 percent absolute alcohol by volume was added, the average rating of three gasolines was increased from 66 to 74, by the addition of 20 percent to 80, and by the addition of 30 percent to 85. (Present ethylized gasoline rates 78.)

The best available information indicates that there should be no difficulty in blending absolute alcohol with the various brands of low-grade automobile gasoline. The volatility of this lower-grade gasoline apparently is not much different from that of the regular gasoline but the octane rating is considerably lower (an average of 55 as compared with about 66). The volatility and octane rating may vary somewhat in different parts of the country, due principally to the source of the crude oil from which the gasoline is obtained and to the nature of the process employed by the refiner. The addition of alcohol would greatly improve the antiknock value of the lower-grade fuel. In fact, the improvement of the octane rating by adding alcohol to the lower grade appears to be greater than that realized from adding the same amount to higher-grade gasoline. Iowa tests have shown that by adding 10 percent alcohol to a gasoline rating 56, the rating was increased to 65,[1] whereas by adding 10 percent alcohol to a gasoline rating 66, the increase was to 74.

PERFORMANCE TESTS

Because of the wide variation in conditions due to weather, inherent features of design, personal equation, and other factors, the performance of different units is bound to vary.

In the tests on a stationary multiple-cylinder engine the maximum horsepower and fuel economy varied slightly from 16.09 horsepower and 7.85 brake horsepower-hours per gallon, respectively, on straight gasoline to 16.34 horsepower and 7.77 horsepower-hours per gallon on 10 percent admixture alcohol and to 16.52 horsepower and 8.05 horsepower per gallon, rsepectively, on 30 percent admixtures.

Road tests with trucks ranged (1) with a one-half ton (unloaded), from 16.67 miles per gallon on straight gasoline to 16.66 on 10 percent alcohol admixture and to 15.92 on 20 percent alcohol admixture fuel; (2) with a 1½-ton (net load 3,380 pounds), from 12.73 miles per gallon on straight gasoline to 12.68 on 10 percent alcohol admixture and to 12.62 on 20 percent; (3) with a 3½-ton (net load 7,700 pounds), from 5.43 per gallon on straight gasoline to 5.79 on 10 percent alcohol admixture and to 5.85 on 20 percent alcohol admixture.

Acceleration tests of the above trucks showed that the pick-up was slightly retarded as the alcohol content of the mixture was increased.

On the tractor belt tests a 4-cylinder tractor engine delivered a maximum horsepower of 31.8 on straight gasoline and 31.6 horsepower on a 10-percent admixture with a fuel consumption of 6 and 6.4 brake horsepower-hours, respectively, per gallon.

A 2-cylinder horizontal tractor engine delivered a maximum horsepower of 31.7 on straight gasoline and 32.2 horsepower on a 10-percent admixture of alcohol with a fuel consumption of 7.7 and 7.6 brake horsepower-hours per gallon, respectively.

In all of the above tests the carburetor setting was kept the same on the different units—the original position set for burning gasoline alone.

[1] Iowa State College, Ames, Iowa. The Use of Alcohol as Motor Fuel. Progress Report No. II. Knock Rating Tests of Alcohol-Gasoline Mixtures.

Exhaust gas analyses showed that the combustion of the mixtures was more complete than of gasoline alone. This may be due to the fact that the ordinary carburetor setting on gasoline was richer than required for maximum economy and that with the greater air fuel ratio existing when the mixture was used more complete combustion took place.

Iowa State College, Ames, Iowa, states that, after experimenting with several cars, it was not found that the alcohol caused the fuel tank or fuel line to rust. Alcohol cleaned out the fuel system, removing dirt and gum. The filters that are installed in all cars should take care of this matter. If they do not, once the system has been cleared, there will be no further trouble from this source.

M. Paul Dumanois reports in La Revue Agricole, May-June 1932, that a small addition of alcohol to gasoline increases the power theoretically and also practically. The maximum increase in power is reached at between 15 and 20 percent of alcohol, when a further increase of alcohol causes a reduction in power.

The consumption per horsepower-hour is practically the same with alcohol as with gasoline to which 10 percent alcohol has been added. The starting is about as easy in the one case as the other. The antiknocking properties are improved, the mixture is stable, and there was no separation during the time the fuel was in storage.

W. E. Cross, in the Industrial and Agricultural Review (France), comes to the conclusion that the addition of alcohol to gasoline gives the following advantages: The explosions are less noisy, the motor heats up less, and the combustion is more complete. The consumption of the fuel and the lubricating oil per kilometer traveled are reduced in spite of the increase in power.

Dr. Brown, of the University of Michigan, in Automotive Industries for April 1, 1933, says:

> Miles obtained from a gallon of motor fuel will be decreased about 4 percent for every 10 percent of alcohol contained in the blend.
>
> Technical difficulties in prospect include dissolving the protecting shellac on cork floats in carburetors and gasoline gauges, stoppage of fuel lines and carburetor screens by scale removed by the alcohol from metal surfaces, corrosion on moving parts of engines.

Herbert Chase, in the June 8, 1922, issue of Automotive Industries, says:

> Ricardo's research work in reference to the maximum compression which various liquid fuels will stand without detonation shows that 98 percent alcohol will stand well over 200 pound equivalent to a ratio of 7.5 to 1 * * *.

This indicates good qualities in alcohol for blending.

Chase states further, after discussing tests made on engines using gasoline and alcohol separately:

> All authorities appear to agree that the use of alcohol fuel results in a much smoother operation of the engine than with gasoline and that detonation does not occur as it often does with gasoline when the compression ratio is no higher than 4 to 1. * * * One of the marked advantages resulting from the use of alcohol as compared to gasoline is the absence of carbon deposit. Engines which carbonize badly in short periods when using gasoline have been run on alcohol for months without trouble from carbon deposit.

In reports from the Imperial Motor Transport Council of Great Britain, W. R. Ormandy, chairman, states that "detonation with alcohol does not occur with compression ratios up to 8 to 1 * * *." Other findings in the report were:

There was no evidence whatever of corrosion in the engine. Power and efficiency are increased by the low temperature of the circulating water. * * *

As the above tests were made on commercial alcohol, the alcohol blends would have a lesser effect, more or less, depending on the alcohol content.

Replies to inquiries sent to eight tractor manufacturers in the United States were for the most part favorable to the use of alcohol fuels. Two reported probable increased cost of operation; one reported greater cylinder wear due to blends; another reported no corrosive action found over a long period of time and smoothness of running very noticeable; and two others reported practically the same power, acceleration, and fuel economy.

A reply from an official of a prominent automobile manufacturer states:

Tests of 10 percent alcohol blended fuels * * * thus far indicate there are some problems that will require solution, technical phases, at least on automobiles, are not insurmountable * * *.

A communication from a prominent oil company states, in part:

Although alcohol has a much lower calorific value than gasoline, the mileage and power output of an engine will be practically the same as that on straight gasoline if not more than 20 percent of alcohol is added to the gasoline. This is partly because the alcohol has a higher viscosity than gasoline, and therefore, if the carburetor adjustment is not changed, but the same setting remains as for straight gasoline, the fuel air ratio of an alcohol-gasoline mixture will be leaner than that commonly used for straight gasoline. * * * Most carburetors are set so as to give a rather rich mixture of gasoline and air, since this provides easier starting than does a lean mixture * * *.

The results of many observations and experiments in the use of alcohol-gasoline mixture in this country and abroad as motor fuel may be summarized as follows:

1. Mixing of alcohol with gasoline makes for smoother engine operation.

2. The adding of small proportions of alcohol to gasoline improved combusion and tends to prevent carbon formation.

3. The corrosive effects of small proportions of alcohol in mixtures with gasoline appear to be negligible.

4. There appears to be a tendency toward harder starting when using blends, particularly in cold weather and as the percent of alcohol is increased.

5. Existing engines appear to be able to handle up to 10 percent absolute alcohol-gasoline blends with but little adjusting of the carburetor or point of ignition.

6. The solvent effect of alcohol may cause trouble with corkfloats in carburetors and fuel tanks. The loosening of scale and gum deposits in fuel systems may cause some difficulty; but this may become negligible after the fuel tank is exhausted the first few times (the action may cause some trouble with diaphrams in automobile fuel pumps). It is also detrimental to automobile body finishes.

7. Alcohol improves the octane rating at the rate of from three fourths to one number for each percent of alcohol added. (By adding 10 percent alcohol to three regular gasolines the average rating was increased from 66 to 74 and increases the rating of low grade more than the regular gasoline.)

8. As the percent of alcohol in the blend is increased the compression could be increased without detonation up to roughly 200 pounds on

pure alcohol. At the optimum compression, fuel consumption of the blend would approach that of gasoline. But a pressure of 200 pounds per square inch would make starting difficult and necessitate change in ignition systems.

9. Equal power and acceleration of alcohol-gasoline blends and gasoline appear possible in the same engine but at a higher fuel consumption with the blend as the alcohol percentage increases. Roughly speaking, the consumption of alcohol alone would be 50 percent greater than with gasoline alone. As the percent of alcohol in the blend is decreased the consumption approaches gasoline.

EFFECT OF WATER ON THE STABILITY AND UTILITY OF ALCOHOL-GASOLINE BLENDS

It is a well-known fact that the addition of water to alcohol-gasoline mixtures decreases the solubility of the alcohol in the gasoline. As more water is added, the alcohol begins to separate as a lower layer, and with sufficient water all the alcohol would be separated. This property has caused considerable concern regarding the general utility of such blended fuels. The facts arrived at by experiment, however, apparently dissipate many of the fears raised in this connection. With the exercise of common precautions dangers from adventitious water may be largely obviated.

The water problems may be considered from two standpoints. First, water may be present in pipe lines, storage tanks, pumps and containers and may therefore eventually be introduced into the blended fuel. Secondly, fears have been expressed that water may be taken up from the air owing to the hygroscopicity of the alcohol-gasoline blend or to the condensation of water from warm air on the colder surface of a blend.

Experience in Sweden with alcohol-gasoline blends indicates that the water problem has been exaggerated in certain quarters. (Hubendick, Petrol. Zeitschr. *26*, Motorentrieb und Maschinen-Schmierung No. 12, pages 3–9, 1930.) The accidental addition of water had practically no effect even when it caused the blend to separate into two layers. See also Petrlik (Chemie et Industrie Ep 200 p. 398 March 1931). This was owing to the fact that the lower alcohol layer still contained sufficient gasoline to pass through the carburetor readily and burn in the engine. On the other hand, addition of equivalent quantities of water to gasoline caused difficulties and stalled the motor until the water which separated evaporated from the carburetor. This difference between blended fuel and gasoline was much more serious in the winter months, as the layer separating from the blend did not freeze because of its high alcoholic content, while that separating from the gasoline did freeze and completely blocked the fuel line. It should be mentioned, however, that the Swedish blended fuels contain 25 percent anhydrous alcohol, which renders the blend much less susceptible to difficulties arising from water.

The point at which water will cause separation of the alcohol depends largely on the temperature and the concentration of alcohol in the blend. Agreement between different investigators concerning separation temperatures is quite good when low concentrations of water are present. Thus, in 10 percent alcohol blends the presence of 1 percent of water in the alcohol has been found to cause separation at temperatures ranging from $-40°$ to $-50°$ F. With higher concentrations of water, agreement is not so evident, but this is in some part due to different experimental conditions. It should be emphasized that with increasing concentrations of alcohol in the blend, the separation temperature is lowered increasingly up to concentrations of 20 percent alcohol. Beyond this point the curve expressing such a lowering tends to flatten. Furthermore, in extreme cases, the addition of other substances, such as ethers, higher alcohols, etc., tends to stabilize the blend in the presence of water; on the other hand, the addition of such stabilizers increases the cost of the blended fuel.

From a consideration of the rather meager data recorded in the literature, it would therefore seem that misgivings concerning the unfavorable effect of the presence of water on the stability of alcohol-gasoline blends have been somewhat exaggerated. The employment of 99.5 percent alcohol and the exercise of slightly more than the usual precautions now observed in the conscientious handling of gasoline should prevent any serious difficulties.

The possibility of the separation of blended fuels into two layers due to the absorption of water from the atmosphere has caused no little concern, but the data available at this time minimize the dangers from this source. These misgivings probably arise from the fact that anhydrous alcohol when exposed to humid air does take up water, particularly when a comparatively large surface is exposed. However, when mixed with gasoline, conditions are entirely different. It has been stated (International Sugar Journal *34*, 26, 1932) that 15 percent anhydrous (99.9 percent) alcohol blends are actually no more hygroscopic than gasoline itself. It has also been reported (Men. Poudres *21*, 386, 1924) that 15 percent blends remain homogeneous under conditions of humidity far more rigorous than those usually encountered under everyday conditions.

In another series of experiments (Chemie et Industrie, Special Number, pages 718–721, May 1923) 15 percent blends (99.9 percent alcohol) were exposed to a moist atmosphere (80 percent relative humidity) at temperatures of 59° F. for 12 days. The ratio, surface exposed volume, was 0.2. When these blends were cooled to −7.6 F., they remained clear. After 43 days, they clouded at 17.6 F.

The dangers arising from the condensation of water from a warm, humid, atmosphere on the surface of a cold blend are more evident than those arising from hygroscopicity. In underground storage tanks, this could not be serious because the fairly constant temperature of the air over the fuel would reduce breathing action to a minimum and hence little opportunity would be offered for the ingress of moisture-laden air. In surface tanks it might conceivably cause considerable difficulty, but experiments carried out recently at Iowa State College would indicate that such is not the case. These experiments were carried out under conditions much more rigorous than ever would be encountered in actual practice. Ten percent blends were alternately exposed, at temperatures of 32 and 99° F., to air the relative humidity of which was 100 percent. The blended mixture was placed in 250 cc Erlenmeyer flasks fitted with a 2 mm bent glass tube so as to simulate an actual storage tank with a breather vent. The flasks were changed from the lower to the higher temperature every 12 hours, so that considerable condensation would take place on the surface of the blend. However, these mixtures did not cloud until exposed to temperature below 4° F. Five and six percent blends proved to be most effected by exposure to humid atmosphere. Under the same conditions as outlined above, the clouding point was 15.8° F. for these blends. Under the extreme conditions of open dish exposure to the same temperatures and humidities, a 10 percent blend clouded at 41° F. after 24 hours exposure.

It might be added that it requires (approximately) 5,250 cubic feet of saturated air at a temperature of 80° F. to hold 1 gallon of water, and if the temperature of this quantity of air were reduced to 30° F., approximately 0.75 gallon of water would be precipitated. Under these conditions it would take 3,500, 11,200, and 24,500 cubic feet of air to produce enough water in addition to that contained in 99.5-percent alcohol to cause separation in a 2-percent, a 5-percent, and a 10-percent blend with gasoline respectively, to start separations.

From a consideration of the above, it appears that the dangers arising from the absorption of water by blends either from humid atmospheres or by actual condensation on the surface, are not as serious as have been heretofore supposed, and should offer no serious bar to the utilization of such blends. Blends containing small percentages of alcohol would, of course, be more subject to separation than those containing 10 or 20 percent of alcohol.

THE EFFECT ON VOLATILITY OF THE ADDITION OF ALCOHOL TO GASOLINE

Experimental evidence indicates (Journal of the Society of Chemical Industry *45*, 273–280T, 1926) that the addition of alcohol (99 percent) has considerable influence on the fractional distillation of gasoline. This is especially evident at the lower temperatures. The alcohol apparently forms azeotropic mixtures with certain of the gasoline fractions, and such mixtures distill at temperatures lower than the boiling point of either the alcohol or the gasoline fractions.

This, of course, is equivalent to saying that such fractions possess a higher vapor pressure and hence a greater volatility than the same fractions of gasoline itself. Twenty-two percent of the alcohol-gasoline blend which contained 9 percent of alcohol (99 percent) distilled under 160° F., while a temperature of 221° F. was necessary to distill the same percentage of the straight gasoline. Other data indicate that the maximum increase in vapor pressure or volatility is reached when the alcohol concentration is around 5 or 6 percent. Such a characteristic is, of course, distinctly advantageous and should influence favorably certain motor car operations. On the other hand, difficulty on account of vapor lock may be increased by the use of alcohol in the fuel.

CHEMICAL AND TECHNOLOGICAL PHASES OF THE PRODUCTION OF ALCOHOL MOTOR FUEL FROM FARM PRODUCTS

The chief materials grown within the United States which are available for alcohol production are (1) the cereal grains, corn, wheat, barley, rye, sorghum grains, and rice; (2) sugar cane and sugar-beet molasses; (3) potatoes, sweetpotatoes, and other starchy root crops; (4) surplus fruits; (5) wood waste and other cellular products.

Of the five general sources of materials above named, wood waste and cellular products may be excluded from consideration as not coming within the scope of a general agricultural relief measure.

Yields of alcohol of from 25 percent to 30 percent of the weight of dry wood have been reported by the processes of Scholler, Bergius, and others. An unfavorable critical review of the technical and economic features of these processes has been recently published by H. Classen in the Chemiker-Zeitung for December 14, 1932 (pp. 989–991) to which reference may be made for detailed information.

The utilization of surplus fruits, such as apples, peaches, etc., in times of over-production, is a problem that occasionally has been referred to the department. The sugar-containing juices of fruit can of course be expressed and fermented into alcohol but this possibility of producing agricultural alcohol is only an occasional one in regions where there has been an abnormal overproduction of fruit or where there may be fruit which has spoiled or which has been made unmarketable otherwise as by the presence of an excess of arsenical spray residue.

The consideration of surplus fruits as a raw material for the production of alcohol is, therefore, only an occasional regional one.

Sugar-beet molasses has been utilized as a source of agricultural alcohol for many years in European countries although it is generally recognized that as an economic proposition the use of molasses as cattle feed is better than using it for alcohol production owing to the great loss in the available energy of the sugars of the molasses resulting from the fermentation process. A new departure by the Great Western Sugar Co. of Colorado is the complete removal of all sugar from beet molasses by its new process of barium desaccharification. This process is a perfect technological success and its rapid extension in the sugar-beet growing regions of the Western States promises to eliminate sugar-beet molasses as a raw material for the production of domestic agricultural alcohol.

The remaining materials enumerated above—namely the cereal grains, potatoes, sweetpotatoes, and cane molasses—are the only ones, therefore that will be considered in this discussion.

PROCESSES FOR PRODUCING ALCOHOL FROM AGRICULTURAL PRODUCTS

Two general processes are involved in the conversion of the agricultural products, just enumerated, into alcohol; the one in starch-bearing materials, namely the cereal grains, potatoes, and sweetpotatoes are used and the other when producing alcohol from saccharine materials such as molasses.

STARCHY MATERIALS

The first step in the manufacture of alcohol from this group of materials is to gelatinize the starch. The cereal grains are generally ground before heating with water or preferably cooking with water under pressure. Potatoes and sweetpotatoes soften readily after cooking and need not be ground. The resultant softened material is placed in a vat and after cooling to the mashing temperature (near 140° F.) is "saccharified," that is converted into sugar, usually by the addition of malt. The malt commonly used is germinated barley, the saccharification being produced by the malt enzyme, diastase.

There are other suitable sources of this essential enzyme, such as taka-diastase (obtained from the mold *Aspergillus oryzae*) and various species of mucor. The latter are employed in the "Amylo" process of alcohol production. There is considerable evidence in the literature to show that greater yields of fermentable sugars can be obtained from starch by the use of some of these organisms, but malt is the only agent being used at the present time in this country for saccharifying starch for the production of alcohol.

The wort or sugar solution obtained after the conversion of the starch to sugar is cooled to the fermenting temperatures of 65 to 80° F., transferred to the fermenting vats and treated with yeast. The temperature of the mixture rises to a final temperature of 100 to 105° F. unless means are provided for controlling the temperature in such a manner that it remains near 90° F. throughout the process. When fermentation is complete, the beer, as it is termed, ordinarily contains 6 to 8 percent of alcohol. Usually the alcohol in the beer is separated by a primary distillation. The resulting distillate still contains, however, too large a proportion of aldehydes, water and higher boiling components (fusel oil) to be used commercially, so it is subjected to a secondary distillation or rectification to produce 95 percent alcohol.

The byproducts of producing alcohol from starchy materials are the spent grains, which are generally dried and sold as "distillers' grains", fusel oil, and carbon dioxide. From corn the corn oil would be an additional by-product possibility. Owing to the feed value of the distillers' grains, this material is considered the most valuable of the byproducts and the one always recovered. Under present economic conditions the market demand does not appear to justify in general additional expenditures for the recovery of the other byproducts.

SACCHARINE MATERIALS

The general process of alcohol manufacture from blackstrap molasses, which is also applicable in principle to other sugar products such as cull fruits, is as follows: The molasses is pumped from the supply tanks to the processing tanks where it is diluted with an equal volume of water and thoroughly mixed. The dilution at this point is not standard and may vary in different distilleries. It is here sterilized and otherwise treated to prepare it for the yeast fermentation. The processed molasses is then run into the fermentation tanks where it is further diluted with water. The final dilution gives a mixture which corresponds approximately to 1 part by volume of the original material to 4, 5, or 6 volumes of water. Yeast is added and the fermentation allowed to take place under conditions similar to those already described. The remainder of the process is essentially the same as when producing alcohol from starchy materials.

The by-products obtainable from molasses are carbon dioxide, fusel oil, and "distillery" slops. The latter are available for the production of a fertilizer material by drying or incinerating. Under present conditions none of these by-products, however, are believed to be of sufficient economic importance to require any special consideration in this discussion.

DEHYDRATION OF ALCOHOL

The old process of dehydrating alcohol by distillation with quick lime is expensive and has now been superseded by cheaper and more modern processes. The one universal process used today is based upon the property which hydrated alcohol has of yielding, with certain hydrocarbons (such as benzene), a ternary azeotropic mixture, i.e., a ternary mixture whose boiling point is lower than that of each of its components.

In 1922, Guinot proposed a modification of the original Young process, employing benzene as the hydrocarbon, which is now used throughout the world. By certain patented modifications it is now possible to make dehydrated alcohol continuously from ordinary 95–96 percent alcohol or even from fermented mash. The actual costs of this process, exclusive of royalties, have been estimated by large producers of alcohol not to exceed 1 cent per gallon.

YIELDS OF ALCOHOL AND COST OF MANUFACTURE FROM DIFFERENT AGRICULTURAL PRODUCTS

The yield of alcohol from the different agricultural products varies, of course, with the character of the materials involved and the efficiency of the distillery operations. The malting of the starchy materials and the fermentation of sugars with yeast require much technical skill and the observance of many precautions to obtain the highest yields of alcohol. In table 1 there are indicated the approximate yields of both 95 percent and absolute (99.5 percent) alcohol from various sources which are obtainable under proper conditions. There is also indicated in this table the quantity of malt required (based upon a mixture by weight of 88 percent grain and 12 percent malt) for starch conversion, and the percentage by weight of the dried distillers' grains which may be recovered and sold as a stock feed. These yields of alcohol and distillers' grains have been used in estimating the cost of alcohol production.

TABLE 1.—*Farm crops available as sources of alcohol—Tabulation of potential yields*

Kind of material	Weight per bushel	Approximate yield gallons of 95 percent alcohol per bushel	Approximate yield gallons of 99.5 percent alcohol per bushel	Bushels of malt required per bushel of base material	Approximate yield of distillers' grains in percent of total material weight
Corn	56	2.5	2.36	0.225	22.3
Wheat	60	2.8	2.64	.241	26.9
Sorghum	50	2.1	1.98	.201	24.4
Rye	56	2.3	2.17	.225	27.1
Rice (rough)	45	1.9	1.79	.181	26.0
Oats	32	1.1	1.04	.120	42.3
Potatoes	60	.8	.76	.073	3.8
Sweetpotatoes	55	1.0	.94	.085	4.0

The cost of producing alcohol obviously depends upon a number of factors, such as the location of the distillery, the kind of materials used, the price paid for the raw materials, the efficiency of the manufacturing plant due to management and the scale of production. There are no published data regarding the cost of producing absolute alcohol from grains under present conditions but estimates which have recently been made have been submitted to the Department of Agriculture.

The pertinent data are summarized in tables 2, 3, and 4. If alcohol is to be produced from agricultural products and blended with gasoline for a motor fuel, it is obvious that corn will be the primary source, although other materials may be used in certain localities depending upon the quantity and market value of these products. In tables 2 and 3 therefore are given the costs of manufacturing alcohol from corn in distilleries utilizing 4,000 and 25,000 bushels of grain per day at various costs of raw materials. In table 4 are given the corresponding costs of producing alcohol from wheat, rye, sorghum grain, and rice at approximate present values, from potatoes at 10 cents a bushel, and from sweetpotatoes at 20 cents a bushel. In regard to potatoes it may be stated that there is available in certain localities a variable supply of culls which have been selling recently as low as 10 cents a barrel (165 pounds). If a sufficient supply were available to operate continuously an alcohol plant of economic capacity, this raw material might well become a competitor of corn and molasses.

TABLE 2.—*Cost of processing and distributing alcohol (99.5 percent) from corn, exclusive of raw materials and byproducts*

Item	Daily capacity of distillery	
	112 tons mixed grain, 88 percent corn—12 percent malt	700 tons mixed grain, 88 percent corn—12 percent malt
	Cents per gallon	*Cents per gallon*
Processing costs (fixed charges, labor, supplies and dehydration)	11.2	7.4
Denaturing	[1] 2.0	[1] 2.0
Profit (10 percent of above)	1.3	.9
Distribution	6.0	6.0
Total, exclusive of grains and credit for byproducts	20.5	16.3

[1] Based on information obtained from the Bureau of Industrial Alcohol, Treasury Department.

TABLE 3.—*Complete cost for producing 99.5 percent alcohol from corn, at different prices for corn and malt*

	112 tons mixed grains, 88 per cent corn, 12 per cent malt			700 tons mixed grains, 88 per cent corn, 12 per cent malt		
Gallons of alcohol produced per day	9,440	9,440	9,440	59,000	59,000	59,000
Cost of corn at distillery (cents per bushel)	25	50	75	25	50	75
Cost of malt at distillery (cents per pushel)	50	100	150	50	100	150
Bushels of corn used per day	3,520	3,520	3,520	22,000	22,000	22,000
Bushels of malt used per day	790	790	790	4,940	4,940	4,940
Feed (distillers' grain) produced (tons per day)	25	25	25	156	156	156
Value of feed (dollars per ton)	10	15	20	10	15	20
Cost of corn (dollars per day)	880	1,760	2,640	5,500	11,000	16,500
Cost of malt (dollars per day)	395	790	1,185	2,470	4,940	7,410
Total	1,275	2,550	3,825	7,970	15,940	23,910
Credit for feed (dollars per day)	250	375	500	1,560	2,340	3,120
Net cost of raw materials (dollars per day)	1,025	2,175	3,325	6,410	13,600	20,790
Net cost of raw materials (cents per gallon of alcohol)	10.9	23.0	35.2	10.9	23.0	35.2
Processing and distributing costs (cents per gallon of alcohol) (see table 2)	20.5	20.5	20.5	16.3	16.3	16.3
Total cost of 99.5 percent alcohol at point of blending with gasoline (cents per gallon)	31.4	43.5	55.7	27.2	39.3	51.5

TABLE 4.—*Cost for producing 99.5 percent alcohol from various farm crops*

	Daily capacity, 112 tons mixed grains (88 percent base grain, 12 percent malt)				Daily capacity, 700 tons mixed grains (88 percent base grain, 12 percent malt)				Root crop alcohol plants with alcohol producing capacity approximately the same as 112 and 700 tons mixed grain plants			
	Wheat	Sorghum	Rye	Rice	Wheat	Sorghum	Rye	Rice	Potatoes	Sweet potatoes	Potatoes	Sweet potatoes
Gallons of alcohol produced per day	9,855	8,870	8,680	8,909	61,594	55,438	54,250	55,681	9,000	9,000	56,250	56,250
Cost of grain at distillery (cents per bushel)	50	25	40	50	50	25	40	50	10	20	10	20
Cost of malt at distillery (cents per bushel)	50	50	50	50	50	50	50	50	50	50	50	50
Bushels of grain used per day	3,285	3,942	3,520	4,380	20,531	24,638	22,000	27,375	11,368	9,095	71,050	56,844
Bushels of malt used per day	790	790	790	790	4,940	4,940	4,940	4,940	830	775	5,188	4,844
Feed (distillers grain) produced (tons per day)	30.1	27.3	30.3	29.1	188.1	170.6	189.4	181.9	13.5	11.5	84.4	71.9
Value of feed (dollars per ton)	10	10	10	10	10	10	10	10	10	10	10	10
Cost of grain (dollars per day)	1,643	986	1,408	2,190	10,269	6,163	8,800	13,688	1,137	1,819	7,105	11,369
Cost of malt (dollars per day)	395	395	395	395	2,470	2,470	2,470	2,470	415	388	2,594	2,422
Total	2,038	1,381	1,803	2,585	12,739	8,633	11,270	16,158	1,552	2,207	9,699	13,791
Credit for feed (dollars per day)	301	273	303	291	1,881	1,706	1,894	1,819	135	115	844	719
Net cost, raw materials (dollars per day)	1,737	1,108	1,500	2,294	10,858	6,927	9,376	14,339	1,417	2,092	8,855	13,072
Net cost of raw materials (cents per gallon of alcohol)	17.6	12.5	17.3	25.7	17.6	12.5	17.3	25.7	15.7	23.2	15.7	23.2
Processing and distributing costs (cents per gallon) [1]	20.5	20.5	20.5	20.5	16.3	16.3	16.3	16.3	20.5	20.5	16.3	16.3
Total cost of 99.5 per cent alcohol at point of blending with gasoline (cents per gallon)	38.1	33.0	37.8	46.2	33.9	28.8	33.6	42.0	36.2	43.7	32.0	39.5

[1] Assumed as the same as for the production of alcohol from corn.

In regard to the cost of producing absolute alcohol from molasses under present conditions no authentic information is available. It is known, however, because of the simpler procedure involved in producing alcohol that, as the gelatinization and malting operations are unnecessary, the capital investment and operating costs, exclusive of the raw materials, are somewhat lower for distilleries of equal production capacity.

An estimate has been made, however, based upon the larger alcohol distillery discussed above and in which the unnecessary items of malting, etc., were eliminated. These data are summarized in tables 5 and 6 for different prices of molasses. The lower price, namely 2½ cents per gallon, is approximately that at which molasses is purchased, c.i.f. distillery at the present time. It may be noted that at this price molasses is the cheapest raw material for producing alcohol. Molasses at 5 cents per gallon is about equivalent to corn at 25 cents, which figure has been substantiated by others. (See Iowa State College, "The Use of Alcohol in Motor Fuels." Progress Report No. 5. "Some Economic Aspects of a Program for the Manufacture of Fuel Alcohol from Corn.")

TABLE 5.—*Cost of processing and distributing alcohol (99.5 percent) from cane molasses, exclusive of raw material*

Item	Capacity, 59,000 gallons, 99.5 percent alcohol per day
	Cents per gallon
Operating costs (factory expense—chemicals, labor insurance, depreciation, dehydration, etc.)	6.4
Denaturing	2.0
Profit	.8
Distribution costs	6.0
Total processing and distribution costs	15.2

TABLE 6.—*Complete cost for producing alcohol (99.5 percent) from molasses*

Item	Unit	Daily capacity of alcohol, 59,000 gallons		
Cost of molasses, per gallon c.i.f. distillery	Cents	2½	5	7½
Molasses required per day	Gallons	147,500	147,500	147,500
Cost of molasses:				
Per day	Dollars	3,688	7,375	11,063
Per gallon of alcohol	Cents	6.3	12.5	18.8
Processing and distribution costs, per gallon (see table 5)	do	15.2	15.2	15.2
Total cost of alcohol at point of blending, per gallon	do	21.5	27.7	34.0

It may be noted that in the calculation made above regarding the cost of producing alcohol from grains, a credit has been made for the value of distillers' grain. The wholesale price of brewers' grain in Chicago April 1 was $15 per ton. Distillers' grain derived from corn ordinarily would sell at prices somewhat higher than brewers' grain. A lower value, $10 per ton, is assumed as the price for this byproduct would be depressed in event alcohol is produced from large quantities of corn and other grains. The credit from the sale of byproduct feedstuffs would increase, of course, as the price of feed generally increased.

THE COST OF DISTRIBUTING ALCOHOL

The cost of taking the alcohol from the distillery to the retailer of the motor fuel may be estimated on the basis of the cost of moving gasoline from the refinery to the consumer. If the mixing were required, no special selling organization would be necessary to distribute the alcohol. If it were denatured at the distillery, no special supervision of its handling would be necessary. A small additional cost might be incurred in the actual mixing or blending process. No additional volume of storage would be necessary except possibly, in same cases, for maintaining storage of alcohol separate from gasoline at mixing points, prior to the actual blending process for distribution to the retail trade.

The railway freight rates on alcohol now appear to be higher than on gasoline. For example, the Interstate Commerce Commission has recently prescribed for the Southwest a scale of rates on gasoline which amounts to about 2.6 cents per gallon for a 500-mile haul; the rate on alcohol from New Orleans is now about 4.9 cents per gallon. In central territory, the Commission has prescribed fifth-class rates for alcohol. These would amount to about 2.7 cents per gallon for a distance of 500 miles. The Commission has recently found that a commodity rate of 32.5 percent of the first-class rate is a proper basis for gasoline rates east of Chicago and St. Louis. Fifth-class rates are 35 percent of first class. In other words, alcohol rates are about 8 percent higher than gasoline rates in this territory at the present time. There is no apparent reason, however, why rates on alcohol in large volume should be in excess of the rates on gasoline.

Obviously the distribution costs for alcohol and the alcohol blend would depend to some extent upon the geographical organization of the alcohol industry in relation to gasoline refineries and the consumption of motor fuel. Many of the distilling plants now in operation are close to large centers of population where large quantities of motor fuel are used. Presumably additional plants would be placed in the interior so that, with the possible exception of New England and the Pacific coast, the alcohol would be produced fairly close to large centers of consumption. Under such circumstances, the transportation expenses involved in taking the alcohol from the manufacturing plant to the retailer's tank will be similar to those for distribution from the gasoline refinery plants to the consumer.

To estimate the actual cost of alcohol or the additional cost of a motor alcohol-fuel blend to the consumer, the cost of transportation and the wholesale and retail margins must be taken into account. Apparently wholesale and retail margins on the sale of gasoline have been maintained without much change in recent years. Available data [2] indicate that in the Twin Cities in 1931, the wholesale margin was 2.60 cents and the retail margin 3.08, making a total wholesale and retail margin of 5.68 for regular price gasoline. This was higher than the margin in 1927 and 1928. The third-grade gasoline wholesale and retail margins amounted to only about 3 cents per gallon.

The transportation cost on a tank car of gasoline delivered in the Twin Cities averaged 2.8 cents. The filling station price in Minneapolis in July 1932 was 14.4 cents, exclusive of tax. Subtracting freight and the margins on the regular price gasoline would leave about 6 cents as the refinery price.

Differences between refinery and retail prices of gasoline at selected points in January 1932 indicated an average spread in Louisiana of about 4 cents per gallon, in Oklahoma 6 cents, Texas 7 cents, Pennsylvania 5 cents, and California 8 cents. Apparently these spreads vary greatly, and possibly range from about 2 cents to 10 cents. These data suggest that the average margin between refinery and retail prices (less tax) is about 6 cents.

Adding 6 cents to the estimated cost of processing the alcohol in a larger scale operating plant would make the total processing and distribution cost about 16.3 cents per gallon. (See table 2.) The cost to the consumer would be this figure plus tax and the cost of the raw

[2] Vaile, R. S., and others. Gasoline Distribution in the Twin Cities, University of Minnesota Press, Minneapolis, 1933.

materials. The average cost of alcohol to the consumer at different prices for corn would be about as follows:

Corn	Cost of alcohol
Cents per bushel	*Cents per gallon*
25	27.2
50	39.3
75	51.5

THE COST OF AN ALCOHOL-GASOLINE BLEND

The cost of an alcohol-gasoline blend depends in part, of course, upon the cost of the gasoline. The refinery price of gasoline is now very low, doubtless, in part because of the depression. The consumption of gasoline in the United States continued to increase until in 1932. Consumption doubled from 1924 to 1929. The average price of gasoline per gallon, excluding tax, at service stations, was 19.1 cents in 1924, and increased to 21 cents in 1926. The consumption in 1929 amounted to 15,792,000,000 gallons, at a price of about 17.8 cents. Consumption continued to increase through 1930 and 1931, reaching a total of 16,949,000,000 gallons in 1931, but the price declined to 13 cents in 1931. Presumably the decline in the price of gasoline was an important factor in maintaining consumption. The average price for 1932 was slightly higher than in 1931, and consumption declined 7.5 percent. Doubtless the continuation and deepening of the depression was an important factor in reducing the consumption of gasoline from 1931 to 1932. Prices are now (April 1933) lower than in 1931.

Petroleum, oil, and gasoline wholesale prices in April 1929–33

[From Brookmire Commodity Bulletin, Apr. 17, 1933, p. 4]

	Crude, Kansas, Oklahoma, 36° at well	Fuel oil, Oklahoma, 24°–26° f.o.b. refinery	Gasoline,[1] Oklahoma, refinery
	Cents per barrel	*Cents per barrel*	*Cents per gallon*
1929	120	66	7.30
1930	129	79	6.75
1931	57	53	3.72
1932	92	40	4.15
1933	66	35	2.37

[1] United States motor grade.

The petroleum and gasoline industries are at present in a chaotic situation. Production increased rapidly to a peak in 1929. The flow of crude petroleum was curtailed to some extent in 1930 and 1931, but the foreign as well as the domestic demand was greatly reduced by the depression. Furthermore, technological developments have greatly increased the gasoline yield from crude oil. The yield increased from 28.8 percent in 1922 to 39.4 percent in 1929. In 1932 the gasoline yield was 44.7 percent. The significance of this increased yield is shown by the fact that the flow of crude petroleum increased from 558,000,000 barrels in 1922 to 1,006,000,000 in 1929, and the production of gasoline from 6,000,000,000 to 18,000,000,000 gallons. From 1929 to 1932 the crude-oil output diminished, but, owing to the higher gasoline yield, the production of gasoline did not decrease as much as the production of crude oil. The yield could be increased further, to about 103 percent by the adoption of the hydrogenation process. However, the present price of gasoline does not warrant the use of this process.

The price of crude oil, from which the gasoline is made, declined more than gasoline, in the period 1929-31. Apparently efforts to check declining prices and stabilize the oil industry in 1932 were temporarily successful. In the beginning of 1933, however, prices were lower than in 1931. Continued efforts in this direction may result in higher prices for crude petroleum. A general recovery from the depression naturally would increase the demand for gasoline and result in higher prices for petroleum and gasoline. That is to say, the recent low gasoline prices are probably below what may be expected in the future.

Displacing 10 percent of the gasoline with alcohol in 15,000,000,000 gallons of motor fuel would thereby reduce the consumption of gasoline in motor fuel to a little under that of 1928, when 13,811,000,000 gallons were used. Other conditions remaining the same, raising the price of motor fuel by 2 or 3 cents per gallon might affect consumption to some extent, but the effect of this might be more than offset by even a moderate recovery in business. Between 1924 and 1926, the average price of gasoline in cities was raised by 1.9 cents per gallon, but consumption increased by more than 40 percent in these 2 years. This was due largely, of course to a rapid expansion in the sale of new automobiles and the increasing availability of good roads. This change is cited merely to suggest the possibility that an increase in the buying power of consumers, brought about by an improvement in the business situation, may materially increase the consumption of motor fuel, even in the face of some increase in price.

The displacement of 10 percent of the gasoline with alcohol in motor fuel probably would not have a proportional effect upon the wholesale price of gasoline or upon the price of crude oil. Gasoline is but one of the products of the petroleum industry. In 1931 the value of the gasoline produced was only slightly more than one half of the total value of the products of petroleum refining. A revival in industry would increase materially the demand for fuel oils, and thus tend to offset any curtailment that there might be in the outlet for gasoline as a motor fuel.

While there is not in view any imminent danger of exhausting petroleum supplies as a source for gasoline, the need for conserving such resources is recognized. The Federal Oil Conservation Board, in a report issued in 1932, says:

> The public must not lose sight of the fact that our reserves are exhaustible and should not be exploited heedlessly. * * * Accumulated stocks and reported large potentials are indicative of overproduction, caused by premature development, rather than the result of abundant underground reserves. * * * At the current rates of production, the equivalent of our present known oil reserves will have been withdrawn from their underground reservoirs in 10 to 12 years.

It may be assumed that new fields will be discovered and that the national oil resources will prove to be much more extensive than now known. However, a continuing increase in demand is to be expected. If the flow is not correspondingly increased, prices will rise. Gasoline may be produced from other sources, but probably only at higher costs, unless new and cheaper processes are developed.

Since alcohol now costs more than gasoline blending it with gasoline would increase the cost of motor fuel to the consumer. The probable increase in cost of the blend may be computed from the estimates of the cost of producing and distributing alcohol and the retail price of gasoline. The average price of gasoline per gallon less tax at service stations in 50 cities for 1931 is taken as the gasoline basis for estimating the price of the blend. It is the lowest average price in the period 1924–32.

The effect of blends upon the cost of a gallon of motor fuel is indicated as follows:

TABLE 7.—*Cost of alcohol-gasoline blend, using gas at 13 cents per gallon*

Alcohol	Cost of corn alcohol per gallon		
	27.2 cents	39.3 cents	51.5 cents
	Cents	*Cents*	*Cents*
2 percent	13.28	13.53	13.77
5 percent	13.71	14.32	14.93
10 percent	14.42	15.63	16.85
	Addition to price of gas on account of alcohol blend		
	Cents	*Cents*	*Cents*
2 percent	0.28	0.53	0.77
5 percent	.71	1.33	1.93
10 percent	1.42	2.63	3.85

MANUFACTURING PLANT CAPACITY

In considering any proposal for the utilization of additional quantities of farm products in the manufacture of alcohol for motor fuel, plant capacity and the rate at which additions could be made to the capacity must be taken into account. The industrial alcohol industry of the United States has never produced more than 107,000,000 wine gallons in a year. At the present time the industry is operating much below capacity. In 1932 only 78,000,000 gallons of 95 percent alcohol were produced. The capacity of existing plants is probably about 250,000,000 to 275,000,000 gallons. The antifreeze, and other industrial requirements for alcohol, probably would continue to take about 75,000,000 gallons. A 2 percent blend with all gasoline used would require about 300,000,000 gallons. Consequently, the producing capacity of industrial alcohol plants would have to be expanded to the extent of at least 100,000,000 gallons to provide the alcohol for such a blend.

The present capacity of alcohol production centers is estimated to be about as follows:

	Gallons
Eastern seaboard	112, 000, 000
Southern district	60, 000, 000
Middle Western district	89, 000, 000
Pacific coast	6, 000, 000
Total	267, 000, 000

The present locations and equipment of plants are such that probably several should continue to produce alcohol from molasses. The capacity of the plants which might not be readily converted to grain alcohol production is estimated to be about 50,000,000 gallons, and these plants might continue to produce for other industrial uses. The remaining 25,000,000 gallon requirement for industrial use, other than in motor fuel, might also be provided from molasses or other materials by the plants now in operation, leaving the remaining capacity, nearly 200,000,000 gallons, to be devoted to the production of alcohol specifically for motor fuel.

The approximate capacity of the convertible alcohol plants is located as follows:

	Gallons
North Atlantic coast	50, 000, 000
Corn Belt	80, 000, 000
New Orleans and vicinity	60, 000, 000
Total	190, 000, 000

This would be equivalent to only about 1¼ percent of the annual consumption of motor fuel, and its manufacture from corn would utilize about 80,000,000 bushels, including the small quantity now being used in the production of industrial alcohol.

If alcohol to the extent of 2 percent of the annual consumption of motor fuel were required or desired for use within a year, this could be obtained only by postponing the effective date of the requirement until stocks could be accumulated. Some time would be required to overhaul and convert some of the plants from the utilization of molasses and other materials to the utilization of corn or other grains. Time would also be required for the distribution of the alcohol throughout the country, to make it available for use in blending with gasoline. In the meantime stocks could be accumulated and the construction of new plants started. The production of a supply of alcohol equivalent to 2 percent of the annual motor fuel consumption would require additional plant capacity to the extent of about 110,000,000 gallons, and the operation of these plants would require an additional 47,000,000 bushels of corn or its equivalent. Additional capacity to provide alcohol to the extent of 5 and 10 percent of the annual motor fuel requirements probably could be developed within 2 or 3 years.

SUPPLIES OF RAW MATERIALS FOR ALCOHOL

Anhydrous alcohol, for a 2 percent blend with 15,000,000,000 gallons of motor fuel, would require equivalents of about 112,000,000 bushels of corn, and 23,000,000 bushels of barley. A 5 percent blend would require about 280,000,000 bushels of corn and 57,000,000 bushels of barley; and a 10 percent blend, 560,000,000 bushels of corn and 114,000,000 bushels of barley.

market, the price of corn on the market, and the feed-livestock relationships. An analysis of corn prices in relation to supply suggests that, while the size of the total crop for the country as a whole is an important factor in the market, the location of the supplies or the quantities directly available for the market have some additional significance. In view of the small proportion of the crop which is marketed as corn, an increase of even 100,000,000 bushels in the annual utilization for industrial purposes would probably have a marked initial effect on corn prices in the central markets. After a time, corn growing and feeding would readjust so that a part of the first advance in prices would be lost.

An attempt has been made at estimating the first effect upon prices of increasing the industrial utilization of corn by 100,000,000, 300,000,000, and 600,000,000 bushels above what is at present so utilized. Since at no time in the history of the United States has the industrial utilization of corn been 600,000,000 bushels larger than it is at present, it is impossible to arrive at any precise statistical measure of the effect of such an increase in utilization. The analysis has been based upon variations in the size of the crop in the Corn Belt States, for the years 1899–1928, exclusive of the war period 1914–20. In these years the price of corn in Chicago was closely related to the supply of corn in the nine principal Corn Belt States. On the average a decrease in supply has increased Chicago prices by about 6 percent for 100,000,000 bushels, 22 percent for 300,000,000 bushels, and 50 percent for 600,000,000 bushels.

An increase in the industrial demand alone would probably have a considerably greater effect because of the fact that any material increase in takings for industrial use would take a relatively large share of the total marketings. It is possible, and even probable, that an increase in industrial demand would raise prices by about half as much again as a corresponding decrease in supply, thus making the increase in the price of corn about 10 percent for 100,000,000 bushels additional use, 33 percent for 300,000,000 bushels, and 75 percent for 600,000,000 bushels additional use.

As readjustments were made by farmers in their plans for disposing of their corn crop, however, a greater amount of corn would be sent to market even if there were no resulting change in the acreage and total production, and feeding would be reduced and other feedstuffs would be substituted for corn. Consequently, a part of the initial improvement in corn prices would be lost. However, it is to be borne in mind that an increase in the amount of corn going to market would result in a decrease in supplies available for feeding hogs and other livestock. Hence, a loss to corn prices as a result of the readjustment would tend to be offset by an improvement in the prices of hogs and other livestock.

In estimating the final effect, the tendency for higher prices to cause an increase in acreage must be taken into account. The extent of the increase will be determined largely by the rise in prices. But it seems altogether possible, in spite of the tendency for acreage to expand as a result of increased price, that about half of the increase in prices indicated for the first year would be retained in later years. In other words, during the next 5 years the average of prices for corn probably would be raised above what they would otherwise be by about 5 percent using 100,000,000 bushels, 16 percent using 300,000,000 bushels, and 37 percent using 600,000,000 bushels. The significance of such increases in terms of income, of course, depends also upon the general price level and what the price of corn would be otherwise. Thus an increase of 5 percent from 25 cents per bushel is only 1¼ cents, but from 75 cents it amounts to 3¾ cents per bushel. An increase of 37 percent adds 9¼ cents to 25-cent corn and 27¾ to 75-cent corn. With an increase in corn acreage there would be some tendency for the reduction in corn prices to be offset by higher prices for other farm products displaced by corn acreage expansion.

BARLEY

The additional use of the necessary quantities of barley to supply malt for the manufacture of alcohol from corn would have similar effects upon the barley market. Increasing the prices of corn and barley would also tend to increase the prices of other crops, and ultimately affect the prices of livestock products. Any estimate of the gain to farmers from thus raising the prices of corn and barley must be based upon consideration of the effects upon agriculture as a whole throughout the country.

EFFECTS UPON AGRICULTURE IN GENERAL

The effect of taking large quantities of corn and barley to manufacture alcohol would be to increase the amount of cash income derived directly from the sale of these products; to reduce the quantities of grain available for feeding and, consequently, to raise the price of feedstuffs and reduce livestock production. If the Chicago price of No. 3 Yellow corn would otherwise be 40 cents, the taking of 100,000,000 bushels of corn for the manufacture of industrial alcohol possibly would raise the price in the first season to about 44 cents. Adding 4 cents per bushel to 2,800,000,000 bushels would increase the value of the crop by $112,000,000; but this is not clear gain to farmers. Since most of the corn is fed, and some farmers buy corn to feed, an increase in the price of corn is to some farmers an addition to their costs. The effect of this change upon their income would be determined by its effect upon the returns from livestock. Although it is practically impossible to determine what would be the net effect of such an increase in the price of corn, an attempt will be made to indicate something of the degree of change in income directly from the sale of corn for nonfeed use and, finally, the probable influence upon income from the sale of livestock products.

The direct cash income from the 1932 corn crop amounted to only $71,000,000 and part of this was from farmers who bought to feed. The sale for nonfeed use probably amounted to not more than $40,000,000. The sale of an additional quantity of corn for the manufacture of alcohol would, in the first place, add the value of that quantity to the income farmers derived directly from the sale of corn. If the Chicago price of No. 3 Yellow corn were about 44 cents per bushel, the average price in the Corn Belt States would be about 34 cents, and the income derived from the sale of 100,000,000 bushels for industrial alcohol would be $34,000,000. The addition of 4 cents to the price of the 200,000,000 bushels of corn sold to be ground into meal and to be used in the production of starch, glucose, and corn sugar would increase income by $8,000,000; thus the income derived directly from the sale of corn for nonfeed use would be increased by about $42,000,000.

The increase in the demand for barley and corn would have about the same effect upon the price of barley as upon the price of corn. The additional quantity that would be required to produce the malt for the manufacture of alcohol from 100,000,000 bushels of corn would be about 20,000,000 bushels. This extra demand probably would raise the farm price of barley in the important barley-producing States in the Midwest from 25 to about 30 cents per bushel. Figuring the increased cash income from barley as for corn, the income from the sale of barley for the manufacture of alcohol would be increased by 20,000,000 bushels at 30 cents and by the increase of 5 cents per bushel in the price of about 100,000,000 bushels sold for other purposes, making a total increase in income of about $11,000,000.

Estimates of increases in cash income from the sale of corn and barley for nonfeed use

Corn, quantities used for alcohol	Income	Barley, quantities used for alcohol	Income	Total income
Millions of bushels	*Millions of dollars*	*Millions of bushels*	*Millions of dollars*	*Millions of dollars*
100	42	20	11	53
300	156	50	28	184
600	420	100	65	485

The prices of wheat, oats, and other grains would be affected to some extent by increasing the demand for corn and barley. Using 100,000,000 bushels of corn, the income from all grains, including corn and barley, might be increased to the extent of about $60,000,000; using 300,000,000 bushels add $200,000,000; and using 600,000,000 bushels of corn result in an increase of $550,000,000 in the total income derived directly from the sale of grains. This is still not a complete accounting of the effects upon farm income. The probable effect upon the income from livestock must also be taken into account.

The income from hogs in the first year might be increased by as much as $10,000,000, $20,000,000, and $30,000,000 by the curtailment of production in response to higher feed prices. Adding such estimates of increases in the income from hogs would make the total increases in income from grains and hogs about $70,000,000, $220,000,000, and $580,000,000. These estimates are submitted not as exact measurements but as some indication of the direct effect of raising the price of corn and barley. The manner in which the increase in the price of feed grains affects the income from hogs will be described later.

As indicated above, raising the price of corn and barley would increase the cost of feeding. Consequently the livestock producer would feed less. Hogs would be marketed at lighter weights. It is possible, however, that the reduced feeding of corn to cattle and dairy cows would be offset by the increased feeding of distillers' grain. The result might be some shifts in feeding without any significant reduction in the amount of cattle or dairy feeding.

An analysis of the relation of hog-corn ratios to the average weight of hogs marketed in recent years indicates the following relationships:

Rise in corn prices	Reduction in hog-corn ratio	Reduction in average weights
Percent	*Points*	*Percent*
10	1.2	1.0
33	3.4	2.1
75	5.6	3.5

If it should be definitely and universally known on or before August 1, 1933, that the new outlet for corn would prevail during the following crop year, it is quite possible that a rise in corn prices would cause some reduction in the number of fall pigs farrowed as a result of larger marketings of sows during the late summer and fall. In such case there would be a reduction in total tonnage in 1933–34 as the result of both a reduction in weights and a reduction in the fall pig crop. The effect of the latter on the total tonnage marketed during the year would be small, however, and a reduction of 5 percent in total tonnage is the maximum that could be expected with a rise in corn prices of 75 percent.

A greater reduction in the total live weight of hogs marketed would occur in the 1934–35 crop year, since breeding operations in 1933–34 would be curtailed. If 600,000,000 bushels of corn were used for alcohol manufacture in 1933–34 and this caused a rise in corn prices of 75 percent, the total tonnage of hogs marketed in 1934–35 probably would be 12 to 15 percent below the supply that would prevail without the development of the new outlet for corn.

The price of hogs to farmers would be increased about twice as much as the percentage of reduction in tonnage. The effect of the increase in price upon income would be offset in part, of course, by the reduction in volume. There would be some net gain, however, the extent of which would be increased as the increased industrial demand for corn would reduce the supply available for feeding hogs.

The net result of using large quantities of corn and barley produced in the Mississippi Valley, to manufacture industrial alcohol, therefore, would be to reduce the amount of feedstuffs utilized for the production of hogs in the Corn Belt and in the States north of the Corn Belt, and make available larger quantities of high protein feeds for cattle and dairy production. The net effect upon the dairy industry is difficult to estimate. The tendency probably would be to check moderately dairy production in the Corn Belt and possibly to increase moderately dairy production in the Eastern States where feeds must be purchased.

COST TO CONSUMERS

The additional income that farmers might receive from the sale of corn and barley and other farm products to be used in the manufacture of alcohol would be offset to some extent by an increase in the cost of motor fuel to them. Apparently farmers use about 15 percent of the gasoline consumed in the country. With corn at 44 cents per bushel at the distillery, about 0.5 cent might be added to the cost of each gallon of motor fuel used by the farmer. If farmers used 2,250,000,000 gallons, at this rate of increase the additional cost would be about $11,250,000, against an additional income from the sale of grain and hogs amounting to about $70,000,000. If the additional cost of the blend were added to the motor fuel bill of the public, including the farmer, it would amount to about $75,000,000. Raising the blend to 5 or 10 percent would correspondingly increase the income to farmers and the additional cost to consumers.

Indications of increase in cost of motor fuel and the increase in the income to farmers from sale of grain and hogs

Alcohol	Price of corn at Chicago, per bushel	Cost of alcohol, per gallon	Increased cost of fuel, per gallon [1]	Increased fuel cost— To farmers	Increased fuel cost— To all consumers	Increased farm income from sale of grain and hogs
	Cents	*Cents*	*Cents*			
2 percent	44	36.4	0.5	$11,250,000	$75,000,000	$70,000,000
5 percent	53	40.8	1.4	31,500,000	210,000,000	220,000,000
10 percent	70	49.1	3.6	81,000,000	540,000,000	580,000,000

[1] Assuming the retail value of gasoline to be 13 cents per gallon.

These figures, of course, are only approximations. They are presented merely for the purpose of giving concreteness to an analysis of the possible effects upon agriculture and upon the consumer of alcohol in motor fuel. The actual cost to the public of a measure encouraging or requiring the use of alcohol in motor fuel would depend upon the extent to which the oil industry and distributors of motor fuel absorbed or passed on the additional costs to the consumer, and the extent to which increasing the income to farmers would tend to improve conditions generally so as to increase the purchasing power of consumers other than farmers. The exact ultimate consequences in these directions cannot be definitely anticipated.

EFFECTS ON EMPLOYMENT AND BUSINESS

The development of an alcohol industry would of course provide additional employment and business for builders, equipment manufacturers, and railroads. It has been estimated that converting to grain those plants which are not operating on grain but which it would be physically and economically feasible to convert to grain would provide about 9,700 man-years of employment. Approximately 152,600 tons of construction material would be added to railway traffic. In the operation of such plants at capacity, the labor of about 1,500 additional men would be required.

The building of new alcohol plants would, of course, provide additional employment. The equivalent of at least five additional plants, each using 25,000 bushels of corn per day and producing about 20,000,000 gallons of alcohol, would be needed to supply currently the additional alcohol necessary for a 2 percent motor-fuel blend. The building of these plants would require about 13,600 men for a year. In addition to the construction work, many men would be engaged in providing materials and in the transportation of materials to the plants. The operation of the plants would continue the employment of about 800 to 900 men. About 65 such additional new plants would be required to produce the anhydrous alcohol for a 10 percent blend, and the building of such plants would employ about 150,000 to 200,000 men, in addition to those engaged in providing materials and transporting materials to plant sites. New plant operations for a 10 percent blend would require about 10,000 to 12,000 men.

Whatever the ultimate consequences, however, the substitution of a blend in appreciable percentages would be followed immediately by a lower level of activity in the oil industry. This would result in some degree of unemployment. The number of wage earners in petroleum refining establishments was 67,936 in 1931. There were 105,224 oil and gas well operatives in 1930. This includes those whose occupations were connected with the drilling of wells. About one fourth or one fifth of wells drilled in recent years have been gas wells. At least 13,704 laborers were engaged in pipe-line transportation in 1930, including both oil and gas pipe lines. A 2 percent curtailment of operations all around would be roughly equivalent to 3,500 workers and 10 percent about 17,500 men. Presumably, however, other outlets for petroleum products would be maintained and further developed to some extent so that the actual curtailment would be slight, if any.

It might be practicable to erect alcohol plants as adjuncts to petroleum refineries. This would make it possible to use part of the facilities, such as power and storage facilities, which exist at petroleum plants and which might be made idle in some degree by substitution of alcohol. At the same time construction costs for alcohol plants would be minimized, and the transference of labor from oil refining to alcohol manufacture expedited. In terms of daily crude oil capacity, and of the total capacity of 4,020,428 barrels, 576,572 barrels are located in the six Corn Belt States of Ohio, Indiana, Illinois, Iowa, Kansas, and Missouri.

EFFECT OF SUBSTITUTION OF ALCOHOL ON THE OIL INDUSTRY

The substitution of alcohol for gasoline would obviously have economic repercussions on the oil industry. If all fuel in the future were to be blended fuel, and if the amount of blend that would be sold to motorists annually should be the same as the amount of gasoline that has been sold in the past, then, obviously, the petroleum refining industry would sell less gasoline. The reduction in sales of gasoline would be equal to the total sales of blend, multiplied by the percentage of alcohol included.

The amount of blend sold, however, might be more or less than the amount of gasoline sold in the recent past. It may conveniently be expressed as the product of the number of automobiles and the average consumption of motor fuel per automobile. In 1930 there was one motor vehicle registered for every 4.6 persons. The growth in population as well as extending the operations of cars will tend to increase the number of automobiles. The present consumption of gasoline per vehicle is about 600 gallons annually. An increase in registration of 1,000,000 vehicles for example, would increase motor fuel consumption 600,000,000 gallons annually without any change in consumption per vehicle. If 2 percent were alcohol, 588,000,000 gallons would be gasoline. Extension of surfaced highways will no doubt proceed, although perhaps at a slower pace. Attractive opportunities for motoring will thus increase. The march of technological progress will be resumed after the depression, thus increasing the real income of the country and the amount of money available for motoring expenditures. The increase in the price of the blend over gasoline which would be necessary might have some restricting effect on consumption; on the other hand, the ability of Corn Belt farmers to buy gasoline, as well as other things, would be increased. It is quite possible that the refining industry will find itself selling considerably more gasoline than indicated above.

Moreover, a decrease in total gasoline sales would not necessarily be accompanied by a corresponding decrease in the scale of refinery operations. Gasoline is only one, although the most important one, of a number of the products of refineries. The quantities and values of these products are shown in table 9. There is considerable room for variation in the proportions in which they are obtained from a given grade and volume of crude oil.

TABLE 9.—*Products of petroleum refining, 1927–31*

Product	Production			Value		
	1927	1929	1931	1927	1929	1931
	Gallons	*Gallons*	*Gallons*	*Dollars*	*Dollars*	*Dollars*
Gasoline [1]	12, 729, 536, 000	17, 538, 789, 000	16, 957, 807, 000	1, 048, 471, 000	1, 531, 242, 000	824, 669, 000
Fuel oils	15, 415, 860, 000	16, 390, 954, 000	13, 855, 861, 000	456, 959, 000	384, 630, 000	265, 720, 000
Lubricating oils [2]	1, 381, 902, 000	1, 553, 711, 000	1, 141, 354, 000	244, 629, 000	304, 673, 000	196, 191, 000
Illuminating oils	2, 217, 591, 000	2, 338, 929, 000	1, 729, 669, 000	147, 925, 000	164, 836, 000	72, 146, 000
Naphtha, benzine, and tops	661, 804, 000	867, 738, 000	492, 331, 000	53, 683, 000	78, 802, 000	22, 376, 000
Greases	44, 912, 000	57, 669, 000	45, 577, 000	12, 961, 000	16, 646, 000	12, 369, 000
All other products				178, 021, 000	158, 836, 000	118, 136, 000
Total				2, 142, 649, 000	2, 639, 665, 000	1, 511, 598, 000

[1] Does not include natural gasoline.
[2] Excludes lubricating oils not produced in petroleum refineries.

For some of these other products the market has been increasing and promises to continue to increase. This is particularly true of fuel oil, the most important item.

The distribution of fuel oil, in thousands of barrels of 42 United States gallons, in 1929 was as follows:

Distribution of fuel oil:	*Barrels of 42 gallons*
Railroads	67, 900, 000
Steamships, including tankers	94, 131, 000
Gas and electric power plants	26, 749, 000
Manufacturing industries	70, 481, 000
Commercial heating	17, 344, 000
Domestic heating	7, 158, 000
United States Navy, Army transports, etc	8, 192, 000
Used as fuel by oil companies	55, 559, 000
Miscellaneous	11, 560, 000
Exports	39, 151, 000

The use of fuel oil by railroads increased rapidly during the decade preceding the depression. Indications are that this expansion will be continued. Fuel oil, in addition to being used in locomotives, is coming into use in Diesel electric rail cars. Substitution of such cars for ordinary train service is a promising way of reducing the expenses of branch-line operation and of providing service in smaller units at more frequent intervals. The substitution of fuel oil for coal under steam boilers in steamships and the construction of Diesel-engined ships using fuel oil has been an outstanding feature of world navigation developments during recent years. This tendency will probably continue. Domestic heating, although at present a small outlet, is a growing one. Between 1923 and 1930 there was a ninefold increase in the consumption of gas oil, fuel oil, and lighter oils in this field. It would seem to have much greater possibilities. Future prospects in some of the other outlets for fuel oil are not so promising. The consumption of oil in gas and electric power plants has been declining, largely because of substitution of natural gas and water power in the area of consumption of oil. On the whole, however, the possibility of diverting crude petroleum from gasoline to fuel-oil uses seems very strong.

The two next most important products of the industry are lubricating oils and illuminating oils (the latter chiefly kerosene). The market for lubricating oils will increase gradually with the development of industry and transportation. Petroleum has no important competitor as a source of lubricants. Of the minor products, asphalt and asphaltic oils have special interest. Extension of improved highways in the future must largely take the form of improvement of secondary roads. Lesser traffic density on these calls for lesser expenditure per mile. Methods have been devised in recent years for providing, at comparatively low cost, smooth surfaces which will stand up under moderate amounts of traffic. These methods involve admixture of asphaltic materials with the gravel soil, or other soil composing the roadbed.

The point of the foregoing discussion is not that the oil industry by exercising greater pressure in the sale of petroleum products other than gasoline, could make up for its future loss of gasoline sales by developing a greater use of fuel oil, etc., than would otherwise occur. It is only that the normal growth of motor fuel consumption will offset all or part of the loss of substitution of gasoline, and that the balance of crude petroleum, if any, for which a gasoline outlet is lost may be absorbed by the expected future growth of fuel-oil sales, etc. The industry may not attain as high a general level of production in the future as might otherwise occur; but it can still attain a level equal to or materially above that of the recent past.

MOTOR FUEL USE OF ALCOHOL IN FOREIGN COUNTRIES

In many foreign countries alcohol is now used in a motor-fuel blend or mixture. Several factors have contributed to the development of the use of alcohol in these foreign countries. In some European countries the objective is to provide additional outlet for potatoes, in some it is molasses or beet roots, and in others, fruits. The use of alcohol has also been supported by nationalistic arguments as to the need of being more independent of foreign supplies of petroleum. In most cases the countries have surplus agricultural products but must import petroleum or gasoline. The appeal for alcohol is the appeal for the use of the home product. Furthermore, the need for restricting purchases of foreign exchange in some cases is a factor of some importance. In practically all cases the price of petroleum or gasoline is higher in foreign countries than in the United States, and the higher prices tend to encourage the substitution or use of alcohol in blends. In Sweden, for example, alcohol can be produced as a byproduct of the wood-pulp industry at a low cost. In all countries, however, with the possible exception of Sweden, aid to agriculture has been a factor in requiring or encouraging the use of alcohol in motor fuel.

Retail prices per gallon of gasoline, including tax, in specified foreign markets, December 1932

Stockholm	19. 1
Vienna	28. 0
Lyons	28. 0
Berlin	33. 3
Rome	42. 7

The United States Department of Commerce has compiled much information as to the use of alcohol in foreign countries.[3] Some of the data are summarized as follows:

TABLE 10.—*Approximate use of alcohol for motor fuel, and consumption of alcohol blends, other blends, and straight gasoline, 1930*

Country	Alcohol used in blends	Consumption of motor fuel		
		Blends containing alcohol	Other blends	Straight gasoline
	Barrels [1]	*Barrels* [1]	*Barrels* [1]	*Barrels* [1]
Australia	5, 700	34, 000	49, 400	6, 364, 100
Brazil [2]	(3)	(3)		1, 822, 000
China	3, 600	6, 500		[4] 711, 400
Czechoslovakia	34, 000	68, 000	120, 000	1, 475, 000
France	168, 000	336, 000	1, 584, 000	15, 450, 800
Germany	425, 000	1, 700, 000		[4] 13, 412, 000
Hungary	75, 000	375, 000		209, 400
Philippines	101, 100	(5)		[6] 646, 700
South Africa	(7)	(7)		[6] 1, 867, 000
Sweden [2]	48, 000	192, 000		2, 635, 000

[1] Barrels of 42 United States gallons.
[2] 1931.
[3] Sales were part of motor fuel supply in 3 cities.
[4] Includes some gasoline used in other blends.
[5] Not available.
[6] Includes gasoline used in alcohol blend.
[7] Sale largely confined to one city.

Among the more important countries that have experimented with alcohol in motor fuel are France and Germany. In Germany the primary purpose is to make a better market for potatoes. Although the cost of gasoline in Germany is relatively high, the use of alcohol made from potatoes increases the cost of the motor fuel. This seems to be the greatest complaint made of its use.

The cost of gasoline delivered at Hamburg is 5.5 cents per gallon, and the tariff adds 15 cents per gallon, according to a cable from Agricultural Commissioner Steere. The Government monopoly pays farmers 29 cents per bushel for potatoes, and the cost of producing alcohol from these potatoes is estimated at from 23 to 28 cents per gallon. The monopoly sells the alcohol (99 percent) to oil companies at 46 cents per gallon. The retail price of gasoline in Berlin was reported on April 20 to be 34 cents per gallon, and the alcohol-gasoline blend was retailed at the same price. The gasoline-benzol-alcohol blend sold at a premium of 4 cents over the straight gasoline and the alcohol-gasoline blend.

The Government does not require all of the motor fuel to include alcohol. The importers and producers of motor fuel are required to

[3] U.S. Department of Commerce Trade Information Bulletin 805.

take from the monopoly alcohol equivalent to 10 percent of their imports or production. About 50 percent of the motor fuel sold is straight gasoline, 10 percent is a gasoline-alcohol blend, and 40 percent a gasoline-alcohol-benzol blend. The benzol blend includes 15 percent alcohol, and the alcohol blend includes 20 percent alcohol.

In general the use of alcohol motor fuel is technically satisfactory in Germany. Some loss of power is reported in small, low-compression motors, but favorable results are obtained in higher compression motors. The chief advantage in its use is from its antiknock effect.

In France also a considerable quantity of alcohol is used in mixture with petroleum. In that country molasses, beet roots, and fruits furnish the alcohol. In France, as in Germany, the alcohol costs more than the gasoline. The French Government pays about 38 cents a gallon for alcohol and in turn sells it to oil companies for 17 cents per gallon, which is approximately the cost of the gasoline. The Government makes up this loss by means of a tax on all gasoline and kerosene, while the blended fuel is now exempt from this tax.[4]

The use of alcohol in gasoline was not required in Czechoslovakia. A special fuel called dynalkol has been in use there since 1922. The composition of this fuel is 30 percent gasoline, 20 percent benzol, and 50 percent alcohol. A law has been drafted to make compulsory the mixture of 20 percent alcohol and 80 percent gasoline, but this proposal has not yet been made effective. In Czechoslovakia the use of alcohol increases the cost of motor fuel about 12 percent.

Sweden, as noted above, uses an alcohol-gasoline blend without any compulsion. The alcohol is obtained from the cellulose residues of pulp factories. The first trials began in 1911. The war gave impetus to its use. It is reported that the use of the blend or mixture involves no change in the operation of the engine. It increases the power and smoothness of the engine without increasing the amount of fuel used. Furthermore, "in spite of the low temperature in Sweden during a very considerable part of the year, the mixture remains homogeneous and causes no difficulty in starting."[5]

The names and content of some mixtures now in use in foreign countries are as follows:

TABLE 11.—*Composition of foreign alcohol motor-fuel blends*

Country	Trade name	Content					
		Alcohol	Gasoline	Ethyl ether	Benzol	Kerosene	Total
		Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Australia	Shellpol	15–35	65–85				100
Brazil [1]		70		30			100
Do		90		10			100
Brazil [2]	Gasalco	88	[3] 12				100
China	Benzolite	55			40	5	100
Czechoslovakia	Dynalkol	50	30		20		100
France	Carburant National	50	50				100
Germany	Monopolin	25	75				100
Do	Aral	20	60		20		100
Do	Bevaulin	25	75				100
Hungary	Motalco	20	80				100
Sweden	Lattbentyl	25	75				100
South Africa [4]	Natalite	60		[5] 40			100

[1] Pernambuco.
[2] Rio de Janeiro, Nictheroy.
[3] Includes "solvent."
[4] Durban.
[5] Includes ether.

[4] Report of special committee of the American Petroleum Institute.
[5] International Bureau of Automobile Manufacturers.

Many foreign countries have tried experiments that have not been notably successful. Administrative difficulties have arisen in many cases. However, as noted above, some have succeeded in developing the use of an alcohol blend or mixture upon its own merit, and others have succeeded in enforcing, directly or indirectly, the use of alcohol. Naturally, motorists and those who are interested in the automobile industry object to the imposing of any additional burdens upon motoring. The taxes on gasoline and upon automobiles are high in many foreign countries, and requirements to use alcohol in motor fuel are looked upon as another form of tax, increasing a burden that already exists. It is interesting to note, however, that the International Permanent Bureau of Automobile Manufacturers, Paris, after condemning vigorously the imposition of additional burdens upon motorists in foreign countries, arrived at the following conclusions:

> To sum up, one can therefore declare that from the strictly technical point of view, the advantages presented by the use of a mixed fuel containing petrol and alcohol, compensate approximately the disadvantages, on condition, nevertheless, that the following rules are complied with:
> (1) The grade or degree of the alcohol mixture should not exceed 25 percent.
> (2) The alcohol used in the mixture must be in a rigorously anhydrous state.
> (3) The distribution of the petrol fuel alcoholized at 15 percent, has to be so made that one may be sure of obtaining it at any time throughout the whole territory, so that the user shall not be forced to constantly change the nature of the fuel which he uses * * *.

This seems to be a very good summary of the results of experience in foreign countries.

TAXATION AS A MEANS OF INDUCING THE USE OF ALCOHOL IN MOTOR FUEL

In most foreign countries special measures have been undertaken as a means of inducing the use of alcohol in motor fuel. In some cases the measures have taken the form of compelling the distributors of motor fuel to buy alcohol proportionate to the amount of gasoline used or sold. Distributors are allowed to make whatever mixtures they find expedient. In some cases attempts have been made to compel the use of a specified percentage of alcohol in the fuel. In other cases the use has been induced or encouraged only by preferential taxation. As previously indicated in only a few countries such as Sweden and Czechoslovakia has the use of the alcohol been induced upon its own merits or on account of economy in use. Doubtless some quantities of an alcohol-gasoline blend could be sold in the United States at the same price or even slightly higher than straight gasoline on account of superior smoothness of operation and antiknock quality. Extensive use, however, could be induced only by legal requirements by some form of differential tax or other special inducements.

The mixing of a given percentage of alcohol with gasoline in the United States probably could be induced by legally requiring a mixture of a specified percentage, by reducing the existing taxes when applied to the blend, or by levying an additional tax on gasoline. The first of these possibilities, namely, compulsory mixing of gasoline and alcohol would involve important questions of administration and of constitutionality. It appears advisable to limit consideration to the problem of inducing the utilization of the alcohol for fuel either by taxing the blend less than at present, leaving the tax on gasoline unchanged, or by increasing the tax on motor fuel not mixed with alcohol according to specifications. Each type of tax differential would be applicable either to an actual blend of a specified percent of alcohol in each lot of fuel, or to a flexible blend consisting of a given quantity of alcohol disposed of for motor fuel but blended with only a part of the gasoline sold as fuel and exempted from the special tax.

REDUCING TAX ON BLENDED FUEL

If the Federal Government should exempt blended fuel from the tax and continue to levy the present gasoline tax of 1 cent a gallon only on motor fuel not blended or associated with alcohol, there would be some inducement in favor of the utilization of blends. This, however, would dry up an important source of Federal revenue which, on the basis of gasoline consumption in 1932, probably amounts to more than $140,000,000 per annum. A tax advantage of 1 cent per gallon would offset the increased cost of fuel containing only about 3½ percent of alcohol made from corn costing the manufacturer about 50 cents per bushel.

The use of a blended fuel containing such a low percentage of alcohol involves certain technical difficulties, referred to earlier in this report. It may be practicable, however, to overcome these by means of a flexible blend obtained by mixing the amount of alcohol representing a given percentage of motor fuel consumption, with only a part of the gasoline as explained at the close of this section. This would allow a higher percentage of alcohol in the actual mixture and permit sale of the remainder of the gasoline as legally presumed to be blended.

Gasoline taxes in the States could be reduced only by action of the State legislatures. It appears probable that it would take a long time to do this in the States, even if the States were willing. A great majority of the State legislatures have met this year, many of them have adjourned or will have adjourned before action on any such proposal could be taken. It is doubtful whether the States would wish to take such action, especially States growing comparatively little of the farm products that may be used in the manufacture of alcohol. It would deprive the States of large amounts of revenue, and the gasoline tax is one of the most stable and productive sources of revenue. Other sources are yielding far less revenue than a few years ago and new sources are hard to find. Taxpayers everywhere register determined resistance to new taxes. Therefore, any reduction in the States gasoline tax, as a measure of inducing the utilization of the blended motor fuel, is hardly to be expected because of the difficulty of securing action by the State legislatures, a difficulty resting primarily upon the serious revenue problems involved. The amount of gasoline tax, net revenue in 1931, and the loss of revenue that would have resulted from a reduction in State taxes of 1, 2, or 3 cents per gallon of gasoline is indicated in table 15.

ADDITIONAL TAX ON NONALCOHOL FUEL

An additional tax levied on motor fuel either containing no alcohol, or in excess of the quantity for which alcohol had been purchased, would induce the utilization of the blend. To obtain the full use of a specified percentage of alcohol the additional tax must of necessity be at least as high and probably somewhat higher than the difference in cost of a given blend and the cost of gasoline alone. At any given difference in cost between alcohol and gasoline, the cost of the blend as compared with gasoline would depend upon the proportion which the alcohol is of the blended fuel.

As indicated earlier in this report, it appears probable that a blend of 2 percent would cost at retail, exclusive of any tax, 0.53 cents per gallon more than gasoline alone, when the price of corn for the manufacture of alcohol is 50 cents per bushel. It would be necessary, therefore, to levy a tax somewhat more than this per gallon of gasoline unmixed with alcohol in order to equalize the difference in cost and to create a slight price advantage in favor of the utilization of the blend. Assuming 39.3 cents per gallon as the cost of alcohol inclusive of corn at 50 cents a bushel, the offsetting tax on gasoline would be about as follows for given percentages of alcohol blended with gasoline:

Alcohol in blend	Tax per gallon of gasoline to offset higher cost of blend
Percent	*Cents*
2	0.6
4	1.0
6	1.6
8	2.1
10	2.7

EFFECT OF INCREASED TAX ON FUEL CONSUMPTION

An increase in cost of fuel as a result of the using of alcohol with gasoline would tend to reduce fuel consumption. The amount of reduction resulting from any given increase in cost per gallon, however, probably cannot be determined accurately, even with a great deal more study of this problem than has been possible in the preparation of this report. Factors affecting gasoline consumption are so numerous and conflicting that it may not be possible at all to measure accurately the influence of each.

As shown in tables 16 and 17 of the appendix the volume of gasoline for motor fuel has increased greatly in recent years despite a rapid extension of the gasoline tax and a marked increase in the tax per gallon. The vast revenues produced by this tax (see table 18, appendix) have been used almost wholly for road construction and maintenance, and this in turn has stimulated the use of motor vehicles and reduced cost of operation per mile. In effect, the tax has stimulated the consumption of gasoline.

Another problem that precludes accurate measurement of the effect which a given increase in the cost of blended fuel would have on fuel consumption, lies in the fact that the total cost of motoring includes many elements of which a few cents difference in the cost of fuel is a small percentage. The influence of this difference may be more than offset by any one of several factors—technical improvements in the automobile or reduction in the purchase price, improvement in business activity and purchasing power of consumers, and reduction in the price of gasoline exclusive of the tax.

The factor last named—lower price of gasoline—is undoubtedly an important reason for the continued large volume of gasoline consumption in the present depression. The oil industry, by force of circumstances or by deliberate policy, has reduced prices and maintained volume of business. How long this could be continued with still higher gasoline taxes or with added cost of blended fuel, or both, is problematical.

Table 19 of the appendix shows among other things the States which increased the gasoline tax in 1932, the amount of gasoline taxed and the percentage change from the preceding year.

A decrease in gasoline consumption occurred in practically all States, the decrease varying from less than 1 percent in New Hampshire to 22.2 percent in Arkansas. In several States having a high tax per gallon the percentage reduction in consumption was higher than in the majority of States. (See table 19.) This relationship, however, cannot be taken as conclusive evidence of the effect of a high tax per gallon on total consumption. Total consumption is also responsive to the varying severity of the decline in income of the motoring public.

A high tax no doubt tends to reduce consumption. No definite conclusion is possible, however, as to the amount of reduction resulting from a given tax, because of the numerous and complex factors that must be taken into account. The foregoing comments on tax rates in relation to consumption suggests that special caution is necessary as to the depressing effect which a given increase in the cost of blended fuel would have on volume of consumption, and that, without such caution, this effect easily might be overestimated.

ADVANTAGES OF A FLEXIBLE BLEND

Some consideration must be given also to the way in which a differential tax is imposed or collected. One procedure would be to require that all motor fuel should include some stated percentage of alcohol as a condition of exemption or preferential tax rate. Experience in foreign countries suggests another procedure, that of requiring importers and producers of motor fuel to buy and utilize, in motor fuel exclusively, quantities of alcohol to the extent of a given percentage of the motor fuel distributed.

This may be illustrated as follows: Suppose that a dealer handles 100,000 gallons of motor fuel and that the use of alcohol to the extent of 2 percent is required. He would dispose of motor fuel consisting of 98,000 gallons of gasoline and 2,000 gallons of alcohol. The most advantageous blend, however, might require that the 2,000 gallons of alcohol be blended with 18,000 gallons of gasoline, making a blended fuel of 10 percent. The remaining 80,000 gallons of gasoline could be sold as "straight gasoline." The special tax levied to induce the use of blended fuel would not apply to any part of this 100,000 gallons of motor fuel. If, however, the dealer handles any amount of additional gasoline as motor fuel, this would be subject to the special tax.

This plan would have several advantages:

First. It would simplify administration. It would be necessary only to determine whether wholesale distributors or other concerns operating on a large scale, handling substantially all the fuel for a given area, used 1 part of alcohol for 9 parts of gasoline, for any quantity of motor fuel exempted from the special tax. The amount of gasoline which a dealer may handle in addition, subject to the special tax, would be easily ascertained. It certainly would be easier to do this than to determine whether every lot of fuel sold to the consumer contained a given percent of alcohol.

Second. It would enable the distributor to blend alcohol and gasoline in such proportions as to give the best performance of motor fuel in the light of technological considerations and public preference.

Third. It would enable dealers to use the alcohol more extensively with low-grade gasoline, and thus add an economic value through greater improvement in the performance of the mixture than might be obtained from using the alcohol with high-grade gasoline.

Fourth. It would be possible to sell a relatively larger quantity of alcohol in those regions where its use seemed most acceptable. Perhaps some motorists would be willing to pay a premium for some special blend. This would help to offset the higher cost of the alcohol itself, thereby enhancing the total advantage of blending, and minimizing the administrative and technological difficulties involved in the distribution and utilization of blended fuel.

The flexible blend, therefore, appears to have distinct advantages for administrative, technical and economic reasons.

APPENDIX

DECLINE IN THE NUMBER OF HORSES AND MULES AND ITS EFFECT ON THE UTILIZATION OF FEED CROPS

The substitution of the internal combustion engine for horse and mule power during the past two decades has restricted the uses of feed crops. The impairment of foreign markets for livestock has had a similar effect. The development of a motor fuel outlet for corn and possibly other grains would tend to fill the void created by these two changes.

The total number of horses and mules on farms in the United States reached its peak in 1918 or 1919. According to estimates of the Bureau of Agricultural Economics the number of horses and mules on farms January 1, 1919, was 26,436,000 head. The peak in the number of horses and mules in towns and cities was reached somewhat earlier than the peak in horse numbers on farms. The total number of horses and mules in towns and cities declined from 3,470,000 head in 1910 to 2,099,000 in 1920.

Since 1919 the number of horses and mules on farms has declined steadily until on January 1, 1933, there were only 17, 730,000 head on farms. The decline in horses and mules in towns and cities has been even more marked during this period. The 1930 Census did not completely enumerate horses and mules not on farms, but incomplete returns indicate that there were relatively few horses remaining in towns and cities.

These available data on the number of horses and mules on farms and in cities and towns indicate that the horse and mule population of the United States has declined from approximately 28,700,000 on January 1, 1919, to a little over 18,000,000 on January 1, 1933. The decline of all horses and mules during the 14-year period was about 37 percent while the decline of horses and mules on farms was 33 percent.

This sharp falling-off in the number of horses and mules in the United States has resulted in a marked decline in the feed requirements for horses. In arriving at an estimate of the reduction the acreage required to raise feed for horses and mules, two things should be kept in mind: (1) The extent of decline in horse numbers from 1919 to date due to the substitution of motor power for horses, and (2) any change that may have taken place in the total requirements for horsepower since 1919. The change in the total requirements for horsepower might be measured by comparing the number of acres of land in cultivation in more recent years with the number of acres in cultivation in 1919. The total acreage in crops has shown little change in the last 14 years. However, there have been some shifts in crop production which might have changed the amount of horsepower required, such as a marked increase in the production of intensively cultivated crops such as vegetables, tobacco, etc. On the other hand, there has also been an increase in the extensively cultivated crops such as wheat in the Great Plains area. Consequently it is unlikely that the horsepower requirements on farms have changed greatly since 1919. The marked expansion in movement of goods and other power requirements in cities, however, would have called for a considerably larger number of horses than were in towns and cities in 1919 and probably, also, a somewhat larger number than were in towns in 1910.

Assuming that the horsepower requirements at the present time are at least as great as they were in 1919, some estimate of the amount of land released for the growing of other crops than feed for horses may be arrived at. In 1919 it was estimated that horses and mules on farms required about 90,000,000 acres of crop land (see 1923 Agricultural Yearbook, p. 466).

Since the number of horses and mules on farms has declined approximately one third since 1919 this would mean that approximately 30,000,000 fewer acres is required for the growing of feed crops. Furthermore, the decline in the number of horses and mules not on farms has probably released an additional 4,000,000 to 5,000,000 acres of land for other purposes. Another method of arriving at the amount of land released for other purposes is to multiply the number of acres required to feed and mature a horse or mule by the decline in the number of horses and mules since 1919. According to studies which have been made on the feed requirements of mature horses and mules, approximately 3⅓ acres are required to produce the feed consumed by a mature horse or mule in a year.[6] As the decline in the horse and mule population of the United States since 1919 has amounted to approximately 10,500,000 head, these figures indicate that about 35,000,000 acres have been released for other purposes. Since a large proportion of the horses and mules in the United States at the present time are of a mature age, this figure may be slightly larger than the actual decline in the number of acres required to grow feed for the horse and mule population. Other methods of arriving at the decline in feed requirements also indicate that approximately 33,000,000 to 35,000,000 acres of land have been released for other purposes.

TABLE 12.—*Total registration of passenger cars and motor trucks in the United States, 1928–32*

[Division of Statistical and Historical Research. 1928–31 compiled from Facts and Figures of the Automobile Industry, 1932 edition, National Automobile Chamber of Commerce; 1932 from Bureau of Public Roads]

Years	Passenger cars	Motor trucks	Total motor vehicles
1928	21, 379, 125	3, 113, 999	24, 493, 124
1929	23, 121, 589	3, 379, 854	26, 501, 443
1930	23, 059, 262	3, 486, 019	26, 545, 281
1931	23, 347, 800	3, 466, 303	25, 814, 103
1932	20, 903, 422	3, 233, 457	24, 136, 879

[6] Regional Changes of Farm Animal Production in Relation to Land Utilization, p. 16.

TABLE 13.—*Registration of passenger cars in selected States, 1928–32*

[Division of Statistical and Historical Research. Compiled from Facts and Figures of the Automobile Industry, 1932 edition, National Automobile Chamber of Commerce; 1932 from Bureau of Public Roads]

State	1928	1929	1930	1931	1932	
					Total	As percentage of 1929
						Percent
Illinois	[1] 1,314,003	[1] 1,411,753	1,430,676	1,411,261	1,311,783	92.9
Indiana	706,713	741,366	747,366	732,846	675,108	91.1
Iowa	672,447	714,919	706,196	670,024	606,523	84.8
Kansas	471,897	[1] 507,529	[1] 511,384	[1] 478,692	432,610	85.2
Minnesota	583,789	630,703	624,902	611,966	581,905	92.3
Missouri	636,717	[1] 671,237	[1] 670,145	[1] 656,830	618,195	92.1
Nebraska	[2] 358,173	375,946	367,587	356,283	322,347	85.7
Ohio	1,450,994	1,560,182	1,555,093	[1] 1,518,696	1,420,550	91.1
Texas	1,060,028	1,165,150	1,159,139	1,086,310	1,001,675	86.0
Wisconsin	646,747	689,447	677,452	640,476	587,906	85.3
Massachusetts	637,153	719,436	743,288	736,302	698,358	97.1
New York	1,760,549	1,922,068	1,966,981	1,966,436	1,931,384	100.5
New Jersey	629,748	698,959	719,696	736,506	726,201	103.9
Pennsylvania	1,420,957	1,515,875	1,534,834	1,522,130	1,448,978	95.6

[1] Busses not included.
[2] Includes only trucks and busses weighing over 3,000 pounds; others included under passenger cars.

TABLE 14.—*Total registration of passenger cars and number on farms in selected States, 1930*

[Division of Statistical and Historical Research. Compiled from Facts and Figures of the Automobile Industry, 1932 edition, National Automobile Chamber of Commerce]

State	Total passenger-car registration	Passenger cars on farms	
		Total	Percentage of total passenger registration
			Percent
Illinois	1,430,676	192,873	13.5
Indiana	747,366	154,556	20.7
Iowa	706,196	240,512	34.1
Kansas	[1] 511,384	171,018	33.4
Minnesota	624,902	185,717	29.7
Missouri	[1] 670,145	176,466	26.3
Nebraska	367,587	141,144	38.4
Ohio	1,555,093	201,552	13.0
Texas	1,159,139	300,176	25.9
Wisconsin	677,452	176,764	26.1
Massachusetts	743,288	17,638	2.4
New York	1,966,981	141,916	7.2
New Jersey	719,696	22,371	3.1
Pennsylvania	1,534,834	152,222	9.9

[1] Busses not included.

TABLE 15.—*Reduction in total State revenue from the gasoline tax at specified rates of reduction in the tax per gallon*

States and regions	Net gallons taxed in 1931 [1]	Net revenue in 1931	Reduction in tax per gallon		
			1 cent	2 cents	3 cents
United States	15,407,650,000	$536,397,000	$154,081,000	$308,153,000	$438,181,000
New England	1,114,749,000	30,934,000	11,148,000	22,295,000	30,133,000
Maine	109,568,000	4,383,000	1,096,000	2,191,000	3,287,000
New Hampshire	66,429,000	2,657,000	664,000	1,329,000	1,993,000
Vermont	49,164,000	1,967,000	492,000	983,000	1,475,000
Massachusetts	558,556,000	15,306,000	5,586,000	11,171,000	16,757,000
Rhode Island	94,632,000	1,893,000	946,000	1,893,000	(2)
Connecticut	236,400,000	4,728,000	2,364,000	4,728,000	(2)
Middle Atlantic	3,179,780,000	80,122,000	31,798,000	63,595,000	80,122,000
New York	1,527,203,000	30,544,000	15,272,000	30,544,000	(2)
New Jersey	570,821,000	17,125,000	5,708,000	11,416,000	17,125,000
Pennsylvania	1,081,756,000	32,453,000	10,818,000	21,635,000	32,453,000
East North Central	3,562,171,000	124,041,000	35,622,000	71,243,000	106,865,000
Ohio	983,201,000	39,328,000	9,832,000	19,664,000	29,496,000
Indiana	450,864,000	18,035,000	4,509,000	9,017,000	13,526,000
Illinois	968,856,000	29,066,000	9,689,000	19,377,000	29,066,000
Michigan	727,745,000	21,832,000	7,277,000	14,555,000	21,832,000
Wisconsin	431,505,000	15,780,000	4,315,000	8,630,000	12,945,000
West North Central	1,842,563,000	53,797,000	18,426,000	36,852,000	50,674,000
Minnesota	369,005,000	11,070,000	3,690,000	7,380,000	11,070,000
Iowa	364,253,000	10,928,000	3,643,000	7,285,000	10,928,000
Missouri	460,328,000	9,207,000	4,603,000	9,207,000	(2)
North Dakota	67,675,000	2,030,000	677,000	1,354,000	2,030,000
Nebraska	227,406,000	9,096,000	2,274,000	4,548,000	6,822,000
South Dakota	84,867,000	3,395,000	849,000	1,697,000	2,546,000
Kansas	269,029,000	8,071,000	2,690,000	5,381,000	8,071,000
South Atlantic	1,498,733,000	76,631,000	14,988,000	29,975,000	44,098,000
Delaware	35,735,000	1,072,000	357,000	715,000	1,072,000
Maryland	185,775,000	7,431,000	1,858,000	3,716,000	5,573,000
District of Columbia	86,315,000	1,726,000	863,000	1,726,000	(2)
Virginia	228,904,000	11,445,000	2,289,000	4,578,000	6,867,000
West Virginia	134,680,000	5,387,000	1,347,000	2,694,000	4,040,000
North Carolina	249,609,000	14,024,000	2,496,000	4,992,000	7,488,000
South Carolina	120,766,000	7,246,000	1,208,000	2,415,000	3,623,000
Georgia	221,892,000	13,314,000	2,219,000	4,438,000	6,657,000
Florida	235,057,000	14,986,000	2,351,000	4,701,000	7,052,000
East South Central	661,221,000	33,350,000	6,612,000	13,224,000	19,836,000
Kentucky	176,203,000	8,810,000	1,762,000	3,524,000	5,286,000
Tennessee	206,707,000	11,461,000	2,067,000	4,134,000	6,201,000
Alabama	162,671,000	7,197,000	1,627,000	3,253,000	4,880,000
Mississippi	115,640,000	5,882,000	1,156,000	2,313,000	3,469,000
West South Central	1,313,882,000	58,026,000	13,140,000	26,278,000	39,416,000
Arkansas	110,579,000	6,448,000	1,106,000	2,212,000	3,317,000
Louisiana	187,956,000	9,398,000	1,880,000	3,759,000	5,639,000
Oklahoma	252,483,000	11,665,000	2,525,000	5,050,000	7,574,000
Texas	762,864,000	30,515,000	7,629,000	15,257,000	22,886,000
Mountain	506,170,000	22,413,000	5,063,000	10,123,000	15,185,000
Montana	60,363,000	3,018,000	604,000	1,207,000	1,811,000
Idaho	51,967,000	2,598,000	520,000	1,039,000	1,559,000
Wyoming	39,675,000	1,587,000	397,000	794,000	1,190,000
Colorado	156,358,000	6,254,000	1,564,000	3,127,000	4,691,000
New Mexico	53,294,000	2,665,000	533,000	1,066,000	1,599,000
Arizona	64,702,000	3,204,000	647,000	1,294,000	1,941,000
Utah	60,363,000	2,309,000	604,000	1,207,000	1,811,000
Nevada	19,448,000	778,000	194,000	389,000	583,000
Pacific	1,728,381,000	57,083,000	17,284,000	34,568,000	51,852,000
Washington	244,530,000	11,032,000	2,445,000	4,891,000	7,336,000
Oregon	155,063,000	6,187,000	1,551,000	3,101,000	4,652,000
California	1,328,788,000	39,864,000	13,288,000	26,576,000	39,864,000

[1] This is assumed to equal the number of gallons of motor fuel that would be affected by an increase in cost of fuel to consumers. Any change in the quality of motor fuel used would of course result in a corresponding change in total cost of the fuel at the specified rates per gallon. See tables for data on gasoline consumption, tax rates, and revenues by States.

[2] Tax rate 2 cents per gallon. Hence this marks the limit of loss of revenue by a reduction in the tax. All States that do not have a tax of less than 3 cents per gallon levy 2 cents. The revenue from the latter tax would be lost if the reduction were 3 cents a gallon in States having a tax of this amount or greater, and 2 cents in States having a tax of 2 cents per gallon.

TABLE 16.—*Gasoline consumption by years*

[Net gallons taxed and used by motor vehicles,[1] as reported by State authorities]

State	1919	1920	1921	1922	1923	1924	1925
Alabama					37, 706, 444	86, 933, 049	107, 040, 092
Arizona			8, 792, 835	17, 460, 636	20, 123, 824	24, 361, 537	28, 531, 686
Arkansas			10, 428, 872	21, 820, 500	41, 813, 419	57, 087, 281	73, 759, 002
California					150, 918, 305	670, 677, 076	747, 839, 462
Colorado	29, 457, 283	45, 839, 482	64, 491, 230	69, 337, 164	73, 753, 225	92, 151, 131	97, 377, 858
Connecticut			22, 278, 380	73, 404, 811	88, 041, 619	107, 243, 282	122, 230, 292
Delaware					10, 523, 330	15, 896, 266	17, 104, 050
Florida			27, 995, 498	63, 566, 073	89, 089, 741	125, 662, 248	210, 323, 517
Georgia			30, 250, 719	75, 382, 697	102, 100, 911	118, 789, 416	138, 802, 152
Idaho					19, 824, 360	27, 267, 351	30, 809, 320
Indiana					144, 139, 437	241, 915, 355	272, 980, 870
Iowa							175, 255, 740
Kansas							145, 259, 690
Kentucky		16, 835, 344	44, 105, 159	52, 103, 634	68, 023, 530	79, 149, 829	101, 385, 318
Louisiana			4, 137, 304	55, 603, 690	76, 675, 153	99, 860, 987	116, 939, 139
Maine					28, 601, 924	52, 167, 313	56, 513, 741
Maryland				39, 554, 553	73, 789, 603	82, 099, 688	98, 851, 813
Michigan							411, 803, 894
Minnesota							199, 464, 097
Mississippi				29, 854, 303	49, 283, 753	64, 083, 314	83, 142, 469
Missouri							207, 955, 474
Montana			17, 316, 809	24, 790, 700	32, 156, 613	34, 385, 261	33, 735, 497
Nebraska							109, 690, 122
Nevada					5, 791, 994	7, 713, 133	8, 850, 407
New Hampshire					18, 274, 750	30, 711, 323	35, 353, 585
New Mexico	4, 306, 935	5, 742, 580	10, 729, 592	15, 815, 874	15, 897, 209	18, 709, 876	20, 490, 892
North Carolina			50, 601, 776	80, 808, 481	123, 268, 452	153, 492, 263	161, 371, 522
North Dakota	[2] 35, 100, 559	17, 892, 656	14, 670, 453	15, 880, 038	40, 106, 291	50, 401, 962	64, 941, 557
Ohio							450, 497, 522
Oklahoma					59, 900, 000	148, 050, 085	176, 753, 177
Oregon	36, 492, 859	47, 737, 782	53, 616, 850	59, 757, 342	76, 961, 919	89, 657, 438	96, 969, 835
Pennsylvania [3]			83, 532, 279	311, 167, 009	341, 370, 362	454, 477, 014	[4] 525, 077, 352
Rhode Island							31, 835, 668
South Carolina				38, 385, 610	57, 031, 244	74, 140, 405	83, 962, 562
South Dakota				36, 870, 169	37, 451, 609	57, 202, 124	64, 024, 928
Tennessee					61, 382, 767	90, 611, 762	122, 000, 680
Texas					168, 256, 660	377, 671, 525	464, 178, 427
Utah					19, 698, 686	28, 183, 440	32, 217, 216

[1] Some States tax all gasoline sold regardless of use.
[2] No exemptions made during year.
[3] Includes distillate taxed at a lower rate per gallon.
[4] Figure revised.

TABLE 16.—*Gasoline consumption by years*—Continued

State	1919	1920	1921	1922	1923	1924	1925
Vermont					17,688,253	23,296,641	25,863,167
Virginia					51,222,641	106,584,177	123,398,365
Washington			47,184,107	95,360,634	122,594,498	136,043,749	151,040,586
West Virginia					26,944,015	63,855,091	76,331,660
Wisconsin							201,583,789
Wyoming					14,947,884	20,262,407	20,746,056
District of Columbia						24,286,384	44,479,898
Total	105,357,636	134,047,844	490,131,863	1,176,923,918	2,365,354,425	3,935,081,183	6,568,764,146

State	1926	1927	1928	1929	1930	1931
Alabama	127,932,538	149,620,507	162,438,774	178,162,903	172,537,281	162,670,816
Arizona	32,608,821	40,216,927	50,455,046	63,995,783	66,750,478	64,701,865
Arkansas	89,632,594	94,345,820	106,147,481	133,620,566	128,545,469	110,579,175
California	825,106,169	928,748,702	985,558,973	1,139,637,244	1,162,337,545	1,328,787,915
Colorado	104,587,460	122,493,107	130,707,467	141,466,891	153,620,645	156,358,455
Connecticut	134,468,607	152,745,302	173,437,589	202,354,590	233,296,627	236,399,661
Delaware	19,520,687	23,486,804	26,678,310	31,198,248	33,778,561	35,735,365
Florida	285,787,156	251,410,081	224,704,496	223,373,467	227,036,915	235,057,035
Georgia	161,518,296	192,103,248	206,137,161	219,609,473	223,184,648	221,891,668
Idaho	37,403,986	40,876,738	47,096,637	48,658,984	54,422,752	51,967,321
Illinois		309,975,466	[5] 41,841,273	[6] 388,659,266	915,747,319	968,856,165
Indiana	299,058,025	337,769,317	372,584,968	410,936,759	428,968,653	450,863,830
Iowa	242,121,370	288,619,674	284,520,934	311,859,516	352,802,277	364,252,984
Kansas	215,169,393	229,732,510	269,742,067	288,716,546	304,016,374	269,029,495
Kentucky	103,477,662	118,267,918	134,835,629	154,717,831	168,294,655	176,202,606
Louisiana	135,428,367	151,702,807	169,046,556	176,645,631	184,781,753	187,955,663
Maine	60,090,659	72,007,253	79,011,319	91,610,422	102,737,416	109,568,209
Maryland	114,692,672	118,335,211	135,646,826	157,429,197	174,779,706	185,775,062
Massachusetts				487,940,778	528,147,350	558,555,950
Michigan	504,088,814	561,144,507	611,161,335	710,300,302	722,462,626	727,744,907
Minnesota	240,234,382	258,743,986	288,404,998	338,631,771	345,303,709	369,005,304
Mississippi	105,887,426	119,342,686	136,334,223	140,902,401	135,823,574	115,640,338
Missouri	283,057,270	316,549,141	347,411,433	384,033,575	431,958,060	460,328,204
Montana	43,535,576	47,879,927	56,113,461	57,514,249	58,837,575	60,363,076
Nebraska	151,996,357	183,245,970	197,058,187	208,869,358	226,510,543	227,406,207
Nevada	10,145,454	11,790,615	13,279,660	16,307,535	16,875,292	19,447,944
New Hampshire	38,429,100	44,897,901	47,079,932	56,676,294	62,486,940	66,428,585
New Jersey		204,142,900	422,346,478	498,063,808	546,685,108	570,821,076
New Mexico	25,428,358	30,117,191	36,738,005	45,479,332	54,385,614	53,294,084

New York	----------	----------	----------	[7] 962, 601, 285	1, 438, 582, 716	1, 527, 203, 055
North Carolina	194, 661, 825	219, 667, 060	244, 675, 269	260, 210, 528	250, 669, 089	249, 609, 024
North Dakota	73, 689, 462	63, 778, 243	73, 973, 434	71, 591, 708	65, 643, 460	67, 674, 591
Ohio	662, 863, 296	752, 028, 064	829, 523, 293	910, 154, 885	927, 036, 272	983, 201, 323
Oklahoma	207, 080, 296	239, 931, 866	279, 996, 597	314, 388, 292	302, 310, 488	252, 483, 145
Oregon	118, 493, 937	122, 822, 563	144, 284, 704	152, 090, 900	154, 986, 497	155, 062, 787
Pennsylvania [3]	588, 379, 021	691, 562, 015	733, 268, 795	1, 047, 914, 175	928, 842, 534	1, 081, 755, 912
Rhode Island	51, 189, 641	56, 144, 687	59, 116, 396	77, 826, 879	86, 612, 980	94, 631, 763
South Carolina	89, 939, 352	101, 607, 700	110, 364, 802	118, 038, 130	119, 071, 835	120, 766, 492
South Dakota	64, 158, 589	65, 965, 089	78, 965, 809	88, 644, 138	87, 597, 064	84, 866, 877
Tennessee	128, 417, 453	149, 206, 016	171, 153, 333	194, 497, 225	214, 383, 900	206, 707, 098
Texas	522, 688, 578	594, 592, 077	681, 135, 373	761, 421, 692	738, 177, 457	762, 863, 942
Utah	35, 943, 117	41, 773, 659	47, 577, 166	56, 546, 967	60, 137, 811	60, 362, 698
Vermont	27, 654, 594	33, 167, 246	37, 311, 088	43, 990, 554	46, 998, 012	49, 163, 593
Virginia	135, 814, 061	158, 423, 951	174, 800, 793	197, 898, 821	215, 501, 157	228, 904, 309
Washington	174, 104, 636	191, 071, 925	210, 325, 734	233, 333, 570	241, 774, 964	244, 529, 589
West Virginia	83, 504, 998	99, 917, 717	107, 547, 068	121, 654, 788	133, 965, 701	134, 680, 421
Wisconsin	260, 490, 262	301, 355, 684	342, 837, 969	374, 251, 957	415, 742, 027	431, 504, 707
Wyoming	22, 743, 572	25, 884, 393	31, 810, 563	34, 242, 816	36, 175, 118	39, 675, 361
District of Columbia	50, 759, 671	57, 439, 721	63, 157, 367	71, 409, 032	79, 984, 431	86, 314, 800
Total	7, 883, 983, 560	9, 366, 651, 892	10, 178, 344, 771	13, 400, 180, 062	14, 751, 308, 978	15, 407, 650, 452

[3] Includes distillate taxed at a lower rate per gallon.
[5] Only January tax shown; law repealed in February.
[6] Tax assessed for last 5 months of year.
[7] Tax assessed for last 8 months of year.

TABLE 17.—*Gasoline tax rates by years, and dates of rate changes during calendar years* [1]

[As reported by State authorities]

State	Gasoline tax rate in cents per gallon during calendar years														Date when various gasoline tax rates became effective	
	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932 [2]	1 cent	2 cents
Alabama					0–2	2	2	2	2–4	4	4	4	4–5			Mar. 1, 1923
Arizona			0–1	1	1–3	3	3	3	3–4	4	4	4	4–5		June 9, 1921	
Arkansas			0–1	1	1–3	4	4	4	4–5	5	5	5	5–6		Apr. 1, 1921	
California					0–2	2	2	2	2–3	3	3	3	3			Sept. 30, 1923
Colorado	0–1	1	1	1	1–2	2	2	2	2–3	3	3–4	4	4		Apr. 9, 1919	July 30, 1923
Connecticut			0–1	1	1	1	1–2	2	2	2	2	2	2		Sept. 1, 1921	July 1, 1925
Delaware					0–1	2	2	2	2–3	3	3	3	3		Apr. 22, 1923	Jan. 1, 1924
Florida			0–1	1	1–3	3	3–4	4	4–5	5	5–6	6	6–7		June 20, 1921	
Georgia			0–1	1	1–3	3	3–3½	3½	3½–4	4	4–6	6	6		Aug. 10, 1921	
Idaho					0–2	2	2–3	3	3–4	4	4	4–5	5			Apr. 1, 1923
Illinois									0–2	2–0	0–3	3	3			[9] Aug. 1, 1927
Indiana					0–2	2	2–3	3	3	3	3–4	4	4			June 1, 1923
Iowa							0–2	2	2–3	3	3	3	3			Apr. 16, 1925
Kansas							0–2	2	2	2	2–3	3	3			May 1, 1925
Kentucky		0–1	1	1	1	1–3	3	5	5	5	5	5	5		June 21, 1920	
Louisiana			0–1	1	1	1–2	2	2	2	2	2–4	4–5	5		Dec. 9, 1921	Aug. 1, 1924
Maine [3]					0–1	1	1–3	3	3–4	4	4	4	4		July 7, 1923	
Maryland				0–1	1	2	2	2	2–4	4	4	4	4		June 1, 1922	Jan. 1, 1924
Massachusetts											2	2	2–3			Jan. 1, 1929
Michigan							0–2	2	2–3	3	3	3	3			Jan. 29, 1925
Minnesota							0–2	2	2	2	2–3	3	3			May 1, 1925
Mississippi				0–1	1	1–3	3	4	4	4–5	5	5	5–5½		Mar. 25, 1922	
Missouri							2	2	2	2	2	2	2			[11] Jan. 1, 1925
Montana			0–1	1	1–2	2	2	2	3	3	3–5	5	5		Mar. 5, 1921	Apr. 1, 1923
Nebraska							0–2	2	2	2	2–4	4	4			Apr. 1, 1925
Nevada					0–2	2	2–4	4	4	4	4	4	4			Mar. 20, 1923
New Hampshire					0–1	2	2	2	2–3	4	4	4	4		July 1, 1923	Jan. 1, 1924
New Jersey									0–2	2	2	2–3	3			July 1, 1927
New Mexico	0–2	2	2–1	1	1	1	1–3	3	3–5	5	5	5	5		[13] Mar. 12, 1921	[10] Mar. 17, 1919
New York											0–2	2	2	3		May 1, 1929
North Carolina			0–1	1	1–3	3	3–4	4	4	4	4–5	5	5–6		Mar. 3, 1921	
North Dakota	0–1	1	1	1	1	1	1	1–2	2	2	2–3	3	3		Mar. 6, 1919	July 31, 1926
Ohio							0–2	2	2–3	3	3–4	4	4			Apr. 18, 1925
Oklahoma					0–1	1–2½	2½–3	3	3	3	3–4	4	4–5	4	July 1, 1923	
Oregon [4]	0–1	1	1–2	2	2–3	3	3	3	3	3	3	4	4		Feb. 25, 1919	Mar. 1, 1921
Pennsylvania			0–1	1	1–2	2	2	2	2–3	3	3–4	4–3	3		Sept. 1, 1921	July 1, 1923
Rhode Island							0–1	1	1–2	2	2	2	2		May 30, 1925	June 1, 1927
South Carolina				0–2	2–3	3	3–5	5	5	5	5–6	6	6			Mar. 1, 1922

South Dakota				1	1–2	2	2–3	3	3–4	4	4	4	4		Jan. 1, 1922	July 1, 1923
Tennessee					0–2	2	2–3	3	3	3	3–5	5	5–6–7			Apr. 1, 1923
Texas					0–1	1	1	1	1–3	3–2	2–4	4	4		June 14, 1923	[15] Sept. 1, 1928
Utah					0–2½	2½	2½–3½	3½	3½	3½	3½	3½	3½–4			
Vermont					0–1	1	1–2	2	2–3	3	3–4	4	4		Apr. 1, 1923	Feb. 26, 1925
Virginia					0–3	3	3	3–4½	4½	4½–5	5	5	5			
Washington			0–1	1	1	2	2	2	2	2	2–3	3	3–5		July 1, 1921	Jan. 1, 1924
West Virginia					0–2	2	2–3½	3½	3½–4	4	4	4	4			July 27, 1923
Wisconsin							0–2	2	2	2	2	2	2–4			Apr. 1, 1925
Wyoming					0–1	1	1–2½	2½	2½–3	3	3–4	4	4		Apr. 1, 1923	
Dist. of Col						0–2	2	2	2	2	2	2	2			May 23, 1924
Av. rate [5]	0.97	1.02	1.10	1.08	1.63	2.04	2.26	2.38	2.76	3.00	3.22	3.35	3.48			
No. of States	4	5	15	19	35	[6] 35	[6] 44	[6] 44	[6] 46	[6] 46	[6] 48	[6] 48	[6] 48			

State	Date when various gasoline tax rates became effective								
	2½ cents	3 cents	3½ cents	4 cents	4½ cents	5 cents	5½ cents	6 cents	7 cents
Alabama				Jan. 25, 1927		July 28, 1931			
Arizona		June 9, 1923		Aug. 12, 1927		[7] Jan. 30, 1931			
Arkansas		Apr. 1, 1923		Jan. 1, 1924		June 9, 1927		Feb. 26, 1931	
California		July 29, 1927							
Colorado		May 1, 1927		May 1, 1929					
Connecticut									
Delaware		Mar. 24, 1927							
Florida		July 1, 1923		June 6, 1925		July 1, 1927		July 1, 1929	[8] Aug. 1, 1931
Georgia		Oct. 1, 1923	Aug. 26, 1925	Sept. 1, 1927				Sept. 1, 1929	
Idaho		Mar. 1, 1925		Mar. 1, 1927		Mar. 1, 1930			
Illinois		[9] Aug. 1, 1929							
Indiana		Apr. 1, 1925		Apr. 1, 1929					
Iowa		July 4, 1927							
Kansas		Apr. 1, 1929							
Kentucky		June 19, 1924				Feb. 21, 1926			
Louisiana				Jan. 4, 1929		Nov. 27, 1930			
Maine [3]		July 11, 1925		Oct. 29, 1927					

[1] For list of States grouped by tax rates as of Jan. 1 and July 1 of current year, see Table G–3a.
[2] The rates for current year are not entered in this column until end of year unless changed from last rate shown in previous year; otherwise rate remains same as in previous year.
[3] Referendum in September 1932 for 5 cent tax.
[4] A tax on distillate is imposed which is ½ cent less than gasoline tax in each instance.
[5] Weighted average used; net gallonage taxed divided into net tax earned.
[6] Not including the District of Columbia.
[7] 2-year emergency tax period ends Jan. 31, 1933, then tax rate to revert to 4 cents.
[8] 2-year emergency tax period ends Aug. 1, 1933, then tax rate to revert to 6 cents.
[9] Tax of 2 cents declared unconstitutional Feb. 25, 1928, and a new law passed in 1929 for 3-cent tax.
[10] 2-year emergency tax period ends Apr. 30, 1933, then tax rate to revert to 2 cents.
[11] By constitutional amendment of Nov. 6, 1928, tax to remain at 2 cents until Nov. 6, 1938.
[13] Tax reduced from 2 cents to 1 cent on Mar. 12, 1921.

TABLE 17.—*Gasoline tax rates by years, and dates of rate changes during calendar years*—Continued

State	Date when various gasoline tax rates became effective								
	2½ cents	3 cents	3½ cents	4 cents	4½ cents	5 cents	5½ cents	6 cents	7 cents
Maryland				Apr. 1, 1927					
Massachusetts		[10] May 1, 1931							
Michigan		Sept. 4, 1927							
Minnesota		May 1, 1929							
Mississippi		May 9, 1924		Apr. 1, 1926		Dec. 1, 1928	Nov. 1, 1931		
Missouri									
Montana		Jan. 1, 1927				[12] Apr. 1, 1929			
Nebraska				Mar. 29, 1929					
Nevada				Apr. 1, 1925					
New Hampshire		May 1, 1927		Jan. 1, 1928					
New Jersey		Dec. 1, 1930							
New Mexico		Mar. 17, 1925				Mar. 7, 1927			
New York		Mar. 1, 1932							
North Carolina		Apr. 1, 1923		Feb. 21, 1925		Apr. 1, 1929		Apr. 1, 1931	
North Dakota		[14] July 1, 1929							
Ohio		May 25, 1927		Apr. 17, 1929					
Oklahoma	Mar. 8, 1924	Mar. 23, 1925		[15] June 22, 1929		[15] Mar. 25, 1931			
Oregon [4]		May 24, 1923		Jan. 1, 1930					
Pennsylvania		[16] July 1, 1927–30		[16] July 1, 1929					
Rhode Island									
South Carolina		Mar. 23, 1923				Mar. 23, 1925		Mar. 16, 1929	
South Dakota		Mar. 10, 1925		July 1, 1927					
Tennessee		Feb. 9, 1925				Feb. 17, 1929		July 1, 1931	Dec. 19, 1931
Texas		[17] Mar. 16, 1927		[17] July 16, 1929					
Utah	Mar. 8, 1923		Apr. 1, 1925	May 12, 1931					
Vermont		June 1, 1927		Apr. 1, 1929					
Virginia		June 27, 1923			Mar. 11, 1926	Mar. 19, 1928			
Washington		July 1, 1929				Apr. 1, 1931			
West Virginia			July 1, 1925	July 1, 1927					
Wisconsin				Apr. 1, 1931					
Wyoming	Apr. 1, 1925	Mar. 1, 1927		Apr. 1, 1929					

[4] A tax on distillate is imposed which is ½ cents less than gasoline in each instance.
[10] 2-year emergency tax period ends Apr. 39, 1933, then tex rate to revert to 2 cents.
[12] Law extends 5-cent tax to Mar. 31, 1941, then tax rate to revert to 3 cents.
[14] Referendum petition prevented execution of 4-cent tax law.
[15] Tax of 5 cents for 9-months' emergency period then reverted to 4 cents on Jan. 1, 1932.
[16] Tax reduced from 4 cents to 3 cents on July 1, 1930, showing two dates under 3 cents.
[17] Tax reduced from 3 cents to 2 cents on Sept. 1, 1928, and later raised to 4 cents on July 16, 1929.

TABLE 18.—*Gasoline tax net earnings by years*

[As reported by State authorities]

State	1919	1920	1921	1922	1923	1924	1925
Alabama					$754,129	$1,738,661	$2,140,802
Arizona			$87,928	$174,606	422,673	730,846	855,951
Arkansas			104,289	218,205	1,149,555	2,283,491	2,950,360
California					3,018,366	13,413,542	14,956,789
Colorado	$294,573	$458,395	644,912	693,372	1,075,739	1,843,023	1,935,329
Connecticut			222,784	734,048	880,416	1,072,433	1,908,809
Delaware					105,233	317,925	349,950
Florida			279,955	635,661	1,846,217	3,769,867	7,657,713
Georgia			302,507	753,827	1,544,020	3,563,682	4,418,824
Idaho					396,487	545,347	895,443
Illinois							
Indiana					2,882,789	4,838,307	7,653,049
Iowa							3,505,115
Kansas							2,905,194
Kentucky		168,353	441,052	521,036	680,235	1,840,513	3,041,560
Louisiana			41,373	556,037	766,752	1,455,985	2,339,543
Maine					286,019	521,673	1,268,348
Maryland				395,546	737,896	1,641,994	2,003,632
Massachusetts							
Michigan							8,236,078
Minnesota							3,863,940
Mississippi				298,543	492,837	1,585,058	2,494,274
Missouri							4,159,115
Montana			173,168	247,907	579,764	612,067	789,070
Nebraska							2,193,802
Nevada					115,840	154,263	318,705
New Hampshire					182,748	614,226	707,072
New Jersey							
New Mexico	86,139	114,852	136,009	158,159	158,972	187,099	526,908
New York							
North Carolina			506,018	808,085	3,086,981	4,604,768	6,082,378
North Dakota	351,006	178,927	146,705	158,800	401,063	504,020	649,416
Ohio							9,009,950
Oklahoma					599,000	3,164,701	5,143,517
Oregon	290,796	443,375	988,247	1,147,556	1,892,013	2,570,654	2,909,095
Pennsylvania			835,323	3,111,670	5,254,836	9,089,540	10,501,547
Rhode Island							318,357
South Carolina				767,712	1,600,611	2,224,212	3,865,403
South Dakota				368,702	624,592	1,144,042	1,847,598
Tennessee					1,227,655	1,812,235	3,407,886
Texas					1,682,567	3,776,715	4,641,784
Utah					492,467	704,586	1,063,594
Vermont					176,883	232,966	502,272
Virginia					1,536,679	3,197,525	3,701,951
Washington			471,841	953,606	1,225,945	2,720,875	3,073,654
West Virginia					538,880	1,277,102	2,186,739
Wisconsin							4,031,676
Wyoming					149,479	202,624	456,297
District of Columbia						485,728	889,598
Total	1,022,514	1,363,902	5,382,111	12,703,078	38,566,338	80,442,295	148,358,087

TABLE 18.—*Gasoline tax net earnings by years*—Continued

State	1926	1927	1928	1929	1930	1931
Alabama	$2, 558, 651	$5, 908, 986	$6, 497, 551	$7, 105, 009	$6, 901, 491	$7, 197, 474
Arizona	978, 264	1, 388, 830	2, 018, 202	2, 559, 831	2, 670, 019	3, 204, 288
Arkansas	3, 585, 304	4, 338, 737	5, 382, 782	6, 681, 029	6, 427, 273	6, 448, 049
California	16, 502, 123	22, 467, 083	29, 566, 769	34, 192, 087	34, 870, 126	39, 863, 637
Colorado	2, 091, 749	3, 139, 594	3, 921, 224	5, 217, 479	6, 144, 826	6, 254, 338
Connecticut	2, 689, 372	3, 054, 906	3, 468, 752	4, 047, 092	4, 465, 933	4, 727, 993
Delaware	390, 414	662, 159	800, 349	935, 947	1, 013, 357	1, 072, 061
Florida	11, 431, 486	10, 980, 586	11, 235, 225	12, 203, 056	13, 622, 215	14, 986, 170
Georgia	5, 653, 140	7, 066, 109	8, 245, 486	10, 224, 108	13, 391, 079	13, 313, 500
Idaho	1, 122, 217	1, 571, 749	1, 883, 865	1, 945, 980	2, 668, 582	2, 598, 366
Illinois	----------	6, 199, 509	[1] 836, 826	[2] 11, 659, 778	27, 472, 420	29, 065, 685
Indiana	8, 971, 741	10, 133, 568	11, 177, 549	15, 610, 251	17, 158, 746	18, 034, 553
Iowa	4, 842, 427	7, 248, 214	8, 535, 628	9, 355, 785	10, 584, 068	10, 927, 589
Kansas	4, 303, 388	4, 594, 650	5, 394, 841	8, 171, 205	9, 120, 491	8, 070, 885
Kentucky	4, 935, 078	5, 913, 396	6, 741, 781	7, 742, 564	8, 414, 733	8, 810, 130
Louisiana	2, 708, 567	3, 034, 056	3, 380, 931	6, 978, 651	7, 546, 448	9, 397, 783
Maine	1, 823, 346	2, 288, 933	3, 192, 384	3, 708, 682	4, 109, 496	4, 382, 728
Maryland	2, 293, 854	4, 169, 397	5, 425, 873	6, 297, 168	6, 991, 188	7, 431, 002
Massachusetts	----------	----------	----------	9, 758, 816	10, 562, 947	15, 306, 376
Michigan	10, 081, 776	14, 260, 564	18, 334, 840	21, 309, 009	21, 673, 879	21, 832, 347
Minnesota	4, 804, 688	5, 174, 880	5, 768, 100	8, 892, 125	10, 359, 111	11, 070, 159
Mississippi	4, 088, 200	4, 890, 686	5, 564, 711	7, 045, 120	6, 791, 177	5, 882, 264
Missouri	5, 661, 145	6, 330, 983	6, 948, 229	7, 680, 672	8, 639, 161	9, 206, 564
Montana	870, 712	1, 436, 398	1, 683, 404	2, 802, 017	2, 941, 879	3, 018, 154
Nebraska	3, 039, 927	3, 664, 919	3, 941, 164	7, 799, 479	9, 060, 422	9, 096, 248
Nevada	405, 818	471, 624	531, 186	652, 301	675, 012	777, 918
New Hampshire	768, 582	1, 268, 907	1, 884, 175	2, 267, 052	2, 499, 478	2, 657, 143
New Jersey	----------	4, 082, 860	8, 446, 930	9, 961, 276	11, 342, 896	17, 124, 632
New Mexico	762, 851	1, 415, 690	1, 836, 900	2, 273, 966	2, 719, 281	2, 664, 704
New York	----------	----------	----------	[3] 19, 055, 174	28, 476, 290	30, 544, 061
North Carolina	7, 786, 473	8, 796, 682	9, 787, 011	12, 006, 384	12, 533, 454	14, 024, 303
North Dakota	988, 493	1, 275, 565	1, 478, 107	1, 799, 226	1, 969, 304	2, 030, 238
Ohio	13, 257, 266	19, 910, 481	24, 885, 699	34, 082, 188	37, 081, 451	39, 328, 053
Oklahoma	6, 212, 409	7, 197, 956	8, 147, 901	10, 841, 609	12, 092, 420	11, 665, 432
Oregon	3, 333, 829	3, 643, 191	4, 008, 259	4, 542, 602	6, 198, 777	6, 186, 918
Pennsylvania	11, 781, 782	17, 286, 333	21, 998, 064	35, 747, 314	33, 315, 729	32, 452, 677
Rhode Island	511, 896	915, 959	1, 182, 328	1, 542, 759	1, 732, 259	1, 892, 635
South Carolina	4, 496, 968	5, 080, 385	5, 518, 240	6, 866, 608	7, 144, 310	7, 245, 989
South Dakota	1, 924, 758	2, 393, 592	3, 158, 873	3, 545, 765	3, 503, 882	3, 394, 675
Tennessee	3, 852, 524	4, 476, 180	5, 134, 600	9, 290, 853	10, 719, 195	11, 461, 023
Texas	5, 226, 886	15, 650, 841	17, 945, 037	22, 317, 494	29, 527, 098	30, 514, 558
Utah	1, 258, 009	1, 461, 261	1, 664, 247	1, 979, 226	2, 104, 823	2, 309, 227
Vermont	553, 093	905, 244	1, 118, 882	1, 703, 091	1, 879, 921	1, 966, 544
Virginia	5, 855, 670	7, 139, 707	8, 616, 239	9, 894, 941	10, 775, 058	11, 445, 215
Washington	3, 482, 093	3, 821, 438	4, 206, 515	5, 943, 039	7, 253, 249	11, 032, 462
West Virginia	2, 922, 675	3, 794, 068	4, 301, 883	4, 866, 192	5, 358, 628	5, 387, 217
Wisconsin	5, 209, 805	6, 027, 114	6, 856, 759	7, 485, 039	8, 314, 841	15, 780, 181
Wyoming	568, 589	756, 049	954, 317	1, 296, 299	1, 447, 005	1, 587, 014
District of Columbia	1, 015, 193	1, 148, 794	1, 263, 148	1, 428, 181	1, 599, 689	1, 726, 296
Total	187, 603, 231	258, 838, 813	304, 871, 766	431, 311, 519	493, 865, 117	536, 397, 458

[1] Only January tax shown. [2] For last 5 months of year. [3] For last 8 months of year.

TABLE 19.—*State gasoline taxes, 1932—Tax earned on motor vehicle fuel, etc., refunds, disposition of fund, and gallons taxed, during full calendar year 1932*

[From reports and records of State authorities]

State	Gross tax assessed prior to deduction of refund	Exemption refund (deducted from gross tax)	Net tax earning on motor vehicle fuel [1]	Other receipts under tax law (licenses, etc.)	Grand total earning (tax and other receipts)
Alabama	$7,000,502		$7,000,502	$586	$7,001,088
Arizona	3,479,597	$579,376	2,900,221	699	2,900,920
Arkansas	5,709,727	544,751	5,164,976		5,164,976
California	40,124,804	3,995,950	36,128,854		36,128,854
Colorado	6,134,473	665,253	5,469,220		5,469,220
Connecticut	4,687,912	3,324	4,684,588	47,924	4,732,512
Delaware	1,145,986	55,836	1,090,150		1,090,150
Florida	14,508,777		14,508,777	22,930	14,531,707
Georgia	11,938,809		11,938,809		11,938,809
Idaho	2,539,950	262,223	2,277,727	9,568	2,287,295
Illinois	29,988,421	1,234,370	28,754,051		28,754,051
Indiana	17,938,367	1,198,806	16,739,561	43	16,739,604
Iowa	10,693,343	1,723,206	8,970,137		8,970,137
Kansas	10,204,096	2,783,601	7,420,495		7,420,495
Kentucky	8,202,889		8,202,889	3,216	8,206,105
Louisiana	8,300,840	118	8,300,722		8,300,722
Maine	4,397,400	190,698	4,206,702	[8] 47,674	4,254,376
Maryland	7,902,161	401,929	7,500,232		7,500,232
Massachusetts	16,805,808	286,530	16,519,278		16,519,278
Michigan	21,730,941	1,299,613	20,431,328	29,283	20,460,611
Minnesota	11,352,359	1,351,802	10,000,557		10,000,557
Mississippi	6,071,654	421,493	5,650,161	[12] 193,589	5,843,750
Missouri	9,183,199	233,506	8,949,693		8,949,693
Montana	3,421,504	731,348	2,690,156		2,690,156
Nebraska	7,893,113	83,648	7,809,465		7,809,465
Nevada	868,091	140,974	727,117		727,117
New Hampshire	2,710,386	71,545	2,638,841		2,638,841
New Jersey	20,963,688	4,346,263	16,617,425	[16] 57,246	16,674,671
New Mexico	2,362,264	170,011	2,192,253	18,249	2,210,502
New York	43,690,844	1,217,157	42,473,687	106,906	42,580,593
North Carolina	14,124,630	220,984	13,903,646	3,731	13,907,377
North Dakota	2,842,042	1,006,330	1,835,712	1,439	1,837,151
Ohio	36,123,658	1,854,479	34,269,179		34,269,179
Oklahoma	9,661,097		9,661,097	21,345	9,682,442
Oregon	6,315,052	723,877	5,591,175		5,591,175
Pennsylvania	30,289,915		30,289,915	511,000	30,800,915
Rhode Island	2,020,740	166,715	1,854,025	3,686	1,857,711
South Carolina	6,261,560	36,633	6,224,927		6,224,927
South Dakota	4,174,644	1,211,296	2,963,348		2,963,348
Tennessee	12,185,360		12,185,360		12,185,360
Texas	30,071,589	3,007,831	27,063,758		27,063,758
Utah	2,174,318	2,406	2,171,912	757	2,172,669
Vermont	1,874,648		1,874,648		1,874,648
Virginia	11,484,414	674,814	10,809,600		10,809,600
Washington	12,329,201	1,282,691	11,046,510		11,046,510
West Virginia	5,184,836	243,045	4,941,791	7,609	4,949,400
Wisconsin	16,346,591	1,398,171	14,948,420		14,948,420
Wyoming	1,418,145		1,418,145		1,418,145
District of Columbia	2,053,901	18,404	2,035,497	4,181	2,039,678
Total			513,047,239	1,091,661	514,138,900

[1] Net gasoline tax earned after deduction of refunds allowed by law.
[8] Includes receipts from 1-cent tax on gasoline not used in motor vehicles.
[12] Includes $117,817 receipts from special gasoline tax, levied in three counties for sea wall.
[16] Includes taxes on 411,404 gallons used by motor boats and taxed 2 cents (rebate of 1 cent on 3-cent tax).

TABLE 19.—*State gasoline taxes, 1932—Tax earned on motor vehicle fuel, etc., refunds, disposition of fund, and gallons taxed, during full calendar year 1932*—Continued

State	Tax rate, 1932			Gasoline or other fuel for motor vehicles taxed	
	Cents per gallon		Date or rate change	Net gallons taxed	Percent change [27]
	Jan. 1	Dec. 31			
Alabama	5	6	Nov. 5	136, 421, 624	−16. 1
Arizona	5	5		58, 004, 441	−10. 4
Arkansas	6	6		86, 082, 940	−22. 2
California	3	3		1, 204, 295, 149	−9. 4
Colorado	4	4		136, 730, 489	−12. 6
Connecticut	2	2		234, 229, 379	−0. 9
Delaware	3	3		36, 338, 331	1. 7
Florida	7	7		207, 268, 239	−11. 8
Georgia	6	6		198, 980, 154	−10. 3
Idaho	5	5		45, 554, 550	−12. 3
Illinois	3	3		958, 468, 356	−1. 1
Indiana	4	4		418, 489, 040	−7. 2
Iowa	3	3		299, 004, 568	−17. 9
Kansas	3	3		247, 349, 852	−8. 1
Kentucky	5	5		164, 057, 785	−6. 9
Louisiana	5	5		166, 014, 436	−11. 7
Maine	4	4		105, 167, 540	−4. 0
Maryland	4	4		187, 505, 794	. 9
Massachusetts	3	3		550, 642, 607	−1. 4
Michigan	3	3		681, 044, 263	−6. 4
Minnesota	3	3		333, 351, 913	−9. 7
Mississippi	5½	6	June 1	96, 732, 445	−16. 4
Missouri	2	2		447, 484, 670	−2. 8
Montana	5	5		53, 803, 120	−10. 9
Nebraska	4	4		195, 236, 623	−14. 1
Nevada	4	4		18, 177, 920	−6. 5
New Hampshire	4	4		65, 971, 040	−. 7
New Jersey	3	3		553, 914, 175	−3. 0
New Mexico	5	5		43, 845, 055	−17. 7
New York	2	3	March 1	1, 485, 127, 929	−2. 8
North Carolina	6	6		231, 727, 434	−7. 2
North Dakota	3	3		61, 190, 398	−9. 6
Ohio	4	4		856, 729, 484	−12. 9
Oklahoma	4	4	[48] Jan. 1	241, 527, 434	−4. 3
Oregon	4	4		[50] 140, 066, 134	−9. 7
Pennsylvania	3	3		1, 009, 663, 827	−6. 7
Rhode Island	2	2		92, 701, 236	−2. 0
South Carolina	6	6		103, 748, 781	−14. 1
South Dakota	4	4		74, 083, 694	−12. 7
Tennessee	7	7		174, 076, 575	−15. 8
Texas	4	4		676, 593, 941	−11. 3
Utah	4	4		54, 297, 788	−10. 0
Vermont	4	4		46, 866, 212	−4. 7
Virginia	5	5		216, 191, 996	−5. 6
Washington	5	5		220, 930, 195	−9. 7
West Virginia	4	4		123, 544, 775	−8. 3
Wisconsin	4	4		373, 710, 495	−13. 4
Wyoming	4	4		35, 453, 612	−10. 6
District of Columbia	2	2		101, 774, 858	17. 9
Total	([56])	([56])		14, 250, 173, 296	−7. 5

[48] Changed from 5-cent tax of previous year.
[50] Includes approximately 2,294,022 gallons of "distillate" at 3½-cent tax.
[56] Weighted average rate, 3.60 cents.

Table 20.—*Consumption of gasoline and production of corn in the United States, 1922 to 1932, inclusive*

[Bureau of Agricultural Engineering]

Year	Gasoline consumption in the United States				Corn production in the United States [5]	Ratio of bushels of corn to gallons of gasoline used [6]
	As reported by refineries			Gasoline taxed as indicated by State tax returns [4]		
	Gross [1]	Gross [2]	Used by motor vehicles [3]			
	Thous. bbl.	*Thous. gal.*	*Thous. gal.*	*Thous. gal.*	*Thous. bu.*	
1922	129,388	5,434,296	4,890,866	[7] 1,176,924	2,906,020	1 to 1.87
1923	158,720	6,666,240	5,999,616	[8] 2,365,354	3,053,557	1 to 2.18
1924	187,022	7,854,924	7,069,432	[9] 3,935,081	2,309,414	1 to 3.40
1925	226,329	9,505,818	8,555,236	[10] 6,568,764	2,916,106	1 to 3.26
1926	264,391	11,104,422	9,993,980	[10] 7,883,984	2,691,531	1 to 4.12
1927	299,818	12,592,356	11,333,120	[11] 9,366,652	2,763,093	1 to 4.56
1928	332,033	13,945,386	12,550,847	[12] 10,178,345	2,818,901	1 to 4.95
1929	375,999	15,791,958	14,212,762	[13] 13,400,180	2,535,386	1 to 6.23
1930	394,800	16,581,600	14,923,440	14,751,309	2,060,185	1 to 7.16
1931	403,418	16,943,556	15,249,200	15,407,650	2,567,306	1 to 6.00
1932	373,770	15,698,340	14,126,506		2,908,045	1 to 4.90

[1] Production in United States plus imports minus exports, Bureau of Mines, U.S. Department of Commerce.
[2] 42 gallons per barrel.
[3] Estimated that 90 percent of gasoline used in motor vehicles.
[4] As reported by Bureau of Public Roads, U.S. Department of Agriculture.
[5] As reported by Bureau of Agricultural Economics, U.S. Department of Agriculture.
[6] Ratio based on Bureau of Mines figures, 1922 to 1929, inclusive, and on Bureau of Public Roads figures, 1930 to 1932, inclusive.
[7] No tax returns from California, Delaware, Idaho, Illinois, Indiana, Iowa, Kansas, Maine, Mississippi, Michigan, Minnesota, Missouri, Nebraska, Nevada, New Hampshire, New Jersey, New York, Ohio, Rhode Island, Tennessee, Texas, Utah, Vermont, Virginia, West Virginia, Wisconsin, Wyoming, and District of Columbia.
[8] No tax returns from Illinois, Iowa, Kansas, Massachusetts, Michigan, Minnesota, Missouri, Nebraska, New Jersey, New York, Ohio, Rhode Island, Wisconsin, and District of Columbia.
[9] No tax returns from Illinois, Iowa, Kansas, Massachusetts, Michigan, Minnesota, Missouri, Nebraska, New Jersey, New York, Ohio, Rhode Island, and Wisconsin.
[10] No tax returns from Illinois, Massachusetts, New Jersey, and New York.
[11] No tax returns from Massachusetts and New York.
[12] No tax returns from (January tax only for Illinois) Massachusetts and New York.
[13] Tax for last 5 months of year for Illinois, and last 8 months of year for New York.

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