October 1982

SERI/SP-451-442

Ethanol Fuels
Reference Guide

a decision-maker's guide to ethanol fuels

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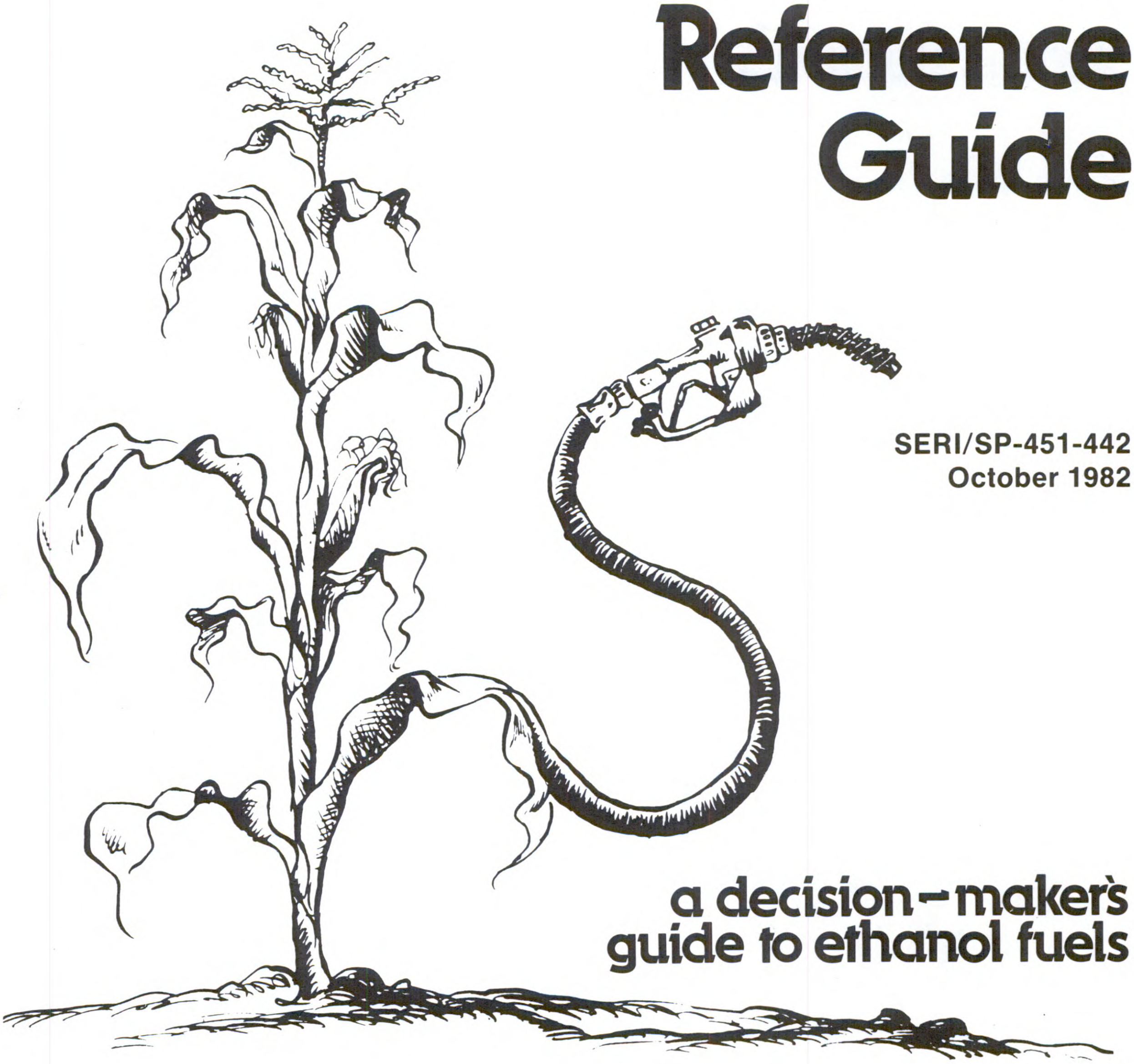

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Published by
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Solar Energy Research Institute, 1617 Cole Boulevard, Golden, Colorado 80401
A Division of Midwest Research Institute
Operated for the U.S. Department of Energy

Preface

The *Ethanol Fuels Reference Guide* is a compendium of information compiled, produced and disseminated by the National Alcohol Fuels Information Center during its operation in 1980 and 1981.

The Center was funded by the Department of Energy Office of Alcohol Fuels and managed by the Congressionally-mandated Solar Energy Information Data Bank. Its purpose was to support the nationwide interest in alcohol fuels by providing business, industry and the public with information about the use and production of this home-grown source of renewable energy and liquid fuel alternative.

Because this information remains timely and is of interest to those currently involved in or considering the production and use of ethanol fuels it has been combined within a single volume as the *Ethanol Fuels Reference Guide*. The *Guide* is being published by the SERI Technical Information Branch which operates as an arm of the DOE Solar Information Program.

After reviewing the material presented in this compendium, the U.S. Department of Agriculture considers it of value to their current and continuing information efforts. They are cooperating in the publication of the *Guide* for the purpose of distributing it through the National Agricultural Library.

The true value of this publication may only be realized when and if the nation again sees need to seriously consider the large-scale development and use of its alcohol fuel resources. Until such time, it serves as a fitting and useful repository of information made possible by a successful national information effort.

Acknowledgments

The *Ethanol Fuels Reference Guide* represents countless hours of cooperative effort by: Professionals in the various disciplines that make up the collective ethanol fuels body of expertise; information and communication specialists; and administrators of both government and private programs and agencies involved in the areas of renewable energy and ethanol fuels.

The editors gratefully acknowledge the time and effort contributed by the following individuals in providing data and reviewing draft manuscripts for various segments of this document.

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No information reaches its intended audience without significant contributions of creative talent, and informational, managerial and communicational skills. The following people and firms were responsible for providing these: *Anderson Advertising Art*, Shelley Lu Arrowsmith, Tony Baer, Maureen Baker, Betsy Baxendale, Gary Cook, Ray David, *Energy Communication Associates*, *Energy Media Corporation*, *Grant Heilman Photography*, Connie Knapp, Charity McDonald, Jim Miller, Joan Miller, Denise Munn, Paul Notari, Dick Piekarski, Amy Pinkerton, Nancy Reece, Steve Rubin, Susan Sczepanski, Marilyn Shartran, *TRW Incorporated*, Mike Wood, Joe Woodburn, and Ken Zweibel.

Finally, there are those associates known only to the above whose support, inspiration and contributions have indirectly made these efforts possible and worthwhile. Although they remain unknown to the reader their contributions are nonetheless appreciated.

Table of Contents

Introduction

By way of introduction to the topic of ethanol fuels, the brochure, **Facts About Ethanol** *is reprinted here in its entirety. This publication was prepared by the SERI Technical Information Branch for the U.S. Department of Agriculture National Agricultural Library.*

Alcohol fuels have recently attracted attention because of their potential as a petroleum fuel substitute. In 1979, the Solar Energy Research Institute (SERI) published "Facts About Gasohol," a brochure containing general information about gasohol's production potential and performance as a motor fuel.

Since that time, much has changed on the alcohol fuels scene: As international oil price increases have slowed, sales of gasohol (10% anhydrous ethanol, and 90% unleaded gasoline) have crested and then dropped.

More attention is now being given to ethanol as a petroleum extender and octane enhancer rather than as a replacement for petroleum. Major gasoline producers are selling premium unleaded gasoline with 10% ethanol additions. This edition of "Facts About Ethanol" provides an update on alcohol fuels, covering these and other developments.

Alcohol Production

Alcohols are a group of organic compounds with the general formula $C_nH_{2n+1}OH$. One member of the group is *ethanol* (ethyl alcohol), obtained from the fermentation of sugars or starches. It is commonly known as grain alcohol. Ethanol is the alcohol most mentioned in the context of motor fuel use, and is the specific component that is blended with unleaded gasoline to produce gasohol.

Methanol, or wood alcohol, can be made by gas synthesis from farm wastes, wood, or coal. Methanol and other alcohols are not commonly used as motor fuels at this time, although — with advanced production techniques — they have the potential to become the fuels of tomorrow. However, this edition is limited to covering ethanol used as a gasoline extender, because such blends are currently available throughout the United States.

Ethanol Production. Fermentation is a microbiological process in which microorganisms — such as yeasts — convert simple sugars to ethanol and carbon dioxide. Some plants are made of simple sugars, while others contain starch or cellulose that can be converted to sugars through cooking or enzymatic processes. In ethanol fermentation, a feedstock is reduced to a mash of simple sugar, to which yeasts are added in order to begin the microbiological process. The mash is kept warm to accelerate the biological action. This yields a beer, which must then be distilled to obtain fuel-grade ethanol.

Grains, sugar crops, potatoes and other starchy plants are commonly used for ethanol production. One bushel of corn (56 pounds) can yield 2.6 gallons of 200-proof (100%) anhydrous ethanol under well-managed conditions. (Potential yields from other feedstocks are shown in the chart.) In addition, 17 pounds of distiller's dried grains (DDG) and solubles will be produced as a coproduct. Carbon dioxide and fusel oils are other coproducts, all of which enjoy potential market value.

Many factors will determine the percentage yield in small-scale ethanol production. SERI has produced two guidebooks to assist producers in obtaining maximum yields through carefully managed processing and fermentation. *Fermentation Guide for Common Grains* specifies optimum procedures for use with corn, wheat, barley, or milo feedstocks. A companion volume, *Fermentation Guide for Potatoes* identifies specific procedures for the potato-to-ethanol producer. Both publications are now available from the U.S. Government Printing Office (complete ordering information for these and other SERI publications are provided on page 7 of this brochure).

Potential Ethanol Yields of Crops Under Well Managed Conditions

Feedstock	*Maximum Ethanol Yield (Wet)*	
Barley	79.2	gal/ton
Cheese Whey	2.43	gal/100 gal
Corn	85	gal/ton
Jerusalem Artichokes	20	gal/ton
Molasses	68-70	gal/ton
Potatoes	22.9	gal/ton
Rice, rough	79.5	gal/ton
Rye	78.8	gal/ton
Sorghum, grain	79.5	gal/ton
Sorghum, sweet	10.5	gal/ton
Sugar Cane	15.2	gal/ton
Wheat	85	gal/ton

Distiller's Dried Grains (DDG). DDG is a coproduct from any grain/alcohol fermentation. This material, containing all of the digestible protein yield of the original feedstock, is a proven livestock feed. Different feedstocks yield different amounts of DDG depending on the protein content of the original crop.

Alcohol as Motor Fuel

The use of ethanol or other alcohols as fuel for internal combustion engines is not a new concept. Henry Ford originally offered automobiles capable of operating on either ethanol or gasoline. With the development of economical petroleum extraction and refining early in this century, gasoline became the more practical fuel and further development of fuel-grade ethanol was shelved. However, alcohol fuels have commonly been used in auto racing because of certain performance characteristics that are superior to gasoline.

Currently, the petroleum "glut" of the early 80's has reduced interest in alternate vehicular fuels. However, because of American experiences with oil shortages within recent years, it is anticipated that the nation will look at alcohol to displace some petroleum-based fuels and chemicals in the future.

Ethanol can be burned directly in modified auto engines, or it can be used as a blend with gasoline — often without engine modification. Many piston-driven engines have been modified to burn straight ethanol after minor adjustments to the carburetor and replacement of certain fuel-line parts. The Solar Energy Research Institute is now studying a novel system that dissociates alcohol into hydrogen and carbon monoxide before combustion. This process has proven to be much more efficient than direct combustion of ethanol or methanol.

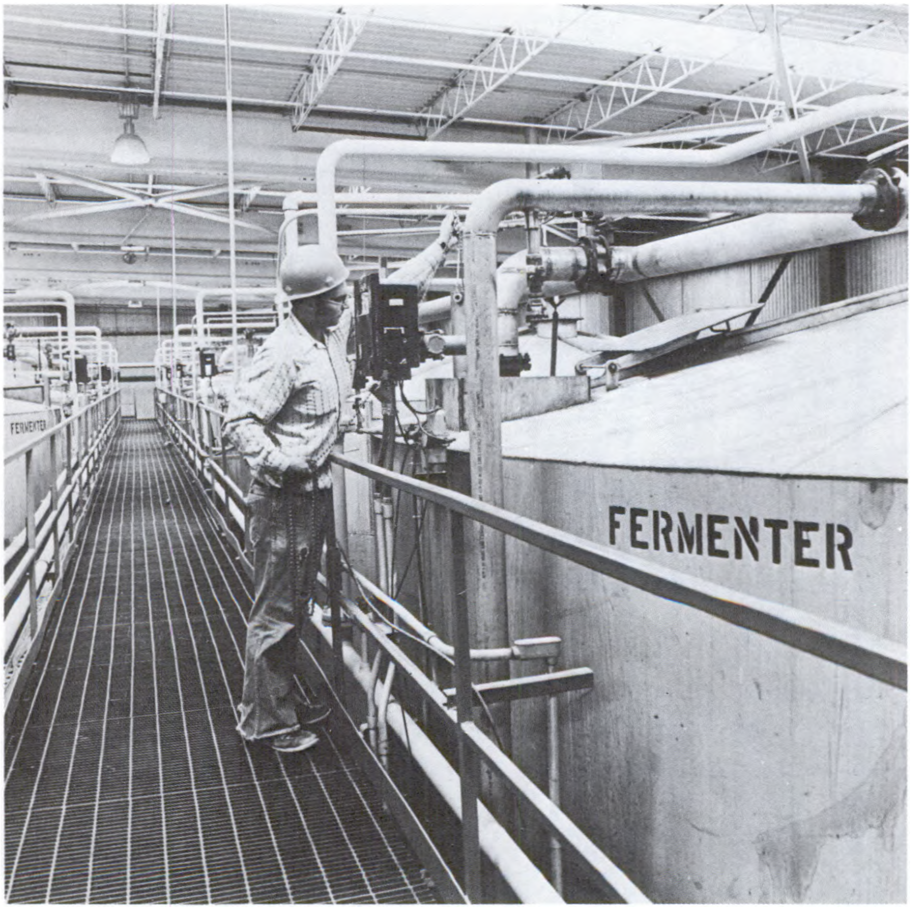
Alcohol/Gasoline Blends. Various alcohol/gasoline blends have been evaluated and are in current use today. Blends using more than 25% alcohol are commonly used in Brazil; they require modification to engine parts for proper performance.

Many American retail dealers offer gasohol (a 10% ethanol blend) as acceptable fuel for most spark-ignition engine autos without engine modification. Recently, many gasoline suppliers have begun marketing blends in which a smaller percentage of ethanol is combined with low-lead or unleaded gasolines to enhance octane rating while maintaining acceptable emissions levels.

Gasohol, one of these blends, contains 10% anhydrous* ethanol and 90% unleaded gasoline. Existing autos can run on gasohol without engine modifications and with little or no discernible loss of performance.

According to the U.S. Department of Transportation, more than 493 million gallons of gasohol were sold in 32 states during 1980. Figures for 1981 are not yet available as of this printing; however, there are clear indications that sales have dropped in several areas of the country, owing largely to increased availability of gasoline and high gasohol prices. However, many retailers are now marketing ethanol as an enhancer in high-octane unleaded fuels rather than as gasohol, and this may significantly contribute to higher overall sales volumes in the future.

Ethanol as a Diesel Fuel. The minimum practical cetane rating for diesel engines is about 30, while the cetane rating of ethanol is 6.** Because the auto-ignition temperature of ethanol is high when compared to that of a good diesel fuel, it is not practical to use it as a straight fuel in a diesel engine. It is difficult to make stable blends of ethanol and diesel fuel because their liquid characteristics are substantially different.



However, there are methods to permit use of ethanol in diesel engines. They include ethanol carburation at the air intake, dual-fuel injection, on-board mixing, use of cetane boosters blended with ethanol, and spark assist. Keep in mind, however, that use of these devices may void engine warranties.

Performance

Drivers of automobiles using gasohol and other alcohol/gasoline blends have reported varying performance results. These range from increased performance, to no noticeable difference or decreased performance. Because the alcohol molecule contains oxygen, it needs less air to burn. This, together with alcohol's higher octane rating, gives it an advantage as a motor fuel and accounts for favorable performance reports (such as improved mileage per gallon of blend).

However, gallon-for-gallon, ethanol has a significantly lower heat content than gasoline, thereby lessening or canceling some of its inherent advantages as a motor fuel. Some of the major aspects of ethanol/gasoline blend performance are summarized here:

Engine: Engine modifications are not required for 10/90 ethanol/gasoline blends. However, blends using greater percentages of ethanol may require modification of the carburetor and fuel-line parts.

Corrosion: Alcohol may corrode some gas-line component materials. However, there have been no reported cases of corrosion in vehicles using fuel blends containing 10% or less of alcohol.

Vapor Pressure: Alcohol/gasoline blends have been identified

**Anhydrous* means that there is no water present.

**The *cetane rating* is a comparative ranking of the auto-ignition properties of diesel fuels against a value arbitrarily assigned to cetane, a good diesel fuel.

Federal Regulations

The design, construction, and operation of alcohol fuel plants requires attention from federal, state, and local authorities in order to ensure maintenance of the public good. Public Law 96-223 simplified federal regulations for plants that produce fuel alcohol. The Department of the Treasury is now directed to expedite all applications, establish a minimum bond, and generally encourage and promote the production of alcohol for fuel purposes. Production plants must qualify to operate under existing provisions of the law. There are severe penalties for failing to comply with regulations that are currently enforced by the Treasury Department's Bureau of Alcohol, Tobacco, and Firearms (BATF). The Bureau has a fact sheet, *Alcohol Fuel Plants* (publication number 5000.4-1), which outlines these regulations. You can obtain it free of charge from the Public Affairs Office, Bureau of Alcohol, Tobacco, and Firearms, Washington, DC 20226.

with vapor lock in some hot-weather situations. This problem seems more commonly associated with methanol/gasoline blends than with ethanol blends. Some state laws set limits on the allowable vapor pressure of gasoline; because alcohol does increase vapor pressure, the alcohol percentage may need to be limited to achieve compliance.

Fuel Filter: In older cars which have accumulated residue in their fuel systems, the detergent action of alcohol in gasoline may release the residues and clog the fuel filter after the first few tankfuls. Replacement of the fuel filter will solve this problem.

Age of Car: A significant performance difference between old and late model autos with ethanol fuels occurs due to the use of closed-loop feedback systems in the exhaust and fuel-induction systems of recent models. In essence, these new systems use an exhaust oxygen sensor which permits the carburetor to maintain an optimal air/fuel mixture for efficient operation. Such a system is able

to accommodate the differences between unleaded gasoline and alcohol/gasoline blends without the adjustments that may be required on older models.

Mileage: Mileage performance with alcohol blends could be less than that for gasoline, especially in most new cars. For many older cars with less-efficient carburetor systems, use of gasohol and other 10/90 blends may actually improve mileage performance by as much as 5%. This is because older carburetors are often not equipped to burn gasoline at the most favorable fuel/air ratio; however, alcohol blends tend to correct this problem.

Emissions: Studies by the Environmental Protection Agency in 1978 concluded that, when compared with the emissions of gasoline-powered vehicles, alcohol blends:

- Increase evaporative emissions about 50%
- Increase nitrogen oxide emissions about 7%
- Decrease exhaust hydrocarbons about 9%
- Decrease carbon monoxide about 35%

Cars using emission control catalytic converters in good working order usually have acceptable emission performance regardless of which fuel is used; therefore, alcohol blends may not significantly reduce emissions for these vehicles. Vehicles using alcohol fuel blends will emit greater amounts of aldehydes (a combustion by-product), substances that are photochemically reactive. There may be slight adverse environmental effects from this increase; however, this condition is not currently preceived as serious.

High Altitude Performance: Some users of alcohol blends have reported superior performance compared with gasoline operation during high-altitude driving. This is possibly a favorable consequence of alcohol's lesser need for oxygen to burn completely.

More Performance Information: Valuable data on alcohol blend performance has been collected by those organizations using gasohol and other blends as fuels for vehicular fleets. SERI has compiled information from 26 fleet tests in a new publication, *Alcohol-Gasoline Blends as Vehicular Fuels.* This volume is also available from the Government Printing Office (see page 7 for ordering information).

Issues Facing Alcohol Fuel Development

Alcohol fuels that are used for transportation carry a number of advantages, among them:

- They are produced from biomass, a renewable resource.
- Surplus or spoiled crops can be used to produce alcohol fuel, thereby creating a new agricultural market.
- Alcohol fuels can be made from domestic sources, consequently reducing our reliance on imported oil.
- Technical barriers to fermenting alcohol should prove minor since the technology is already proven.

However, concerns have been raised about producing alcohol fuels to extend or replace petroleum on a national basis. Fears have been voiced that alcohol fuel production will displace food production, forcing up food prices and curtailing surplus crop exports. It is also feared that producing alcohol will drain, rather than supplement conventional fuel reserves. Finally, many fear that ethanol fuel will never be competitive in cost with its conventional counterparts, and that current production incentives will be eliminated. These concerns are discussed here.

Fuel vs. Food Production: Alcohol and food production are *not* mutually exclusive. Based on 1977-78 figures, the U.S. can generate enough *surplus* grain production to provide 8.5 billion gallons of ethanol yearly, equivalent to 8% of total gasoline use at present consumption levels. This level can be achieved *without* disrupting the production of any major food crop.

In fact, most of the food value of the original feedstock is not destroyed by producing alcohol, because DDG (which contains all the protein of the original feedstock) can be produced as a by-product of alcohol fermentation. This protein is reinvested in food production whenever DDG is used as a livestock feed.

Ethanol can also be produced from agricultural feedstocks which do not influence national food production, such as excess, crops, distressed or marginal crops, spoiled vegetable or fruit, and food processing wastes.

Liquid Fuel Gain with Ethanol: It takes energy to convert biomass to ethanol. The energy needed to ferment and distill grain, combined with the energy required to grow and harvest it, can be greater than the energy contained in the ethanol that is produced. However, by designing an efficient ethanol plant that uses minimal fuel in the production process, substantially more liquid fuel will be produced than consumed.

The Price of Ethanol: Due to rapidly fluctuating feedstock prices, it is difficult to predict the market price of ethanol. A 1980 U.S. Department of Agriculture study suggests that, based on corn prices of $2.00 per bushel, ethanol production from corn would cost about $1.75/gallon.

Alcohol fuels are exempt from the 4¢/gallon federal tax on motor fuels. This amounts to an effective subsidy of 40¢/gallon of ethanol for the 10% ethanol component in gasohol. Many states have enacted similar legislation to lower the selling price of ethanol fuel and stimulate consumer demand.

However, even with these subsidies, the price of ethanol blends at the pump is usually higher than the price of competing gasoline fuels. And, most of the state subsidies expire in the mid-1980's. At present there is a significant gap between ethanol and gasoline prices that must be overcome in order for ethanol to become competitive.

Summary

Much has changed in the alcohol fuels market in the last few years. International petroleum prices have slowed their rise, and gasohol sales have dipped. However, ethanol can increase the octane and serve as a valuable extender of petroleum fuels, offering good promise as a new market for spoiled and surplus crops.

For More Information

Facts About Ethanol is an update of the 1979 SERI publication, *Facts About Gasohol.* This new edition briefly presents some of the major factors involved in producing ethanol, along with its use as a fuel extender and octane enhancer.

SERI has published a variety of books that cover these and other ethanol issues in detail. These publications (listed below) may be obtained from: Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. When ordering, please make a check or money order payable to the "Superintendent of Documents," and be sure to specify the title and GPO stock number. The prices listed below are subject to change.

- *Fuel From Farms: A Guide to Small-Scale Ethanol Production* provides a comprehensive guide for farm-based ethanol production. Describes fermentation procedures and offers worksheets and guidelines to help the reader evaluate the feasibility of farm-based production. Appendices provide feedstock data, equipment information, manufacturer and supplier lists, application requirements and regulations enforced by BATF, glossary, bibliography, and more. Price $5.00. GPO Stock #061-000-00372-0.

- *A Guide to Commercial-Scale Ethanol Production and Financing* thoroughly examines the factors involved in setting up a large-scale production operation. Discusses large-scale fermentation technology and offers guidelines and criteria for potential investors and operators. With detailed appendices. Price $8.50. GPO Stock #061-000-00472-6.
- *Fermentation Guide for Common Grains* describes optimum procedures for manufacturing ethanol from corn, wheat, barley, or milo feedstocks. Price $3.00. GPO Stock #061-000-00553-6.
- *Fermentation Guide for Potatoes* outlines recommended procedures when using potatoes as the feedstock. Price $3.00. GPO Stock #061-000-00560-9.
- *Alcohol-Gasoline Blends as Vehicular Fuels* describes the results of 26 fleet tests using alcohol fuels. Price $3.95. GPO Stock #061-000-00558-7.

The Bureau of Alcohol, Tobacco, and firearms has compiled the fact sheet, *Alcohol Fuel Plants*, outlining current regulations. Write: Public Affairs Office, Bureau of Alcohol, Tobacco and Firearms, Washington, D.C. 20226. (BATF Publication #5000.4-1. Copies free.)

Additional copies of *Facts About Ethanol* may be obtained from:

U.S. Department of Agriculture
National Agricultural Library
Room 111
Beltsville, MD 20725
(Free while supply lasts)

Superintendent of Documents
U.S. Government Printing Office
Washington, D.C. 20402
(Inquire for price)

The following organizations can provide additional information on producing alcohol fuels:

- Land Grant Colleges of the United States
- College & University Energy Information Centers
- State Energy Offices
- State Gasohol Commissions
- Federal/State Cooperative Extension Services
- County Extension Agents

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Gasohol: Answers to the Basic Questions

Introduction

The "energy crisis" has become so protracted that it is an accepted fact of life. As shortages, real or contrived, have arisen, various assumptions about energy resources and use have been made that are not based on fact. We are not running out of energy. What we are running out of are inexpensive fuels that are easily convertible to other more useful forms of energy. Up until now, fossil fuels have provided most of the world's energy. In a practical sense, these resources are nonrenewable (our consumption rate greatly exceeds the natural production rate). When the world actually will run out of such fuels is difficult to predict: experts have widely divergent opinions on the date.

The fact that nonrenewable energy resources are being depleted implies two choices: long-term drastic reductions in energy consumption (comparable to the levels used in the preindustrial era) or development of renewable fuels. In the meantime, politics and economics affect access to much of the remaining fossil fuels.

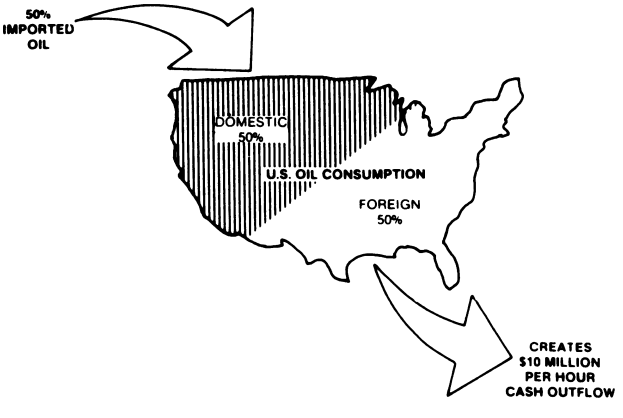

Figure I-1.1 Impact of Foreign Oil Consumption

Ironically, since the beginning of Project Energy Independence in 1973 the United States has increased its petroleum imports. From a pre–1973 import quota of less than 30%, the United States has increased petroleum imports to more than 40% of total consumption (U.S. Bureau of Mines, 1978). Of these imports, more than 40% has been directly converted to gasoline and about 15% to diesel fuel (Society of Automotive Engineers, 1979). Most imported petroleum is used for vehicular transportation.

U.S. attempts to achieve energy independence have taken various forms with limited success. One lesson learned has been that no single energy resource can alleviate the energy crisis. Various resources and technologies must be considered and adapted for use where appropriate. Alternative liquid fuels or significant liquid-fuel extenders provide part of the solution for immediate and long-term domestic energy needs. However, it is important to undertand that any effort to convert one fuel form to another results in a net loss of available energy.

With the minor exceptions of geothermal and nuclear power, all of our energy resources, including the conventional ones, are derived directly or indirectly from the sun. Since photosynthesis by plants captures and stores solar energy less expensively on a large scale than any of the devices humans have contrived, it is reasonable to conclude that the largest potential for production of renewable fuels centers on the conversion of plants, or biomass, to fuel.

Alcohol fuels produced from domestically available renewable resources can extend the amount of fuel produced from imported, nonrenewable crude oil. Ethanol blended with gasoline not only directly replaces the gasoline made from imported crude oil

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on a gallon-by-gallon basis, but it also can be used to enhance the octane of low-octane gasoline. Previously, lead compounds were the principal octane enhancer for gasoline, but these have been proven to damage human health, and the Environmental Protection Agency has set a timetable for the removal of these lead compounds from gasoline. Without another octane enhancer, refineries need to spend more energy and consume more crude oil to produce a high-octane gasoline. By using ethanol to increase octane ratings, refinery energy costs can be reduced by 6% per gallon of production (U.S. Department of Energy, 1979).

Fermentation ethanol is produced by a technology that is neither new nor esoteric. Fermentation-ethanol production has a long history and does not require complex technologies or expensive and difficult-to-obtain equipment. Therefore, it would be feasible to establish a nationwide production system in a short period of time.

In the United States in the mid–1800s, ethanol replaced whale oil in lamps because it was clean and odorless. In the early days of automobile production, ethanol was used as a motor vehicle fuel but was later replaced by gasoline, which was cheaper at that time. Today ethanol is used as a fuel for race cars because it provides excellent engine performance.

During the Depression, a blend of ethanol and gasoline was marketed in the Midwest under the name "Agrol." During World War II, ethanol was used in U.S. synthetic rubber manufacturing, to fuel torpedoes and submarines, and as an additive in jet-fighter fuels. In 1944, the United States was producing close to 600 million gallons of ethanol—more than the Department of Energy's current target for the end of 1980.

After the war, interest in ethanol declined, and little was done about using ethanol blended with gasoline until 1971. At that time, the combination of rising fuel prices and the need for new markets for agricultural products prompted the State of Nebraska to pass legislation reducing their gasoline tax for gasohol (10% ethanol, 90% gasoline). Since the oil embargo in 1973 and the continual rising price of crude oil, other states, institutions, and government agencies have explored various aspects of developing alcohol fuels, particularly gasohol.

Recent interest in gasohol and other alcohol fuels has led to public- and private-sector experimentation, contributing to the improvement of the production process, particularly in the areas of efficiency, cost, and energy use.

The use of ethanol-fuel blends appears to reduce the expensive and deleterious effects of auto emissions in some vehicles. Such blends burn more completely than gasoline; therefore, in cars without catalytic converters, they will produce fewer hydrocarbon and carbon monoxide emissions (Allsup, 1979).

Alcohol fuels blended with gasoline, and perhaps used alone, have many advantages as liquid fuels, and the U.S. Government has made a commitment to increase their use. This guide presents much of the currently available information for evaluating the potential of gasohol as well as information in less detail for evaluating other alcohol blends.

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Gasohol: Answers to the Basic Questions

What Are Alcohol Fuels?

Alcohols are members of a group of chemicals identified by their unique combination of carbon, hydrogen, and oxygen atoms. Alcohols range from methanol, which has only one carbon atom, to ethanol with two, to the higher alcohols, with progressive additions of carbon atoms.

Because alcohols can be burned with oxygen to give off large amounts of heat, they have a significant potential value as liquid fuels. In general, the higher alcohols, those with the most carbon atoms, have the highest heating value. This is because more carbon-hydrogen bonds can be broken to form carbon dioxide and water, releasing more energy. However, it is more difficult and expensive to produce the higher alcohols. Therefore, the simpler alcohols—methanol and ethanol—are favored for use as alcohol fuels.

Methanol, the simplest alcohol, has a chemical formula of CH_3OH. It is most commonly produced by gasification of coal, a nonrenewable resource. Methanol-production techniques acceptable in terms of environmental standards and resource availability are not cost-effective at this time. However, methanol can also be produced from environmentally safe biomass feedstocks, and much research is focused on this area.

Ethanol can be produced by fermentation of simple sugars, reaction of carbon monoxide and hydrogen, reaction of carbon dioxide and hydrogen, and catalytic hydration of the petroleum by-product ethylene. The reactions of carbon monoxide and carbon dioxide with hydrogen require high-reactor temperature and pressure. The catalytic hydration of ethylene to produce ethanol also requires high temperature and pressure, but more importantly it uses ethylene, a coproduct of petroleum, another nonrenewable resource. In addition, ethylene is a principal chemical feedstock for plastic manufacturing. In general, this guide only discusses fermentation ethanol produced for use as a liquid fuel.

Since ethanol, also called grain alcohol, is the intoxicant in alcoholic beverages, its production, use, distribution, and marketing are regulated by the Bureau of Alcohol, Tobacco, and Firearms (BATF) of the U.S. Department of the Treasury.

Ethanol is legally measured in proof gallons. Each number of proof represents the ethanol content in increments of one-half percent by volume. Therefore a mixture of 50% ethanol by volume is referred to as 100 proof, while pure ethanol, which is anhydrous, or water free, is 200 proof.

Methanol and ethanol can be used alone as fuels for spark-ignited internal combustion engines. However, because methanol has less than half the heat content of gasoline, and ethanol has less than two-thirds, engine modifications must be made in order to achieve satisfactory performance. On the other hand, blends up to about 10% of either of these two alcohols with gasoline have been successfully used in vehicles without engine modifications, although other components such as fuel lines may require exchanging.

The term "gasohol" was coined and registered as a trademark in 1973 by the Nebraska Agricultural Products Industrial Utilization Committee. By its definition, gasohol is a blend of 10% anhydrous, agriculturally derived ethanol and 90% unleaded gasoline. Through popular usage it has become the generic term for all ethanol or methanol and gasoline blends. For the sake of accuracy, however, it is best to identify other ethanol-gasoline blends with a number identifying the percentage of ethanol used, as in fuel blend E20. Similarly, for methanol-gasoline blends, fuel blend M10 identifies a 10% mix in methanol gasoline. Most of the information in this guide focuses on gasohol and its component, fermentation ethanol. Gasohol made from fermentation ethanol is the most widely used alcohol fuel in the United States today.

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Gasohol: Answers to the Basic Questions

How Is Fermentation Ethanol Made?

Fermentation ethanol can be made from any vegetable material that either directly produces fermentable sugars, such as glucose, or contains starch or cellulose, which may be broken down into such sugars. In practice, no commercially feasible process yet exists to convert cellulose into a fermentable sugar. Because cellulosic materials are readily available at low cost, much current research is aimed at finding an efficient way to release their sugar.

Fermentable sugars may be obtained directly from such crops as sugarcane, sugar beets, and sweet sorghum by crushing or pressing the material. The starch in feedstocks such as grains and potatoes can be broken down into fermentable sugars by enzymatic or acid hydrolysis. Enzymatic hydrolysis requires four steps. The feedstocks are ground into a meal and mixed with water. The proper enzyme is added, and the mixture is cooked. This produces a solution of water and dextrins, which are polymeric, nonfermentable sugars. The next process, saccharification, further breaks down the dextrins to glucose. The process involves adding another enzyme, holding the mash at the proper temperature, and stirring continuously. Temperature, pH, and selection of the proper enzyme are all important factors affecting enzymatic hydrolysis. Acid hydrolysis is less frequently employed to produce ethanol. When it is, dilute sulfuric acid is the most commonly used agent.

Once the appropriate sugar is obtained from the feedstock, fermentation may begin. Ethanol fermentation is the conversion of a six-carbon monomeric sugar—usually glucose—into ethanol, carbon dioxide, and heat through the addition of specific yeasts. These yeasts produce the enzymes causing the necessary series of biochemical reactions to take place. Several factors influence the fermentation process: pH, selection of yeast strains, meeting the nutritional requirements of the yeast strains, sugar concentration, temperature, maintaining anaerobic (airless) conditions, and controlling unwanted microbial contamination. The process basically requires establishing the right conditions for fermentation to take place, and then allowing enough residence time in the vats or fermenters for the chemical reactions to occur.

The next process is distillation. Ethanol is separated from the ethanol-water mixture. The difference in boiling temperatures for water (212°F/100°C) and ethanol (172°F/77.7°C) allows for the separation to occur. The distillation process of heating, vaporization, and condensation is repeated until a solution of up to about 95.6% ethanol is obtained. At this point, the ethanol and water mixture forms an azeotrope, which is a mixture of two liquids that, at a certain concentration, boils at a constant temperature. When the azeotrope is formed, distillation no longer separates the ethanol from water. One means of overcoming this is called azeotropic distillation. This is accomplished by adding a substance to the mixture that changes its boiling characteristics. Another means of further "drying" the ethanol-water mixture is to filter it through a substance that removes the water; such substances are called molecular sieves.

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Gasohol: Answers to the Basic Questions

Does Gasohol Affect Vehicle Performance?

For many years, lead compounds have been added to gasoline to increase the octane rating. It has been proven, however, that lead compounds are a serious health and environmental hazard. Conversion back to unleaded fuels is currently taking place. Ethanol, like lead, is also an octane booster, but without the health and environmental hazards. Therefore, it may serve as a substitute for lead compounds.

Studies by S. J. W. Pleeth (1949) indicated that blends of ethanol and gasoline show an increase in power output with increasing ethanol concentration up to about 17%. These tests showed that specific fuel consumption dropped in direct relation to the concentration of ethanol up to about 16%, at which point fuel consumption began to increase. (It should be noted that the gasoline Pleeth used had an average octane

Anhydrous ethanol can be blended with gasoline for direct use in unmodified engines. Gasohol is a combination of 10% anhydrous ethanol and 90% unleaded gasoline.

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rating lower than gasoline in current use.)

Recent studies by Dr. William Scheller and others indicate that a blend of 10% ethanol and 90% gasoline yields an overall decrease in specific fuel consumption (Scheller, 1979). The lack of a control group in these tests, and questions regarding pump calibrations, have caused doubts about the validity of the results. Subsequent tests by the Environmental Protection Agency and others have not confirmed Scheller's findings (Allsup, 1979).

The results of gasohol vehicle testing depend on both the test conditions and the vehicles tested; therefore, comparisons are difficult. Data existing on specific fuel consumption indicate a margin of error on either side great enough to suggest that the most plausible conclusion is that there is no significant change in fuel consumption. However, it is well known that ethanol has a lower energy content than gasoline. Therefore, one would expect that fuel consumption would rise in direct proportion to the amount of ethanol in the blend. But this doesn't happen. The reason is that ethanol's high octane and cool burning give it a high thermodynamic efficiency that offsets its lower-than-gasoline energy content.

In addition to its use in gasohol or other fuel blends, ethanol can be used alone as a motor vehicle fuel in the form of lower-proof ethanol, as anhydrous (water-free, or 200-proof) ethanol, and as a dual-fuel diesel supplement. Lower-proof ethanol can be burned in spark-ignition internal combustion engines with some engine modifications. These include enlarging the jet size in the carburetor and changing the intake manifold to ensure proper vaporization of the ethanol. Performance problems may occur as the concentration of water increases. Anhydrous ethanol used alone would require the same modifications. Diesel engines may be modified to have two separately injected fuels: ethanol and diesel (U.S. Department of Agriculture, 1980).

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Does Ethanol Production Affect Food Supply?

Obtaining fuel from farms has occasionally been interpreted as obtaining fuel from food. As important as the development of domestic fuel is, adequate food production certainly has higher priority. One of the criteria for developing alcohol fuels, or any other form of alternative energy, is that such developments should not adversely affect essential industries such as food production. However, it is feasible to obtain the necessary feedstocks for producing fermentation ethanol at a reasonable level without decreasing the human food supply. There are several means for accomplishing this.

One obvious possibility is to convert to ethanol production a percentage of feed crops (crops used for livestock feed); feed crops include 90% of the corn grown in the United States (U.S. Department of Agriculture, 1978). The advantage is that not only is fuel produced, but a residue of the process, stillage, is a high-protein coproduct. The production of ethanol from agricultural feedstocks uses the carbohydrate and leaves the remaining nutrients in a concentrated form. For example, dried stillage from grains contains approximately threefold more protein by weight than the grain. This coproduct is an excellent animal feed. It lacks the carbohydrate needed in animal feed, but carbohydrates can be added by using readily available, inexpensive, low-protein, high-carbohydrate forage crops such as hay.

Putting idle land into production can also increase the capacity for growing crops for fuel. Marginal land that could not economically support food crops may sometimes be used quite productively for fuel feedstocks. Examples are the production of grain sorghum (milo) and Jerusalem artichokes in semiarid areas, which cannot currently produce food crops competitively.

In 1978, the United States produced 500 million bushels of wheat in excess of "disappearance." (Disappearance is based on domestic production plus imports, minus domestic consumption and exports [U.S. Department of Agriculture, 1978]). The extra wheat could have produced 1.3 billion gallons of ethanol, based on 2.6 gallons produced from each bushel.

It has been estimated that 5% to 10% of the grain produced annually in the United States is considered distressed, or marginal, and unfit for human consumption. In 1978, 12 billion bushels of grain were grown in the United States (U.S. Department of Agriculture, 1978). Thus at least 600 million bushels were unusable as grain, which could have been converted to 1.5 billion gallons of ethanol, based on 2.5 gallons per bushel.

In addition, there is a certain amount of perishable produce that spoils in the fields, during transport, and on the shelf. At this time, the only portion that is practical to collect is that which spoils in the fields. However, it may be possible to use this resource and also to establish a collection system for the remainder of the spoiled crops and convert them to alcohol.

Other possibilities for increasing alcohol feedstocks include developing crops specifically for fuel production and increasing the amount of ethanol that can be produced per acre of feedstock.

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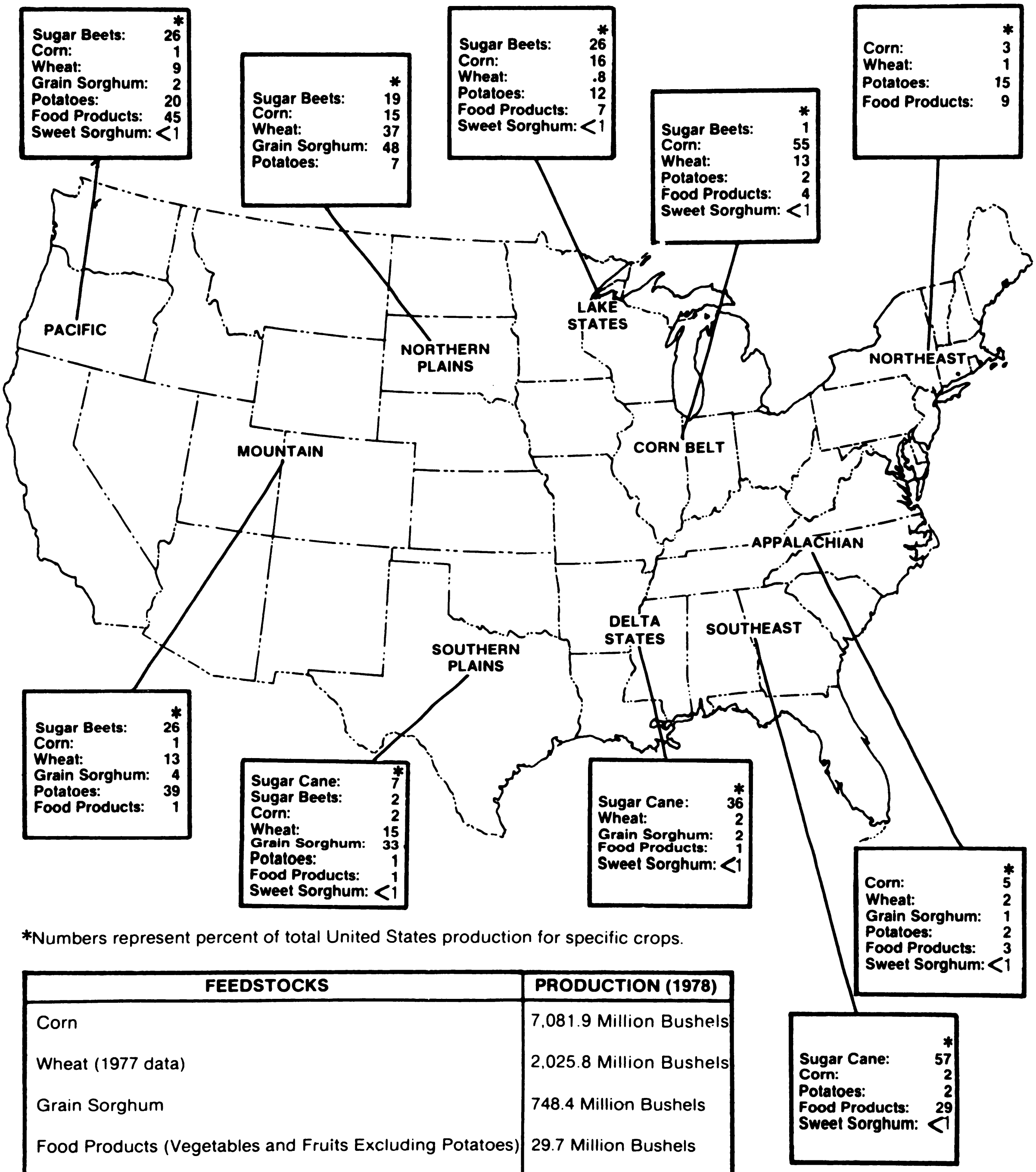

*Numbers represent percent of total United States production for specific crops.

FEEDSTOCKS	PRODUCTION (1978)
Corn	7,081.9 Million Bushels
Wheat (1977 data)	2,025.8 Million Bushels
Grain Sorghum	748.4 Million Bushels
Food Products (Vegetables and Fruits Excluding Potatoes)	29.7 Million Bushels
Sugar Beets	25.9 Million Bushels
Sugar Cane	16.0 Million Bushels
Potatoes (1977 data)	17.6 Million Bushels
Sweet Sorghum	Minimal at Present

Figure I-5.1 Potential Ethanol Feedstocks and Their Availability by Regions

Gasohol: Answers to the Basic Questions

What Is the Energy Balance for Ethanol Production and Use?

Roughly the same amount of energy is required to grow grains or sugar crops and convert them to ethanol as is contained in the ethanol itself. Consequently, if premium fuels (oil and natural gas) are used to supply this energy and if the ethanol is used solely for its fuel value (e.g., as in most on-farm uses), then ethanol production and use could actually result in an increase in U.S. consumption of the premium fuels. (Note that no such problem exists with methanol production.)

However, a net displacement of premium fuels can be achieved by taking three steps.

First, if the distillery is fueled by coal or solar energy (including biomass), then in most cases less premium fuel will have been used to produce the ethanol than it contains. For most sources of grains and sugar crops, each gallon of ethanol will contain the energy equivalent of 0.2 to 0.5 gal of gasoline more than the energy needed to grow and harvest the crop. (The actual value will depend on farming practices and yields.) In some extreme cases, such as grain sorghum grown in poor soil, however, the farming energy may still be greater than the energy content of the resultant ethanol.

Second, if the ethanol is used as an octane-boosting additive to gasoline, rather than for its fuel value alone, substantially more premium fuel can be displaced. Because the oil refinery requires less energy if it produces a lower octane gasoline, the energy equivalent of up to 0.4 gal of gasoline can be saved at the refinery for each gallon of ethanol used as an octane-boosting additive. An additional saving may be obtained at the point of use because automobiles appear to obtain better mileage with gasohol than would be expected from its energy content alone. Various road tests have resulted in widely varying estimates for the size of this savings, but laboratory tests and the average of all road test data are consistent with a savings of 0.15 gal of gasoline per gallon of ethanol with existing vehicles.

Third, distilleries can take advantage of the feed value—and consequent energy credit—for their by-product (distiller's grain, or DG). With the feed rations commonly used today, DG can be a substitute for soybean meal or other protein concentrate. The credit for displacing soybean meal is the energy equivalent of slightly less than 0.1 gal of gasoline per gallon of ethanol.

The above factors combine so that each gallon of ethanol produced from corn has the potential to displace premium fuels with the energy equivalent of up to 1 gal of gasoline. Whether this potential is actually achieved will depend primarily on the fuel used in the distillery and the end use of the ethanol.

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Gasohol: Answers to the Basic Questions

What Economic Issues Affect Alcohol-Fuel Production and Use?

Financial incentives, allocation priorities, refinery production of crude oil, and capital and operating costs for ethanol production provide a healthy economic situation for developing a national industry to produce fermentation ethanol for use in gasohol and other fuel blends.

One of the major areas of economic impact on the development of alcohol fuels involves the financial incentives established or being considered by Congress. Production incentives include loan guarantees, investment tax credits, and grants. Use incentives include excise tax credits of $0.04 per gallon of blend and U.S. Department of Energy entitlements worth $0.05 per gallon of ethanol, as of late 1980. In addition, many states have passed or are considering state fuel tax exemptions for gasohol.

The economic feasibility of establishing production facilities is a criterion for developing alcohol fuels. In early 1980, a review of firms selling ethanol-plant systems showed prices ranging from $250,000 to $500,000 for a 250,000-gallon-a-year plant.

There are three primary concerns when considering operating costs for a fermentation-ethanol plant:

1. The efficient recovery of all the alcohol produced is essential.
2. All costs must be tabulated to determine production feasibility.
3. A fair-market value must be charged for the stillage coproduct, whether used on-farm or sold.

Operating costs include feedstocks; labor; chemicals and supplies; enzymes and yeasts; fuel; electricity; water; denaturant; insurance; bonding; property taxes; depreciation; maintenance; and overhead costs such as accounting, legal, and engineering fees.

On-farm ethanol production should be considered an alternative cash crop, as opposed to a stopgap strategy. As a hypothetical example, if 5,000 bushels of grain sold in the market produced $0.20 per bushel profit, the net profit would be $1,000. If that same grain had been used to produce ethanol, 12,500 gallons of ethanol would have been produced with a profit range averaging $0.30 per gallon, for a net profit of $3,750. This does not include potential income from the high-protein stillage coproduct.

A final issue is that the refinery receives economic benefits. By producing low-octane gasoline for ethanol-fuel blends, the productivity of crude oil is extended. Therefore, more income per barrel of refined crude oil can be generated.

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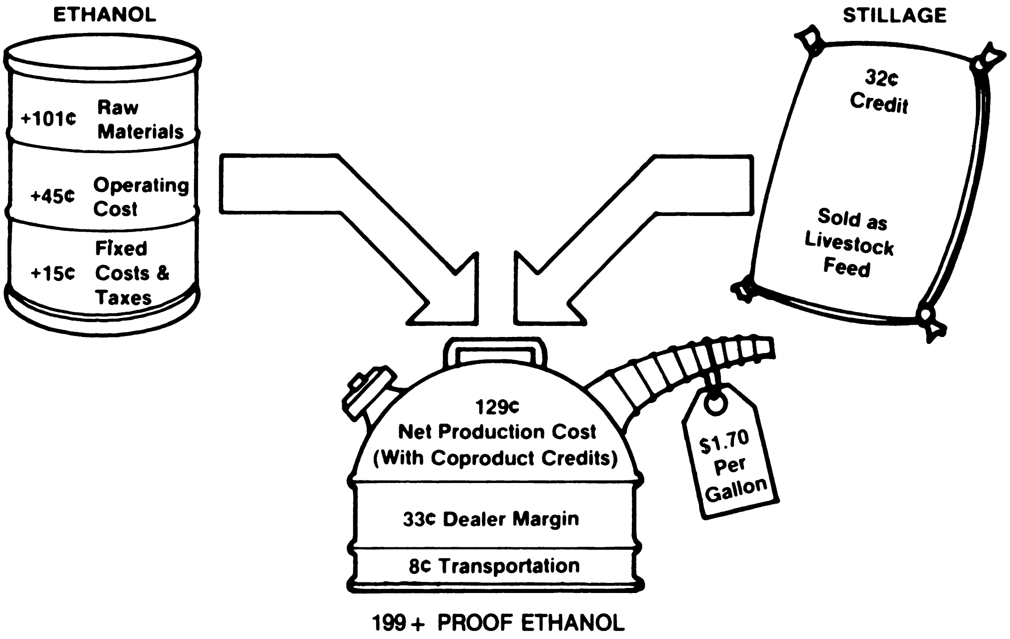

SOURCE: U.S. DOE 1st Annual Report to Congress (Revised)

Figure I-7.2 Breakout of Production Costs for Ethanol

Feedstocks and Their Coproducts

Introduction

Feedstocks are the raw materials from which ethanol is produced. Ethanol fermentation is a biochemical process in which an organic substance, or substrate, is converted into ethanol, carbon dioxide, and additional minor products—such as lactic acid and fusel oils—by the action of enzymes produced by microorganisms. The major substrates for ethanol production are so-called six-carbon monomeric sugars, which include glucose. Since agricultural crops and crop residues contain six-carbon sugars or compounds of these sugars, theoretically they are candidates for ethanol production. With the exception of sugar crops, the six-carbon sugars in agricultural crops are bound up in complex compounds, such as starch and cellulose. Because of this, the feedstocks must be processed by methods that reduce these compounds to monomeric sugar in order for fermentation to begin.

Wheat produces high ethanol yields and the chaff can be burned for process heat.

Feedstocks for ethanol production generally may be divided into starch crops, including grains and tubers; sugar crops; and cellulosic residues and crops. The last includes forage grasses and agricultural wastes. In addition, research is underway using industrial and food-processing wastes as a potential alcohol feedstock. Crop and ethanol yields will vary, depending on location, production methods, soil conditions, weather, etc.

It is essential to use resources in ways that guarantee future productivity most efficiently. Developing agricultural land for those crops most suitable for food or for fuel is one part of this concept. Therefore, understanding the relationship of feedstock production to efficient land use and land conservation practices is essential. For example, some crop residue should remain on the land to improve tilth; the amount is dependent upon local conditions.

Feedstock selection should include the following considerations:

- production ease and cost of obtaining monomeric sugar;
- yield of fermentable sugar per acre;
- yield of residue from the production process per volume;
- cost, composition, and quality of residue for potential use as a coproduct such as animal feed; and
- appropriateness of land cultivation practices for feedstock cultivation.

The following table compares crop yields for corn, grain sorghum, potatoes, and wheat for ethanol production.

The ethanol-fermentation process yields several coproducts. The economic implications of these coproducts are, in part, dependent on the ease with which they may be recovered, the amount recovered, and the existence of a commercial market or on-site use for the product. The amount and, to some extent, the specific characteristics of the coproducts are influenced by the original feedstock. In the case of stillage these conditions also affect its potential use. The primary coproducts of the fermentation ethanol process are carbon dioxide, fusel oils, yeast, and stillage.

Carbon Dioxide

CO_2 is used in carbonated beverages, fire extinguishers, and food preservatives. CO_2 may also be flash-cooled to −40°C to make solid dry ice (Paturau, 1969). Presently it is not practical to recover CO_2 at small-scale plants, and although possible at larger plants, such recovery is dependent on available markets.

A great deal of CO_2 is produced by the sugar-to-ethanol conversion during fermentation. For instance, 90 kilograms of glucose become about 46 kilograms of ethanol and 44 kilograms of CO_2.

Fusel Oils

The high molecular weight alcohols, or fusel oils, end up in fuel alcohol. They are principally amyl and iso-amyl alcohol and have a slightly higher energy content than ethanol. The approximate composition of fusel oil is:

Ethyl alcohol	5.0%
n-Propyl alcohol	12.5%
Isobutyl alcohol	15.0%
Amyl and iso-amyl alcohol	62.5%
Additional residue distilling higher than 140°C	5.0%

Using molasses as the feedstock, 6% or about 1.1 liter of fusel oil per 1,000 kilograms of molasses is produced (Paturau, 1969). Using corn as the feedstock, about 3% of the total alcohol produced is fusel oil.

Yeast

The fermentation process provides the medium for yeast propagation. Yeast can be recycled in the process; recovered for other commercial uses, primarily as a high-protein feed; or left to enhance the protein content of the stillage. If recovered during the production cycle, a centrifuge system is usually used either before or after distillation. When considered as a coproduct, yeast's value should be determined and used in production-cost calculations.

Stillage

Because the feedstocks for ethanol production are agricultural crops, the relationship between crops for food and crops for fuel must be considered. Feedstocks for ethanol production need not be, or displace, crops for food. An agricultural approach is possible that provides sufficient crops to meet the needs for food and fuel without upsetting the economics and supplies of U.S. food production. The use of stillage as an animal feed is one means of achieving this.

The yeast produced during fermentation is a high-protein food source. If left as part of the stillage remaining at the end of production, the yeast contributes to the high-protein base of this residue. The

Table II-1.1 Comparison of Selected Starch Crop Yields for Ethanol Production

Material	Average Yield 1977-78 (normal unit of sale per acre)[a]	Yield (gallons EtOH per normal unit of sale)	Yield (gallons EtOH per acre)
Corn	96.0 bu	2.6 /bu[b]	250
Grain sorghum	55.7 bu	2.5 /bu[c]	140
Potatoes	12.5 tons	29.0 /ton[b]	362
Wheat	31.1 bu	2.6 /bu[b]	81

Sources:
[a] U.S. Department of Agriculture, 1979.
[b] University of Nebraska, 1980.
[c] Hedrick, 1980.

Mature cattle can consume about seven pounds of dry stillage per day or, roughly, the stillage resulting from the production of 1 gallon of ethanol.

protein content of the stillage is not only a function of the yeast in the residue, but also is affected by the amount of protein in the original feedstock. If a high-protein feedstock is used, the stillage will also be high in protein, since little protein is consumed during fermentation. For example, fermentation of grains generally provides a higher protein-content residue than fermentation of sugar crops. Specific feedstocks also vary. For example, sugar beets are higher in protein than sugarcane.

The stillage from fermentation contains the following: a fibrous carbohydrate material that can be metabolized only by ruminants (ruminants are animals that are cud chewing; e.g., cattle, sheep, goats); a high-protein yeast; varying levels of protein from the original feedstock; and other nonfermentable solids and solubles, which contain minerals and other nutrients. This stillage may be considered either a waste or a resource. As a waste it is a high-cost, high-impact pollutant; as a coproduct it may be used as an animal feed or as a feedstock for anaerobic digesters to produce methane gas. It may also be possible to use dried stillage as a protein additive in human foods.

Stillage is basically a liquid, which causes problems when it is used as an animal feed. (It has a moisture content of 90%.) Energy and money are consumed to dry it enough to be stored or transported. For small-scale plants, a feedlot operated in conjunction with the plant could obviate the need for removing the moisture. Larger plants must install drying equipment.

Except for cereal grains, little information exists for the composition and quality of the residue from potential feedstocks. This creates problems when these feedstocks are being evaluated for use as animal feeds. Cereal grain stillage is known to be an excellent animal feed.

Human-Grade Protein and Fiber from Wet Milling

Wet milling is a method used in feedstock preparation that separates protein, fiber, and starch from grain. The starch is then converted into sugar to make alcohol, and the protein and fiber may be treated as coproducts. The protein can be consumed by humans. Because of the high initial costs for wet milling, it is only appropriate for large-scale plants.

The following steps make up the wet-milling process:

- The grain is soaked in a very dilute aqueous solution of sulfur dioxide.
- The hulls are ripped apart, without mashing the germ, by metal grinding wheels.
- The germ is separated from the rest of the grain in a centrifuge.
- The material is passed over a screen to separate the starch and protein from the fiber and hulls.
- The starch and protein are blended with water to make a slurry.
- The slurry is sent to a centrifuge, which separates the protein (gluten) from the starch.

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Feedstocks and Their Coproducts

Starch Crops

Starch crops include the grains (corn, grain sorghum, wheat, and barley) and the tubers (potatoes and sweet potatoes). Starch has a long, branched chain of six-carbon sugars. It is unlike sugar crops, which have individual or paired six-carbon sugars. The composition of starch presents both an advantage and disadvantage in ethanol production. It is more complicated (thus more expensive) to break down the chain into fermentable, monomeric sugar. This is usually accomplished through enzymatic or acid hydrolysis. However, in relation to total ethanol-production costs, starch breakdown is a small part. On the other hand, there are several advantages associated with starches: they store better than sugar crops, and their coproduct stillage is of a higher value. Nonetheless, specifics of feedstocks often determine their utility.

Table II-2.1 gives the basic composition of the four primary grains.

The stillage from starch-crop fermentation contains nonfermentable material in the form of solids in suspension (ranging from very fine to very coarse) and water-soluble material in solution. The coarser solids can be separated out, and when grain is the feedstock these are called distiller's grains. When dried and blended with the dried soluble material, these solids are called distiller's dark grains (DDG) or distillers dried grains with solubles (DDGS). (The acronym "DDG" is used for both distillers dark grains and distillers dried grains. DDGS is used in this guide to represent the combination of dried grains and solubles, and DDG is used to refer to distillers dried grains only.) The nutritional content of these products will vary according to the feedstock and production process used, although representative values can be established. The value is primarily determined by the nutritional content of the grains used as the feedstock. There is generally a threefold concentration of protein by weight after the starch is removed for alcohol production.

Table II-2.1 Composition of Various Grains

Constituent	Corn	Sorghum	Barley	Wheat
Digestible energy, kcal/kg[a]	3,610.0	3,453.0	3,080.0	3,520.0
% Protein[a]	8.9	11.0	11.6	12.7
% Lysine[a]	0.18	0.27	0.53	0.45
% Methionine-cystine[a]	0.18	0.27	0.36	0.36
% Tryptophan[a]	0.09	0.09	0.18	0.18
% Calcium[a]	0.02	0.04	0.08	0.05
% Phosphorus[a]	0.31	0.29	0.42	0.36
% Fiber[a]	2.0	2.0	5.0	3.0
% Ether Extract[a]	3.9	2.8	1.9	1.7

Sources:
[a] Texas Department of Agriculture, 1978.
[b] U.S. Department of Agriculture, 1975.

For some time, all stillage products from beverage distilleries have been used as animal feed in areas near these distilleries. Corn is a usual feedstock, and its stillage primarily comes from the bourbon industry. Wheat and rye are also used as feeds. In addition to the value of distiller's feeds for protein and energy, research in the 1950s showed such feeds stimulated certain digestive processes in ruminants (cud-chewing animals), primarily in the area of cellulose digestion (Distillers Feed Research Council, p. 36). The use of distiller's feed for various animals is summarized below:

- Poultry—Layers and Breeders: Excellent for poultry production and hatchability. Feeding formulas using up to 20% distiller's dried grains with solubles (DDGS) have been shown to produce very satisfactory results (Distillers Feed Research Council, p. 23).
- Poultry—Broilers and Chick Starters: Excellent for chick starter and broiler rations. Eighty percent of the corn in a poultry diet can be replaced by DDS from yeast fermentation of cereal grains and can be mixed in an all-mash ration in the proportion of two parts syrup to one part mash (Distillers Feed Research Council, p. 14).
- Turkeys: DDGS can be used to levels of up to 10% in turkey diets. Positive effects on egg production and hatchability have been reported (Distillers Feed Research Council, p. 32).
- Dairy Cattle: Used as a silage additive, distiller's feeds have a positive effect on milk production, and for the lactating cow they are palatable and highly digestible. Studies also indicate a favorable effect on milk production (Distillers Feed Research Council, p. 48).
- Calves—Starters: Can replace ingredients such as linseed meal and dried whey in starter formulas for calves (Distillers Feed Research Council, p. 58).
- Sheep: Limited research indicates characteristics of palatability, digestibility, and a stimulating effect on rumen function, making DDGS a good feed supplement (Distillers Feed Research Council, p. 61).
- Swine: Up to 10% DDGS can be used in swine diets. Several studies indicate the product is an excellent source of feed (Distillers Feed Research Council, p. 63).
- Dogs: Both growth and reproductive studies with dogs indicate DDS as an excellent dog food supplement (Distillers Feed Research Council, p. 70).
- Fish: Can be used in formulas for both trout and warm-water fish, such as catfish. [The trout diet consists of approximately 21% DDS (Distillers Feed Research Council, pp. 73–74).]
- Mink: DDS as a replacement for more expensive feed ingredients in mink diets has not sacrificed growth and pelt quality (Distillers Feed Research Council, p. 76).
- Beef Cattle: A palatable and highly digestible protein source for beef cattle. Feeds also help utilize cellulose and urea, and stimulate growth when used in liquid-feed supplements as a source of the urea-protein factor. (Distillers Feed Research Council, p. 39).

Corn

Corn is the most commonly used feedstock for ethanol production. Table II-2.2 gives the area, yield, and production of corn in the United States for 1977–78. More than 90% of the corn grown in the United States is used for livestock feed, both domestically and when exported (Freedman, 1980). Table II-2.3 shows the nutritional composition of distiller's feeds when corn is the feedstock. Table II-2.4 shows the energy available in DDG, DDS, and DDGS for cattle, poultry, and swine.

Corn, which has been used extensively for the production of beverage-grade alcohols, is one of the most popular ethanol feedstocks.

Table II-2.2 Corn Area, Yield, and Production, 1977-78

			Corn for Grain					
	Area Planted for All Purposes[a] (1,000 acres)		Area Harvested (1,000 acres)		Yield per Harvested Acre (bushels)		Production (1,000 bushels)	
State	1977	1978	1977	1978	1977	1978	1977	1978[b]
AL	840	640	375	544	29.0	50.0	10,875	27,200
AZ	65	70	50	50	100.0	115.0	5,000	5,750
AR	55	40	43	30	53.0	58.0	2,279	1,740
CA	430	420	247	281	116.0	126.0	28,652	35,406
CO	960	1,000	695	720	116.0	110.0	80,620	79,200
CT	54	53	—	—	—	—	—	—
DE	203	187	185	175	56.0	96.0	10,360	16,800
FL	623	430	299	370	35.0	52.0	10,465	19,240
GA	2,240	1,700	1,000	1,500	24.0	50.0	24,000	75,000
ID	120	123	28	39	86.0	87.0	2,408	3,393
IL	11,350	11,000	11,080	10,730	105.0	111.0	1,163,400	1,191,030
IN	6,400	6,100	6,210	5,900	102.0	108.0	633,420	637,200
IA	13,800	13,300	12,700	12,500	86.0	117.0	1,092,200	1,462,500
KS	2,030	1,820	1,680	1,500	96.0	102.0	161,280	153,000
KY	1,650	1,570	1,470	1,410	90.0	85.0	132,300	119,850
LA	86	65	65	47	52.0	59.0	3,380	2,773
ME	51	50	—	—	—	—	—	—
MD	730	690	600	590	72.0	97.0	43,200	57,230
MA	42	43	—	—	—	—	—	—
MI	2,800	2,670	2,320	2,250	85.0	81.0	197,200	182,250
MN	6,900	7,000	6,000	6,190	100.0	104.0	600,000	643,760
MS	250	215	160	135	36.0	56.0	5,760	7,560
MO	2,900	2,400	2,650	2,200	76.0	87.0	201,400	191,400
MT	90	88	11	5	68.0	72.0	748	360
NE	7,150	7,100	6,550	6,550	99.0	113.0	648,450	740,150
NV	3	—	—	—	—	—	—	—
NH[c]	26	27	—	—	—	—	—	—
NJ	149	135	95	95	70.0	91.0	6,650	8,645
NM	135	90	114	72	90.0	105.0	10,260	7,560
NY	1,357	1,300	640	600	80.0	90.0	51,200	47,400
NC	2,000	1,760	1,740	1,600	51.0	76.0	88,740	121,600
ND	620	600	237	253	73.0	79.0	17,301	19,987
OH	3,900	3,850	3,620	3,610	105.0	105.0	380,100	379,050
OK	140	120	95	73	82.0	65.0	7,790	4,745
OR	45	45	12	13	95.0	95.0	1,140	1,235
PA	1,615	1,615	1,160	1,190	92.0	95.0	105,720	113,050
RI	4	4	—	—	—	—	—	—
SC	825	640	690	550	36.0	55.0	24,840	30,250
SD	3,000	3,250	2,150	2,560	59.0	67.0	126,850	171,520
TN	900	820	730	660	65.0	66.0	47,450	43,560
TX	1,800	1,600	1,650	1,440	98.0	100.0	161,700	144,000
UT	80	92	13	16	89.0	90.0	1,150	1,440
VT	110	112	—	—	—	—	—	—
VA	855	825	560	615	55.0	82.0	30,800	50,430
WA	128	130	64	65	119.0	121.0	7,616	7,865
WV	100	93	54	58	74.0	77.0	3,996	4,466
WI	3,850	3,750	2,800	2,750	104.0	98.0	291,200	269,500
WY	89	87	30	34	85.0	81.0	2,550	2,754
U.S.	83,568	79,719	70,872	69,970	90.7	101.2	6,425,475	7,081,849

Source: U.S. Department of Agriculture, 1979.

[a] Includes corn for grain, corn fed whole (with stalks) to cattle, and abandoned corn.

[b] Preliminary.

[c] Estimates discontinued after 1977 crop.

Table II-2.3 Nutritional Content of Distiller's Feeds from Corn

Constituent	Distiller's Dried Grains	Distiller's Dried Solubles	Distiller's Dried Grains and Solubles
Moisture, %	7.5	4.5	9.0
Protein, %	27.0	28.5	27.0
Fat, %	7.6	9.0	8.0
Fiber, %	12.8	4.0	8.5
Ash, %	2.0	7.0	4.5
Amino Acids, %			
Lysine	0.60	0.95	0.60[a]
Methionine	0.50	0.50	0.60[a]
Cystine	0.20	0.40	0.40
Histidine	0.60	0.63	0.60
Arginine	1.10	1.15	1.00
Aspartic acid	1.68	1.90	1.70
Threonine	0.90	0.98	0.95
Serine	1.00	1.25	1.00
Glutamic acid	4.00	6.00	4.20
Proline	2.60	2.90	2.80
Glycine	1.00	1.20	1.00
Alanine	2.00	1.75	1.90
Valine	1.30	1.39	1.30
Isoleucine	1.00	1.25	1.00
Leucine	3.00	2.60	2.70
Tyrosine	0.80	0.95	0.80
Phenylalanine	1.20	1.30	1.20
Tryptophan	0.20	0.30	0.20
Fatty acids			
Linoleic			
% fat	47.2	49.1	48.5
% ingredient	3.6	4.4	3.9
Linolenic			
% fat	5.2	5.1	5.0
% ingredient	0.38	0.46	0.40
Vitamins			
Folic acid, mg/kg	1.1	1.7	1.0
Pyridoxine, mg/kg	4.0	13.0	6.5
Niacin, mg/kg	42.0	120.0	77.0
Pantothenic acid, mg/kg	6.6	22.0	11.0
Biotin, mg/kg	0.20	0.50	0.30
Riboflavin, mg/kg	3.3	22.0	9.0
Vitamin B_{12}, mg/kg	0.00025	0.007	0.0015
Thiamine, mg/kg	2.0	7.0	3.5
a-Tocopherol, mg/kg	—	55.8	30.5
Inositol, gm/kg	0.95	8.8	3.2
Choline chloride, gm/kg	1.0	5.8	3.4
Minerals			
Phosphorus, %	0.37	1.60	0.95
Potassium, %	0.15	2.10	1.00
Calcium, %	0.05	0.30	0.35
Magnesium, %	0.07	0.60	0.35
Sodium, %	0.05	0.15	0.05
Sulfur, %	0.56	0.58	0.40
Iron, ppm	105.0	200.0	200.0
Copper, ppm	15.0	55.0	50.0
Zinc, ppm	50.0	100.0	80.0
Manganese, ppm	10.0	60.0	30.0
Selenium, ppm	0.3	0.4	0.3
Cobalt, ppm	0.05	0.08	0.1
Barium, ppm	1.15	3.15	2.45
Aluminum, ppm	—	9.2	5.0
Strontium, ppm	1.3	8.8	3.4
Boron, ppm	4.3	9.5	8.2
Chromium, ppm	3.2	3.7	2.5
Iodine, ppm	0.05	0.05	0.05

Source: Distillers Feed Research Council.

[a] Available.

Table II-2.4 Feed Energy Available from Corn

Energy	DDG	DDS	DDGS
Cattle			
DE, kcal/kg	3,408	3,608	3,570
ME, kcal/kg	2,794	2,959	2,927
TDN, %	83	80	82
NEmilk, kcal/kg	2,150	2,210	2,210
NEm, kcal/kg	2,050	2,030	2,035
NEp, kcal/kg	1,347	1,335	1,335
Poultry			
ME, kcal/kg	1,631	2,750	2,620
Swine			
DE, kcal/kg	2,030	3,305	3,085
ME, kcal/kg	1,835	2,985	2,790
TDN, %	46	75	70

Source: Distillers Feed Research Council, p. 10-11.

DE = Digestible energy

ME = Metabolized energy

TDN = Total digestible nutrients

NE = Net energy

NEm = Net energy available per kg of feed to maintain the animal's life (no production).

NEmilk = Net energy available per kg of feed when the animal is producing milk.

NEp = Net energy available per kg of feed when the animal is producing meat.

Table II-2.5 Grain Sorghum Area, Yield, and Production, 1977-78

			Sorghum for Grain					
	Area Planted for All Purposes[a] (1,000 acres)		Area Harvested (1,000 acres)		Yield per Harvested Acre (bushels)		Production (1,000 bushels)	
State	1977	1978	1977	1978	1977	1978	1977	1978[b]
AL	75	65	27	34	27.0	37.0	689	1,258
AZ	100	80	90	73	80.0	78.0	7,200	5,694
AR	285	230	252	200	52.0	60.0	13,104	12,000
CA	150	210	132	185	73.0	71.0	9,636	13,135
CO	460	490	263	280	31.0	31.0	8,153	8,680
GA	75	85	24	43	28.0	29.0	672	1,247
IL	80	80	64	68	64.0	68.0	4,096	4,624
IN	23	25	15	15	78.0	65.0	1,170	975
IA	45	36	32	24	74.0	75.0	2,368	1,800
KS	4,850	4,700	4,050	4,020	60.0	52.0	243,000	209,040
KY	50	37	32	23	57.0	62.0	1,824	1,426
LA	35	30	20	17	33.0	34.0	660	578
MS	60	65	24	21	32.0	38.0	768	798
MO	1,050	930	930	850	73.0	80.0	67,890	68,000
NE	2,300	2,000	2,070	1,830	71.0	75.0	146,970	137,250
NM	297	336	245	267	48.0	46.0	11,760	12,282
NC	110	125	72	86	37.0	52.0	2,664	4,472
OK	765	700	565	485	38.0	36.0	21,470	17,460
SC	23	26	12	15	16.0	32.0	192	480
SD	29	29	343	340	49.0	50.0	16,807	17,000
TN	40	45	20	24	51.0	51.0	1,020	1,224
TX	5,600	5,700	4,800	4,650	48.0	49.0	230,400	227,850
VA	24	25	10	11	43.0	47.0	430	517
U.S.	16,993	16,483	14,092	13,681	56.3	55.1	792,983	747,790

Source: U.S. Department of Agriculture, 1979.

[a] Includes grain sorghum for grain, for silage and forage, and abandoned sorghum.

[b] Preliminary.

Table II-2.6 Grain Sorghum Silage Use, 1977-78

	Sorghum for Silage					
	Area Harvested (1,000 acres)		Yield per Acre (tons)		Production (1,000 tons)	
State	1977	1978[a]	1977	1978[a]	1977	1978[a]
AL	15	18	10.5	10.0	158	180
AZ	6	5	17.0	17.0	102	85
AK	17	12	10.5	10.5	179	126
CA	7	12	17.0	17.0	123	204
CO	21	19	7.0	11.0	147	209
GA	18	29	7.0	12.5	126	363
IL	11	7	12.5	11.5	138	81
IN	6	7	12.0	13.0	72	91
IA	11	9	13.0	14.0	143	126
KS	300	230	12.5	10.0	3,750	2,300
KY	11	8	12.5	12.0	138	96
LA	9	9	11.0	10.0	99	90
MS	27	35	12.5	13.0	338	455
MO	44	33	11.0	11.5	484	380
NE	90	70	11.5	13.0	1,035	910
NM	8	4	12.0	13.0	96	52
NC	22	24	8.0	13.5	176	324
OK	34	45	11.0	9.0	374	405
SC	11	11	6.5	9.5	72	105
SD	56	55	8.0	7.5	448	413
TN	8	11	10.0	10.5	80	116
TX	100	50	8.0	10.5	800	525
VA	10	11	9.0	11.0	90	121
U.S.	842	714	10.9	10.9	9,168	7,757

Source: U.S. Department of Agriculture, 1979.

[a] Preliminary.

Table II-2.7 Grain Sorghum Production Cost, 1978

	Central Plains	Southern Plains	Southwest	United States
Costs per Acre				
Variable				
Seed	$ 3.46	$ 3.46	$ 7.57	$ 3.60
Fertilizer	12.14	11.89	29.70	12.37
Lime	0.02	NA[a]	NA[a]	0.01
Chemicals[b]	3.83	1.85	2.00	2.95
Custom operations[c]	4.73	4.82	4.96	4.77
All labor	10.42	14.07	39.04	12.53
Fuel and lubrication	7.37	12.51	26.80	9.94
Repairs	6.70	10.75	12.55	8.54
Drying	2.17	—	—	1.20
Purchased irrigation water	— -	—	23.28	0.45
Interest	1.29	1.61	5.32	1.50
Total—Variable	52.23	60.96	151.22	57.86
Machinery Ownership				
Replacement	15.82	25.06	25.96	19.95
Interest	6.96	10.13	11.41	8.40
Taxes and insurance	2.12	3.00	3.39	2.52
Total—Machinery Ownership	24.90	38.19	40.76	30.86

(Table continued)

Table II-2.7 Grain Sorghum Production Cost, 1978 (concluded)

	Central Plains	Southern Plains	Southwest	United States
General Farm Overhead	6.63	6.52	11.56	6.67
Management[d]	8.38	10.57	20.35	9.54
Total—Excluding Land	92.14	116.24	223.89	104.94
Land Allocation, Composite with:				
Current value[e]	42.00	28.56	82.01	37.04
Average acquisition value[f]	27.58	17.74	56.42	23.94
Costs per Bushel				
Variable	0.91	1.34	2.16	1.10
Machinery Ownership	0.43	0.84	0.58	0.59
Farm Overhead	0.12	0.14	0.16	0.13
Management	0.15	0.23	0.29	0.18
Total—Excluding Land	1.61	2.55	3.19	2.00
Land Allocation, Composite with:				
Current value	0.73	0.63	1.17	0.71
Average acquisition value	0.48	0.39	0.80	0.46
Total Per-Bushel Costs of Production to a Renter				
Cost to share renter[g]	2.36	3.48	4.54	2.83
Cost to cash renter[h]	2.05	3.03	3.71	2.63
Weighted renter cost[i]	2.33	3.42	4.20	2.81
Yield per acre (bushels)	57.2	45.5	70.2	52.5
Percent of U.S. production	58.9	36.0	2.5	97.4

Source: U.S. Department of Agriculture, 1979.

[a] Not applicable.

[b] Includes herbicides, insecticides, and rodenticides not otherwise included under custom operations.

[c] Includes custom application of crop chemicals, the cost of chemicals in some cases, and custom harvesting and hauling.

[d] Based on 10 percent of above costs.

[e] Based on prevailing tenure arrangements in 1974, reflecting actual combinations of cash rent, net-share rent, and owner-operator land allocations, land values, land tax rates, and cash rates updated to current year.

[f] Same as footnote "e," except average value of cropland during the last 35 years is used for owner-operated land instead of current land value.

[g] Share-renter portion of cost divided by share-renter portion of crop.

[h] Cash-renter costs including cash rent divided by total yield.

[i] Weighted average of share renter and cash renter based on prevailing tenure arrangements in 1974.

Table II-2.8 Wheat Area, Yield, and Production, 1977-78

State	Area Planted for All Purposes[a] (1,000 acres)		Area Harvested (1,000 acres)		Yield per Harvested Acre (bushels)		Production (1,000 bushels)	
	1977	1978[b]	1977	1978[b]	1977	1978[b]	1977	1978[b]
AL	135	130	90	65	28.0	26.0	2,520	1,690
AZ	147	145	140	138	72.0	70.0	10,080	9,660
AR	825	400	660	300	39.0	37.0	25,740	11,100
CA	915	770	678	715	64.5	64.1	43,700	45,825
CO	3,030	2,950	2,575	2,444	22.2	23.4	57,225	57,268
DE	40	32	35	28	30.0	36.0	1,050	1,008
FL	19	17	13	12	29.0	36.0	377	432
GA	135	160	100	120	33.0	32.0	3,300	3,840
ID	1,330	1,360	1,190	1,295	42.6	57.7	50,730	74,730
IL	1,650	1,050	1,570	930	43.0	38.0	67,510	35,340
IN	1,350	900	1,240	815	45.0	39.0	55,800	31,785
IA	130	75	109	55	37.0	31.0	4,033	1,705
KS	13,200	11,300	12,100	10,200	28.5	30.0	344,850	306,000
KY	380	280	274	195	37.0	35.0	10,138	6,825
LA	50	40	25	17	34.0	36.0	850	612
MD	140	115	120	108	36.0	37.0	4,320	3,996
MI	870	470	825	450	40.0	40.0	33,000	18,000
MN	3,425	2,850	3,327	2,776	39.6	33.6	131,894	93,225
MS	140	100	105	65	34.0	31.0	3,570	2,015
MO	2,000	960	1,760	840	39.0	34.0	68,640	28,560
MT	5,400	5,100	5,060	4,840	25.9	30.2	130,920	146,050
NE	3,300	2,900	2,950	2,550	35.0	32.0	103,250	81,600
NV	30	29	28	26	55.7	59.2	1,560	1,540
NJ	61	48	42	33	31.0	36.0	1,302	1,188
NM	555	477	425	298	21.5	19.0	9,137	5,662
NY	190	86	175	75	39.0	35.0	6,825	2,625
NC	235	220	200	180	30.0	33.0	6,000	5,940
ND	9,960	9,760	9,254	9,585	24.8	29.8	229,907	286,065
OH	1,580	1,200	1,540	1,125	47.0	39.0	72,380	43,875
OK	7,800	7,000	6,500	5,400	27.0	27.0	175,500	145,800
OR	1,308	1,285	1,230	1,225	38.7	42.4	47,620	51,925
PA	285	255	270	245	33.0	33.0	8,910	8,085
SC	107	95	95	78	29.0	33.0	2,755	2,574
SD	3,655	3,575	3,016	3,090	23.9	21.4	71,964	66,000
TN	373	310	280	220	36.0	35.0	10,080	7,700
TX	6,300	5,700	4,700	2,700	25.0	20.0	117,500	54,000
UT	251	215	204	188	23.1	29.8	4,716	5,599
VA	250	205	205	155	31.0	35.0	6,355	5,425
WA	3,120	3,120	2,985	2,910	33.9	46.0	101,305	133,980
WV	12	11	10	9	31.0	33.0	310	297
WI	83	48	75	45	41.0	34.7	3,075	1,560
WY	353	351	281	294	20.0	25.9	5,620	7,606
U.S.	75,119	66,094	66,461	56,839	30.6	31.6	2,036,318	1,798,712

Source: U.S. Department of Agriculture, 1979.

[a] Includes areas seeded in the preceding fall for winter wheat.

[b] Preliminary.

Table II-2.9 Red Winter Wheat and All Wheat Production Costs, 1978

Cost Item	Central Plains	Southern Plains	Northern Plains	Southwest	United States	All Wheat Total
Costs per Acre						
Variable						
Seed	$ 2.26	$ 2.79	$ 2.75	$ 9.19	$ 2.64	$ 3.89
Fertilizer	4.27	5.80	6.18	18.38	5.28	7.81
Lime	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	0.12
Chemicals[b]	0.61	1.21	1.05	4.74	0.94	1.16
Custom operations[c]	2.36	3.03	2.66	7.49	2.72	2.92
All labor	9.14	9.01	7.19	21.60	9.15	8.63
Fuel and lubrication	5.37	5.80	4.25	6.24	5.40	5.19
Repairs	5.81	5.65	5.91	7.63	5.81	5.89
Purchased irrigation water	NA[a]	NA[a]	0.73	33.16	0.80	0.55
Interest	1.28	1.38	1.36	4.66	1.40	1.48
Total—Variable	31.10	34.67	32.08	113.09	34.14	37.64
Machinery Ownership						
Replacement	13.52	13.64	14.51	17.69	13.76	14.15
Interest	5.90	5.59	6.71	7.63	5.93	6.17
Taxes and insurance	1.81	1.68	2.05	2.31	1.80	1.87
Total—Machinery Ownership	21.23	20.91	23.27	27.63	21.49	22.19
General Farm Overhead	6.63	5.17	6.16	13.44	6.36	6.55
Management[d]	5.90	6.08	6.15	15.42	6.20	6.64
Total—Excluding Land	64.86	66.83	67.66	169.58	68.19	73.02
Land Allocation, Composite with:						
Current value[e]	38.72	29.02	44.36	86.28	37.27	43.68
Average acquisition value[f]	23.96	15.96	21.71	62.39	21.96	25.07
Costs per Bushel						
Variable	1.13	1.66	1.00	1.84	1.28	1.27
Machinery Ownership	0.77	1.00	0.73	0.45	0.80	0.75
Farm Overhead	0.24	0.25	0.19	0.22	0.24	0.22
Management	0.21	0.29	0.19	0.25	0.23	0.22
Total—Excluding Land	2.35	3.20	2.11	2.76	2.55	2.46
Land Allocation, Composite with:						
Current value	1.40	1.39	1.39	1.41	1.40	1.47
Average acquisition value	0.87	0.76	0.68	1.02	0.82	0.84
Value of Pasture	0.06	0.35	NA[a]	NA[a]	0.12	0.06
Total Per-Bushel Costs of Production to a Renter						
Cost to share renter[g]	3.48	4.65	3.09	3.66	3.73	3.62
Cost to cash renter[h]	3.44	3.73	3.13	3.72	3.57	3.61
Weighted renter cost[i]	3.48	4.44	3.10	3.69	3.71	3.62
Yield per acre (bushels)	27.6	20.9	32.0	61.3	26.7	29.7
Percent of U.S. production	54.7	24.6	13.3	4.9	97.5	96.9

Source: U.S. Department of Agriculture, 1979.

[a] Not applicable.

[b] Includes herbicides, insecticides, and rodenticides not otherwise included under custom operations.

[c] Includes custom application of crop chemicals, the cost of chemicals in some cases, and custom harvesting and hauling.

[d] Based on 10 percent of above costs.

[e] Based on prevailing tenure arrangements in 1974, reflecting actual combinations of cash rent, net-share rent, and owner-operator land allocations, land values, land tax rates, and cash rates updated to current year.

[f] Same as footnote "e," except average value of cropland during the last 35 years is used for owner-operated land instead of current land value.

[g] Share-renter portion of cost divided by share-renter portion of crop.

[h] Cash-renter costs including cash rent divided by total yield.

[i] Weighted average of share renter and cash renter based on prevailing tenure arrangements in 1974.

Table II-2.10 Barley Area, Yield, and Production, 1977-78

State	Area Planted for All Purposes[a] (1,000 acres)		Area Harvested (1,000 acres)		Yield per Harvested Acre (bushels)		Production (1,000 bushels)	
	1977	1978[b]	1977	1978[b]	1977	1978[b]	1977	1978[b]
AZ	62	42	55	35	76.0	71.0	4,180	2,485
CA	1,150	1,100	950	950	56.0	48.0	53,200	45,600
CO	280	280	230	240	59.0	64.0	13,570	15,360
DE	34	33	22	24	44.0	44.0	68	1,056
GA[c]	9	—	7	—	37.0	—	259	—
ID	1,000	950	940	930	47.0	60.0	44,180	55,800
IL	10	10	9	7	42.0	36.0	378	252
IN[c]	9	—	8	—	40.0	—	320	—
KS	90	72	78	60	36.0	44.0	2,808	2,640
KY	39	37	25	23	46.0	43.0	1,150	989
MD	100	105	70	85	49.0	45.0	3,430	3,825
MI	21	20	19	19	52.0	47.0	988	893
MN	1,100	1,070	1,080	1,050	51.0	49.5	55,080	51,975
MO[c]	10	—	8	—	37.0	—	296	—
MT	1,550	1,500	1,430	1,375	36.5	41.0	52,195	56,375
NE	47	33	43	29	45.0	38.0	1,935	1,102
NV	21	22	19	20	65.0	60.0	1,235	1,200
NJ	40	39	17	20	48.0	46.0	816	920
NM	35	33	26	25	51.0	57.0	1,326	1,425
NY	11	11	10	10	44.0	42.0	440	420
NC	67	70	55	59	40.0	51.0	2,200	3,009
ND	2,690	2,500	2,530	2,450	39.0	46.0	98,670	112,700
OH	13	11	11	10	51.0	48.0	561	480
OK	140	100	120	80	35.0	34.0	4,200	2,720
OR	210	200	190	185	47.0	50.0	8,930	9,250
PA	135	135	125	125	50.0	47.0	6,250	5,875
SC	24	27	21	24	40.0	47.0	840	1,128
SD	680	600	640	565	42.0	37.0	26,880	20,905
TN	24	22	13	13	39.0	34.0	507	442
TX	150	110	85	40	40.0	27.0	3,400	1,080
UT	144	148	115	131	54.0	56.0	6,210	7,336
VA	115	123	92	101	44.0	50.0	4,048	5,050
WA	420	400	350	380	27.0	65.0	9,450	24,700
WV	10	11	9	10	42.0	44.0	378	440
WI	31	28	29	27	54.0	49.0	1,566	1,323
WY	150	145	133	131	55.0	63.0	7,315	8,253
U.S.	10,621	9,987	9,564	9,233	43.9	48.4	420,159	447,008

Source: U.S. Department of Agriculture, 1979.
[a] Includes areas seeded in the preceding fall.
[b] Preliminary.
[c] Estimates discontinued after 1977 crop.

Table II-2.11 Barley Production Costs, 1978

Cost Item	Northeast	Northern Plains	Southern Plains	Southwest	Northwest	United States
Costs per Acre						
Variable						
Seed	$ 6.23	$ 4.05	$ 4.57	$ 7.32	$ 5.43	$ 4.75
Fertilizer	14.16	5.60	7.07	18.52	10.73	7.01
Lime	2.74	NA[a]	NA[a]	NA[a]	NA[a]	0.04
Chemicals[b]	1.78	1.26	2.75	1.50	2.35	1.54
Custom operations[c]	3.24	2.60	2.52	4.38	3.26	2.95
All labor	9.76	7.90	13.24	21.38	12.42	10.62
Fuel and lubrication	4.95	4.83	12.68	5.87	4.12	5.19
Repairs	5.23	5.89	7.60	7.23	5.80	6.11
Purchased irrigation water	NA[a]	0.97	NA[a]	25.35	4.57	4.63
Miscellaneous	NA[a]	0.11	NA[a]	NA[a]	NA[a]	0.07
Interest	2.29	0.71	1.57	3.53	1.14	1.20
Total—Variable	50.38	33.92	52.00	85.08	49.82	44.11
Machinery Ownership						
Replacement	14.38	14.20	21.61	16.63	15.38	15.03
Interest	6.02	6.37	9.04	7.05	7.07	6.68
Taxes and insurance	1.81	1.93	2.79	2.12	2.13	2.02
Total—Machinery Ownership	22.21	22.50	33.44	25.80	24.58	23.73
General Farm Overhead	8.35	5.55	5.60	11.15	7.05	6.56
Management[d]	8.09	6.20	9.10	12.20	8.15	7.44
Total—Excluding Land	89.03	68.17	100.14	134.13	89.60	81.84
Land Allocation, Composite with:						
Current value[e]	109.79	34.31	40.23	71.92	60.55	44.82
Average acquisition value[f]	40.56	18.46	25.12	46.61	30.52	24.66
Costs per Bushel						
Variable	1.16	0.78	1.09	2.02	0.88	0.97
Machinery Ownership	0.51	0.51	0.70	0.62	0.43	0.52
Farm Overhead	0.19	0.13	0.12	0.26	0.12	0.14
Management	0.19	0.14	0.19	0.29	0.14	0.16
Total—Excluding Land	2.05	1.56	2.10	3.19	1.57	1.79
Land Allocation, Composite with:						
Current value	2.57	0.79	0.85	1.71	1.06	0.98
Average acquisition value	0.93	0.42	0.53	1.11	0.53	0.54
Total Per-Bushel Costs of Production to a Renter						
Cost to share renter[g]	3.59	2.31	2.95	4.89	2.20	2.72
Cost to cash renter[h]	2.74	2.17	3.23	3.84	2.11	2.46
Weighted renter cost[i]	2.83	2.26	2.98	4.63	2.19	2.64
Yield per acre (bushels)	43.5	43.7	47.6	42.1	57.1	45.8
Percent of U.S. production	1.3	56.5	4.0	10.8	18.5	91.1

Source: U.S. Department of Agriculture, 1979.

[a] Not applicable.

[b] Includes herbicides, insecticides, and rodenticides not otherwise included under custom operations.

[c] Includes custom application of crop chemicals, the cost of chemicals in some cases, and custom harvesting and hauling.

[d] Based on 10 percent of above costs.

[e] Based on prevailing tenure arrangements in 1974, reflecting actual combinations of cash rent, net-share rent, and owner-operator land allocations, land values, land tax rates, and cash rates updated to current year.

[f] Same as footnote "e," except average value of cropland during the last 35 years is used for owner-operated land instead of current land value.

[g] Share-renter portion of cost divided by share-renter portion of crop.

[h] Cash-renter costs including cash rent divided by total yield.

[i] Weighted average of share renter and cash renter based on prevailing tenure arrangements in 1974.

Table II-2.12 Potatoes Area, Yield, Production, and Value, 1964-78

Year	Area Planted (1,000 acres)	Area Harvested (1,000 acres)	Yield per Harvested Acre (cwt)	Production (1,000 cwt)	Season Average Price per cwt by Farmers (dollars)	Value of Production (1,000 dollars)
1964	1,311.3	1,271.9	190	241,076	3.50	846,017
1965	1,418.4	1,383.1	210	291,109	2.53	730,527
1966	1,497.6	1,462.6	210	307,242	2.04	622,581
1967	1,499.1	1,459.9	209	305,766	1.87	567,557
1968	1,414.5	1,383.3	214	295,401	2.23	657,202
1969	1,457.6	1,415.5	221	312,578	2.24	697,845
1970	1,449.5	1,421.0	229	325,716	2.21	715,123
1971	1,432.1	1,391.0	230	319,329	1.90	602,907
1972	1,301.1	1,255.6	236	296,359	3.02	895,903
1973	1,329.8	1,306.6	230	300,013	4.90	1,471,942
1974	1,421.6	1.391.6	246	342,395	4.01	1,354,928
1975	1,303.6	1,264.0	255	322,254	4.48	1,444,608
1976	1,407.3	1,374.5	260	357,674	3.59	1,282,856
1977	1,397.5	1,358.7	261	354,576	3.55	1,253,616
1978	1,394.8	1,368.1	263	360,467	3.56	1,273,604

Source: U.S. Department of Agriculture, 1979.

Grain Sorghum

Grain sorghum is also called yellow sorghum, or milo. Its importance as a feed crop has increased in the United States in the last two decades. One of its greatest values is that it can be grown in semiarid regions without extensive irrigation. It is used as feed for beef and dairy cattle, sheep, swine, and poultry. Some sorghum varieties contain high amounts of tannin, which decreases palatability as a feed crop. Development efforts with yellow sorghum, however, have resulted in a low-tannin variety. Table II-2.5 gives area, yield, and production of grain sorghum in the United States for 1977–78. Table II-2.6 shows silage and forage utilization in 1977–78, and Table II-2.7 gives production costs for 1978.

Wheat and Barley

Table II-2.8 provides information on area, yield, and production of wheat in the United States for 1977–78; Table II-2.9 gives wheat-production costs for 1978, and Tables II-2.10 and II-2.11 give similar information for barley. Table II-2.1 gives a comparison of the compositions of wheat, barley, corn, and grain sorghum. Both wheat and barley produce results similar to those of corn when used in ethanol production.

Potatoes and Sweet Potatoes

Little specific information exists on the fermentation of potatoes or sweet potatoes. They have a high starch content, which can be converted to fermentable sugar. Harvesting may adversely affect the cost-effectiveness of using potatoes. Table II.2.12 shows area, yield, production, and value for potatoes grown in the United States from 1964 to 1978.

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Feedstocks and Their Coproducts

Sugar Crops

Sugar crops include sugarcane, sugar beets, sweet sorghum, Jerusalem artichokes, fodder beets, and fruits. They contain individual or bonded pairs of six-carbon sugars, making processing for preparation of fermentation a simple, mechanical procedure of pressing or crushing, and extracting the juice. Low equipment, labor, and energy costs are some advantages of using sugar crops. (Molasses, a by-product of sugarcane refining, is not a crop but is considered a sugar feedstock for ethanol production.)

Because of the high moisture and sugar content of these crops, microorganisms tend to attack them, and they spoil quickly. Storage for any length of time requires concentrating the sugar solution, usually by evaporation, which has a high equipment and energy cost. Sterilization of the juice may be a workable short-term storage alternative and is being investigated.

Chemically, all that is necessary to prepare sugar feedstocks for fermentation is to hydrolyze the single bond between the monomeric sugars. The enzyme diastase, which is produced by many of the *Saccharomyces* species of yeast, will convert sucrose, a disaccharide of fructose and glucose, to monomeric form.

The following table compares Jerusalem artichokes and sugar beets.

Table II-3.1 Comparison of Crop Yields for Ethanol Production

Material	Average Yield 1977-78 (normal unit of sale per acre)[a]	Yield (gallons EtOH per normal unit of sale)[b]	Yield (gallons EtOH per acre)
Jerusalem artichokes	15-20 tons	20/ton	300-400
Sugar beets	2.45 tons	20/ton	409

Sources:

[a]U.S. Department of Agriculture, 1979.

[b]SERI, 1980.

Sugarcane

Sugarcane yield and production for 1977–78 are shown in Table II-3.2, and sugar production for 1977–78 is shown in Table II-3.3. In addition to the advantage of its high sugar concentration and yield, the cane residue, or bagasse, can be used as a fuel for the process heat in ethanol production. Sugarcane juice may be fermented in a mash up to 17% sugar (Paturau, 1969). A disadvantage of sugarcane is the limited geographical area in which it may be grown in the United States—an area that comprises Florida, Louisiana, Texas, and Hawaii.

Table II-3.2 Sugarcane Yield, 1977-78

	Area Harvested (1,000 acres)		Yield of Cane per Acre (tons)		Cane Production (1,000 tons)	
State	1977	1978[a]	1977	1978[b]	1977	1978[a]
FL	285.0	296.0	29.8	30.8	8,493	9,117
HI	96.8	101.2	92.9	97.5	8,994	9,867
LA	304.0	278.0	23.9	21.0	7,265	5,838
TX	33.5	33.8	29.2	31.1	978	1,051
U.S.	719.0	709.0	35.8	36.5	25,830	28,873

Source: U.S. Department of Agriculture, 1979.

[a] The growth of 9 months in Louisiana, 12 months in Florida, and 18-24 months in Hawaii. The sugar harvest usually ends by December or early January in Louisiana; by March in Florida, following the season of growth. The harvest takes place throughout the year in Hawaii.

[b] Preliminary.

Table II-3.3 Sugarcane Yield, 1977-78

	Sugar per Ton of Cane, Raw Value[a] (pounds)		Sugar Produced, Raw Value[a] (1,000 tons)		Equivalent Refined[b] (1,000 tons)	
State	1977	1978[c]	1977	1978[d]	1977	1978[c]
FL, LA, TX	197	199	1,650	1,594	1,542	1,491
HI	230	210	1,034	1,037	966	969
U.S.	209	203	2,684	3,262	2,508	2,460

Source: U.S. Department of Agriculture, 1979.

[a] Raw value is the equivalent in terms of ordinary commercial sugar that tests as 96° optical polarizing quality as defined in the Sugar Act of 1948.

[b] Calculated on the basis that 100 pounds of raw sugar is required to produce 93.46 pounds of refined sugar.

[c] The growth of 9 months in Louisiana, 12 months in Florida, and 18-24 months in Hawaii. The sugar harvest usually ends by December or early January in Louisiana; by March in Florida, following the season of growth. The harvest takes place throughout the year in Hawaii.

[d] Preliminary.

Molasses

Molasses, the residue of sugar production from sugarcane, is a valuable ethanol feedstock. Because of its high concentration of mineral constituents and nonassimilable compounds with a high osmotic pressure, it is best fermented with sugar concentrations of 14% or less. Table II-3.4 shows molasses production in the United States in 1977–78; Table II-3.5 shows the composition of molasses. The stillage, or residue, from molasses fermentation has been used as an animal feed. It is generally evaporated to about 50% solids in a multiple-effect vacuum evaporator. It contains about 80 milligrams riboflavin per gram and 30% protein, and it is generally mixed with a feed concentrate. It also has been used as a fertilizer and may be applied directly to the soil or after liming. The dried stillage contains 1.5% potash, 0.2% phosphate, and 1% nitrogen (Paturau, 1969, pp. 183, 201).

Table II-3.4 Molasses Production, 1977-78

State	Molasses 1977 (1,000 gallons)	1978 (1,000 gallons)[a]
FL, LA, TX	114,330	112,432
HI	50,564[b]	53,040
U.S.	164,894	165,472

Source: U.S. Department of Agriculture, 1979.

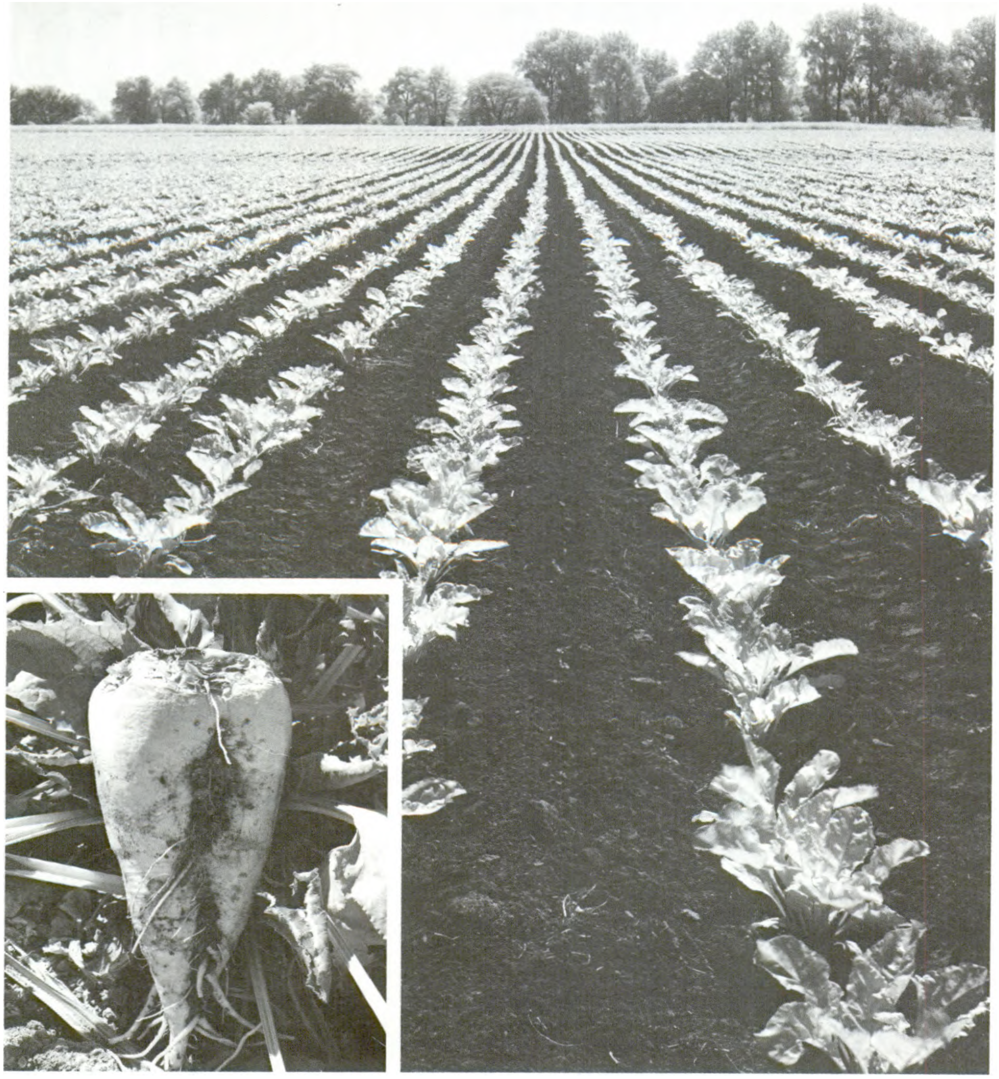
[a] Blackstrap (80° Brix), high-test molasses from frozen cane, and edible molasses.

[b] 85° Brix.

Table II-3.5 Composition of Molasses

Components	Composition % Range	Average
Water	17-25	20
Sucrose	30-40	35
Dextrose (glucose)	4-9	7
Levulose (fructose)	5-12	9
Other reducing substrates	1-5	4
Ash	7-15	12
Nitrogenous compounds	2-6	4.5
Non-nitrogenous acids	2-8	5
Waxes, sterols, phospholipids	0-1	0.4

Source: Paturau, 1969.



Sugar beets are presently grown in 19 states, and the potential for cultivation in other parts of the country is high because sugar beets tolerate a variety of climatic and soil conditions.

Sugar Beets

Sugar beets tolerate a wide range of climatic and soil conditions and are grown in 18 states. The beet pulp and beet tops provide high-yield coproducts. The beet pulp may be used as an animal feed and the beet tops, which may also be considered for animal feed, can provide organic material and ground cover to prevent erosion, provide nutrients to the soil, and improve tilth. One disadvantage of beet growing is the need to rotate sugar beets with nonroot crops because of the detrimental effect of nematodes, which build up in the soil with continuous planting of any root crop. The generally accepted ratio is one beet crop per four-year period. Table II-3.6 gives the area, yield, and production data for sugar beets for 1977 and 1978. Table II-3.7 lists the value of sugar beet production state-by-state in 1977.

Table II-3.6 Sugar Beet Area, Yield, and Production, 1977-78

State	Area Planted (1,000 acres)		Area Harvested (1,000 acres)		Yield per Harvested Acre (tons)		Production (1,000 tons)	
	1977	1978[a]	1977	1978[a]	1977	1978[a]	1977	1978[a]
AZ[b]	12.9	15.7	12.8	15.0	22.3	20.5	285	308
CA[b]	227.0	207.0	217.0	195.0	26.1	24.5	5,664	4,778
CO	77.0	89.0	72.0	84.0	19.5	18.3	1,404	1,538
ID	115.4	136.3	107.4	134.1	19.5	20.3	2,094	2,722
KS	26.0	18.0	24.0	26.0	16.7	17.0	401	442
MI	92.3	93.0	85.5	91.0	21.0	19.3	1,796	1,756
MN	264.0	265.0	260.0	263.0	18.2	18.9	4,732	4,971
MT	46.4	45.4	45.0	44.0	19.9	19.8	896	885
NE	75.0	79.0	67.7	67.7	20.0	18.0	1,354	1,368
NM	1.3	2.1	1.2	1.2	19.2	20.6	23	37
ND	157.8	156.2	155.2	155.2	17.8	19.7	2,769	3,056
OH	24.9	24.5	23.3	23.3	20.3	16.9	457	394
OR	8.9	9.2	8.9	8.9	25.1	24.0	206	214
TX	19.9	28.0	23.5	23.5	17.3	17.6	309	414
UT	10.4	14.9	14.7	14.7	17.7	17.0	173	250
WA	63.9	69.2	68.5	68.5	24.3	26.5	1,495	1,815
WY	49.5	49.5	48.8	48.8	19.6	18.9	949	922
U.S.	1,272.6	1,312.0	1,216.2	1,273.5	20.6	20.3	25,007	25,868

Source: U.S. Department of Agriculture, 1979.

[a] Preliminary.

[b] Relates to year of harvest.

Table II-3.7 Sugar Beet Production and Value, 1977

State	Production (1,000 tons)	Season Average Price per Ton Received by Farmers (dollars)	Value of Production (1,000 dollars)
AZ	285	24.40	6,954
CA	5,664	26.40	149,530
CO	1,404	26.30	36,925
ID	2,094	25.50	53,397
KS	401	21.90	8,792
MI	1,796	21.10	36,100
MN	4,732	20.60	97,479
MT	896	29.10	26,074
NE	1,354	27.00	36,558
NM	23	25.00	575
ND	2,769	21.40	59,257
OH	457	20.20	9,231
OR	206	23.00	4,738
TX	309	23.40	7,231
UT	173	26.50	4,619
WA	1,495	26.50	39,618
WY	949	28.80	27,331
U.S.	25,007	24.20	604,399

Source: U.S. Department of Agriculture, 1979.

Sweet Sorghum

Sweet sorghum is the common name given to varieties of *Sorghum bicolor*, which contains more sugar than its more familiar relative, grain sorghum. There are various strategies for using sweet sorghum. When immature, the entire plant, sugar and cellulose both, can be converted to ethanol with known processes. When mature, the grain (milo) can be processed. Other strategies are being studied.

Principal advantages of sweet sorghum are its great tolerance to a wide range of climatic and soil conditions and its relatively high yield of ethanol per acre. The plant can be harvested three ways:

1. The whole plant can be harvested and stored in its entirety.
2. It can be cut into short lengths (about four inches long), with juice extraction carried out immediately.
3. It can be harvested and chopped for silage.

Since many varieties of sweet sorghum also bear significant quantities of milo, the harvesting procedure will depend on what strategy is used for conversion. The leaves and fibrous residue of sweet sorghum contain large amounts of protein, making the stillage a potential livestock feed. The fibrous residue can also be used as a fuel for alcohol processing (Solar Energy Research Institute, 1980, p. 41).

Jerusalem Artichokes

A member of the sunflower family, this crop is native to North America and well-adapted to a variety of climates. It can grow in various soils and does not require great soil fertility. The Jerusalem artichoke is a perennial; small tubers left in the field will produce next season's crop, so no plowing or seeding is necessary. Like the sugar beet, Jerusalem artichokes produce sugar in the top growth and store it in the roots and tuber. The majority of the sugar produced in the leaves does not enter the tuber until the plant has reached the end of its productive life. It may be possible to harvest a portion of the stalk of the Jerusalem artichoke when the sugar content in the stalk reaches a maximum, thereby avoiding harvesting the tuber. In this case, the harvesting equipment and procedures are essentially the same as for harvesting sweet sorghum or corn for silage (Solar Energy Research Institute 1980, p. 41).

The Jerusalem artichoke is traditionally grown for the tuber, however, the majority of the sugar produced in the leaves does not enter the tuber until the plant has nearly reached the end of its productive life.

Jerusalem artichokes contain the same percentage of carbohydrate as potatoes, but the sugar yield per acre is greater. Reportedly they are less difficult than potatoes to cultivate and less susceptible to diseases and pests. The tubers are not affected by frost and can be stored easily in silos. Their sugar is in the form of inulin, a fructose polysaccharide, which is relatively easy to convert to monomeric sugar through dilute-acid hydrolysis. Inulin also has a fast fermentation time (10 hours for completion of batch fermentation). The yield of ethanol per ton of tubers is 20.4 gallons, and the yield of ethanol per acre is from 300 to 400 gallons. The residues contain 20% to 25% protein (Agricultural Alcohol Blended Fuel Study Conference, 1959).

Fodder Beets

Another promising sugar crop is the fodder beet, species *Beta vulgaris*. Test plots in New Zealand indicate the possibility of very high per-acre yields. The fodder beet is a forage crop obtained by crossing two other beet species—sugar beets and mangolds. It is agronomically similar to sugar beets. The attraction of this crop lies in its higher yield of fermentable sugars per acre relative to sugar beets, and its comparatively high resistance to loss of fermentable sugars during storage. Culturing of fodder beets requires fewer fertilizer requirements than does culturing of sugar beets (Solar Energy Research Institute, 1980, p. 41).

Fruit Crops

Fruit crops are unlikely to be used directly for ethanol production because of their value for direct human consumption. However, the wastes from processing fruit crops are useful as an ethanol-production feedstock, with the added benefit of reducing the potential environmental impact of these wastes. Table II-3.8 gives the production of selected U.S. fruit crops from 1964 through 1978. The amount of resulting waste is unknown at this time.

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3. Solar Energy Research Institute. 1980. *Fuel from Farms: A Guide to Small-Scale Ethanol Production.* Golden, CO: SERI. Available from: Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

Table II-3.8 Production of Selected Fruit Crops, 1965-78

Year	Apples Commercial Crop (1,000 tons)	Peaches (1,000 tons)	Pears (1,000 tons)	Grapes (1,000 tons)
1964	3,160	1,726	728	3,478
1965	3,070	1,737	500	4,351
1966	2,881	1,695	748	3,734
1967	2,718	1,344	464	3,069
1968	2,735	1,818	624	3,549
1969	3,410	1,842	727	3,899
1970	3,199	1,498	549	3,103
1971	3,187	1,441	749	3,994
1972	2,939	1,186	612	2,579
1973	3,133	1,295	730	4,198
1974	3,290	1,459	742	4,199
1975	3,765	1,419	749	4,366
1976	3,237	1,510	841	4,398
1977	3,336	1,492	787	4,298
1978	3,817	1,351	727	4,567

Source: U.S. Department of Agriculture, 1979.

Feedstocks and Their Coproducts

Industrial and Food-Processing Waste

A potential feedstock source for alcohol production is industrial and food-processing waste. Currently this is an area of research and development rather than commercial application.

The two primary food-processing wastes that might be used as feedstocks for alcohol production are cheese whey and cannery wastes, including both vegetable and fruit wastes. Cannery wastes can be processed to provide protein, methane, or alcohol. No commercial operations exist using these wastes for alcohol production, and little research is under way. Cheese whey, on the other hand, is the focus of considerable research, including work at the Solar Energy Research Institute.

Cheese whey is easily fermentable and contains 6.5% solids, including 4.5% to 5% sugar in the form of lactose, 0.8% protein, and mineral salts. The present yield of cheese whey, a waste product of the dairy industry, could be converted to 100 million gallons of ethanol a year and 4,000 tons of protein, which could be used for human food.

Ethanol production from cheese whey would require each dairy-processing plant to have its own ethanol-production plant on site. Initial calculations indicate that transportation of the whey more than 100 miles makes costs prohibitive. The average dairy plant yields 30,600 pounds of cheese whey a day. This means 1,200 pounds of lactose could be converted into about 91 gallons of ethanol per day, which would require a small-scale plant. The Milbrew Company in Juneau, Wisconsin, is currently producing two million gallons a year of 193-proof ethanol from cheese whey.

One problem that needs to be solved cost-effectively is treatment of the stillage after alcohol production. This waste has a high biological oxygen demand (BOD), an indication of its potential for environmental damage. If a sewage-treatment type of facility is not used, whey waste becomes a major pollutant. Research is focusing on shortening the fermentation process, adopting continuous fermentation, extracting protein, and scaling up the processes for commercial applicability. In addition, the economics of operating such a plant on a profitable basis must be demonstrated.

The only industrial waste currently being used as a feedstock for ethanol production is lignosulfonate waste produced from the sulfite process used in certain pulp mills. Only this particular pulp-mill process yields fermentable sugars appropriate for alcohol production. Of the 11 such mills in the United States, only the Georgia Pacific Company has an alcohol-production plant connected to a pulp mill. Located in Bellingham, Washington, this plant has been operating since 1944. The plant was originally built to produce ethanol for use in manufacturing synthetic rubber during World War II. Today it produces 5.3 million gallons of 190-proof ethanol per year, of which 1.8 million gallons is converted to 200-proof ethanol. (In May 1980, ethanol sold for $1.80 per gallon to gasohol distributors and other markets.)

The Georgia Pacific operation is commercially viable for these reasons: the plant was built in 1944, so today's capital costs are not a factor; a continuous fermentation process is used, maximizing production; and the company has a strong research program on the use and market development of desugared lignin, the waste from the fermentation process. This lignin can be used in a variety of industrial processes, for

Table II-5.1 Sulfite Process Pulp Mills

Pulp Plant; Location	Pulp (Tons per Day)
ITT—Rayonier; Hoquiam, Washington	450
Finch; Pruyn, New York	200
Crown Z; Lebanon, Oregon	100
Consolidated Paper, Appleton, Wisconsin	130
Boise-Cascade; Salem, Oregon	200
Wausau; Wausau, Wisconsin	160
American Can; Green Bay and Rothschild, Wisconsin	350
Flambeau; Wisconsin	100
St. Regis; Wisconsin	80
Badger Paper; Wisconsin	100

Source: Georgia-Pacific Co., Bellingham, Washington.

example, as a resin or as a filler. (Georgia Pacific holds several patents on lignin production and use, giving them an advantage in the marketplace.)

Alcohol-fermentation plants must be located on site with the pulp mill to be cost effective. Table II–5.1 lists the plants using the sulfite process to produce pulp; most of them, however, currently burn the wastes for process heat, which at this time is a more cost-effective use.

Most pulp mills operate 350 days a year and could produce 26 gallons of 190-proof ethanol per ton of pulp. The potential alcohol production from these pulp mills is a little more than 17-million gallons of ethanol per year. Currently the addition of alcohol-production plants to these pulp mills appears not to be economically viable.

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Ethanol Production Processes

Introduction

Ethanol may be produced two ways. One involves fermentation of sugar. The other is a process involving ethylene, a by-product of petroleum refining. In the petroleum process, ethanol is produced either with a chemical reaction between ethylene and sulfuric acid or by subjecting ethylene to direct catalytic hydration (U.S. Department of Agriculture, 1950). Because the purpose of this guide is to examine ethanol as an alternative to petroleum-based fuels, the oil-derivative process is not discussed.

Fermentation has a long history. Fermented beverages were mentioned in the *Rig Veda*, an ancient sacred book of India; the Old Testament of the *Bible;* and early Egyptian and Arabic records. A comprehensive text on alcohol, *Das Kleine Distillierbuch*, was published in Strasbourg, France, in 1500. In 1808, the first continuous still was built in France. The use of ethanol as an industrial chemical increased in the 1800s. Because ethanol can be an alcoholic beverage, it usually was heavily taxed, which made it infeasible for industrial use until a process called denaturing was adopted. The first denaturant law was passed in Great Britain in 1855. It provided for the addition of a substance (the denaturant) to ethanol to make it unfit for human consumption. This exempted ethanol from beverage excise taxes. Both World War I and II brought increased use of fermentation ethanol, which was used in synthetic rubber production and as an airplane fuel; but the emphasis since World War II has been on ethanol production from petroleum (Paturau 1969, p. 169). It is only in the past 10 years, with increased concern about depletion of renewable resources and rising imported crude oil prices, that interest has been rekindled in fermentation ethanol.

Fermentation is a biochemical process in which an organic substance (called a substrate) is changed through the action of enzymes produced by micro-

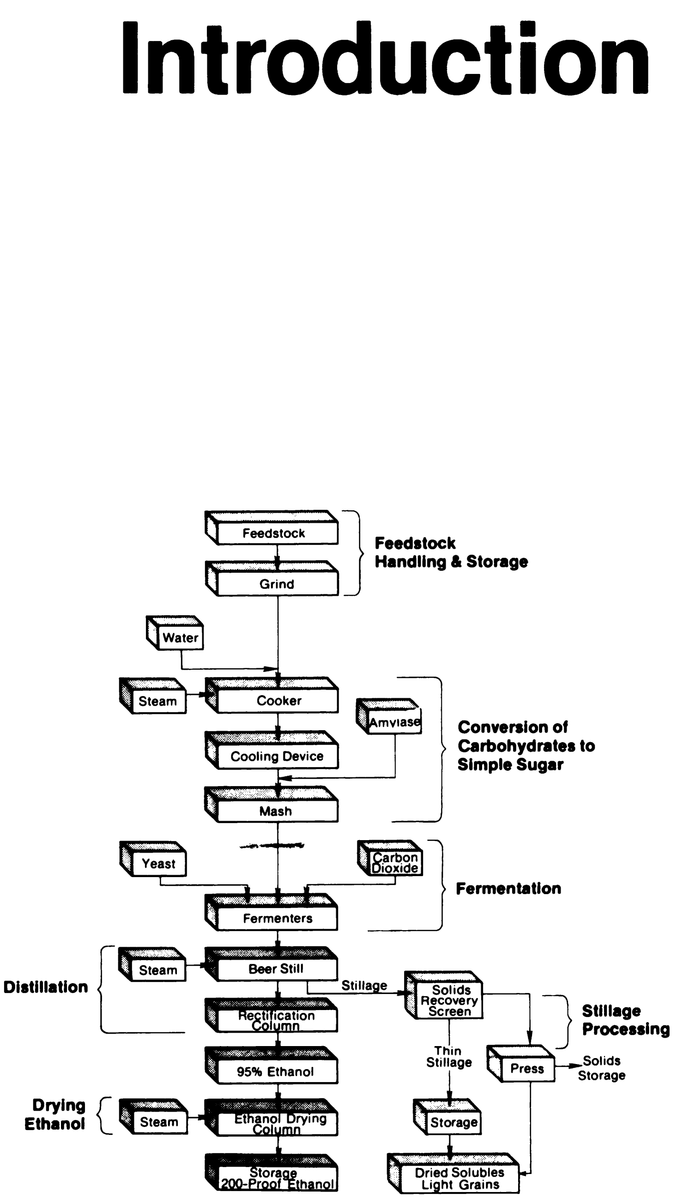

Figure III-1.1 Anhydrous ethanol production flow chart

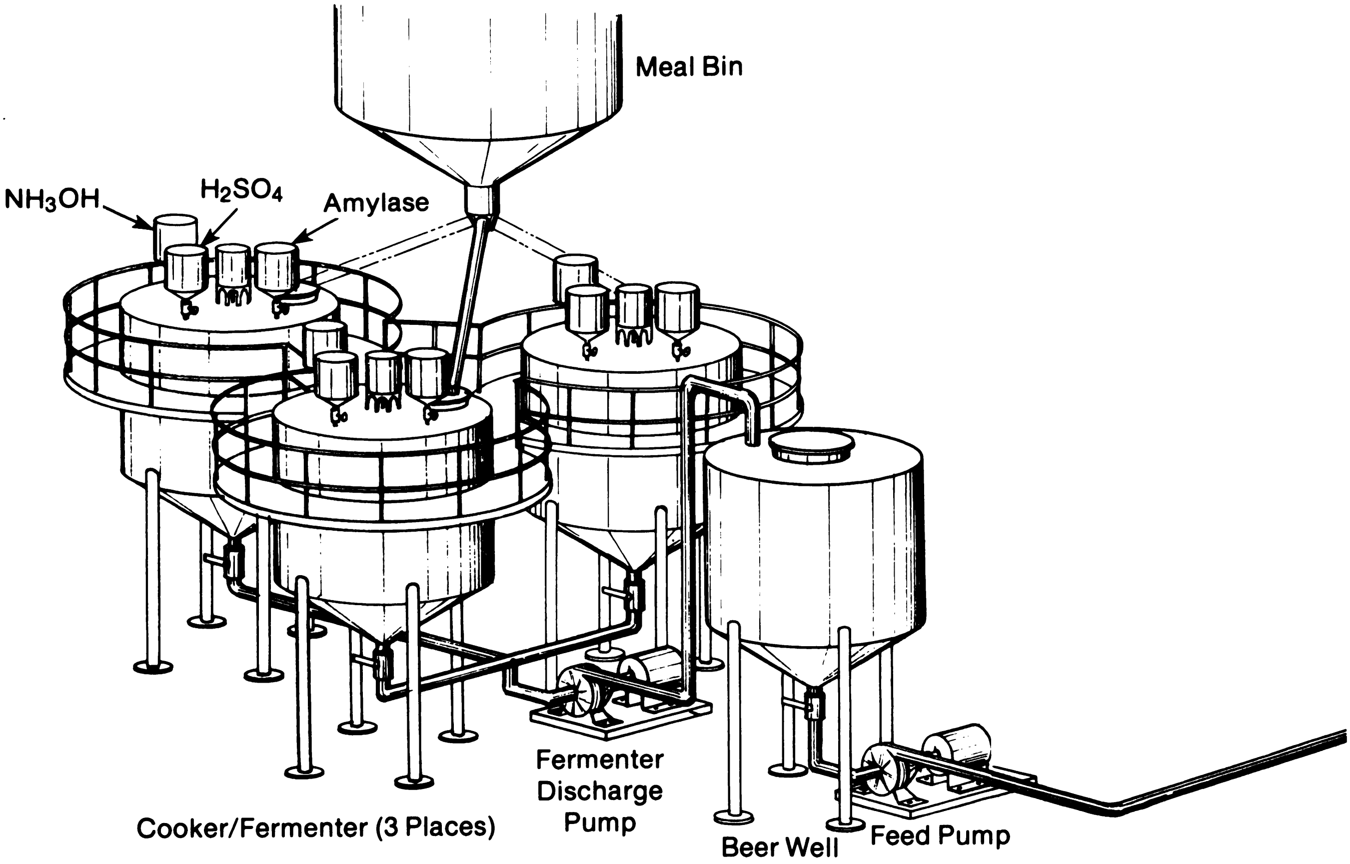

Figure III-1.2a Fermentation Part of Generic Ethanol Plant

organisms. In the case of ethanol fermentation, the substrate is a six-carbon sugar (e.g., glucose and maltose). The process is called anaerobic fermentation and is carried out by anaerobic microorganisms. There are two types of anaerobic microorganisms: strict anaerobic and facultative anaerobic. The latter can grow under both anaerobic and aerobic conditions. They have a greater potential for commercial fermentation use.

The microorganisms involved in fermentation include yeasts, molds, and bacteria. They differ considerably but have one characteristic in common. They lack chlorophyll. Therefore, they cannot manufacture their own food through photosynthesis as other plants can. Instead they produce enzymes that act as catalysts to convert carbohydrates from the organic material around them into energy for the yeast metabolic processes. The enzymes that anaerobic microorganisms produce are of two main types: hydrolases (or hydrolyzing enzymes) and demolases (or metabolizing enzymes).

The complex chemical reactions of the anaerobic breakdown of glucose to ethanol is described by the glycolytic, or Embden-Meyerhof-Parnas, pathway. The major reaction, however, can be summarized as:

$$\underset{\text{glucose}}{C_6H_{12}O_6} \rightarrow \underset{\text{ethanol}}{2C_2H_5OH} + \underset{\text{carbon dioxide}}{2CO_2} + \text{Heat}$$

This simplified equation implies that only ethanol and carbon dioxide are produced. However, minor products such as glycerols, acetic acid, succinic acid, butylene glycol, acetaldehyde, lactic acid, and fusel oils may also be produced. The type and proportion of these minor products is a function of the materials in

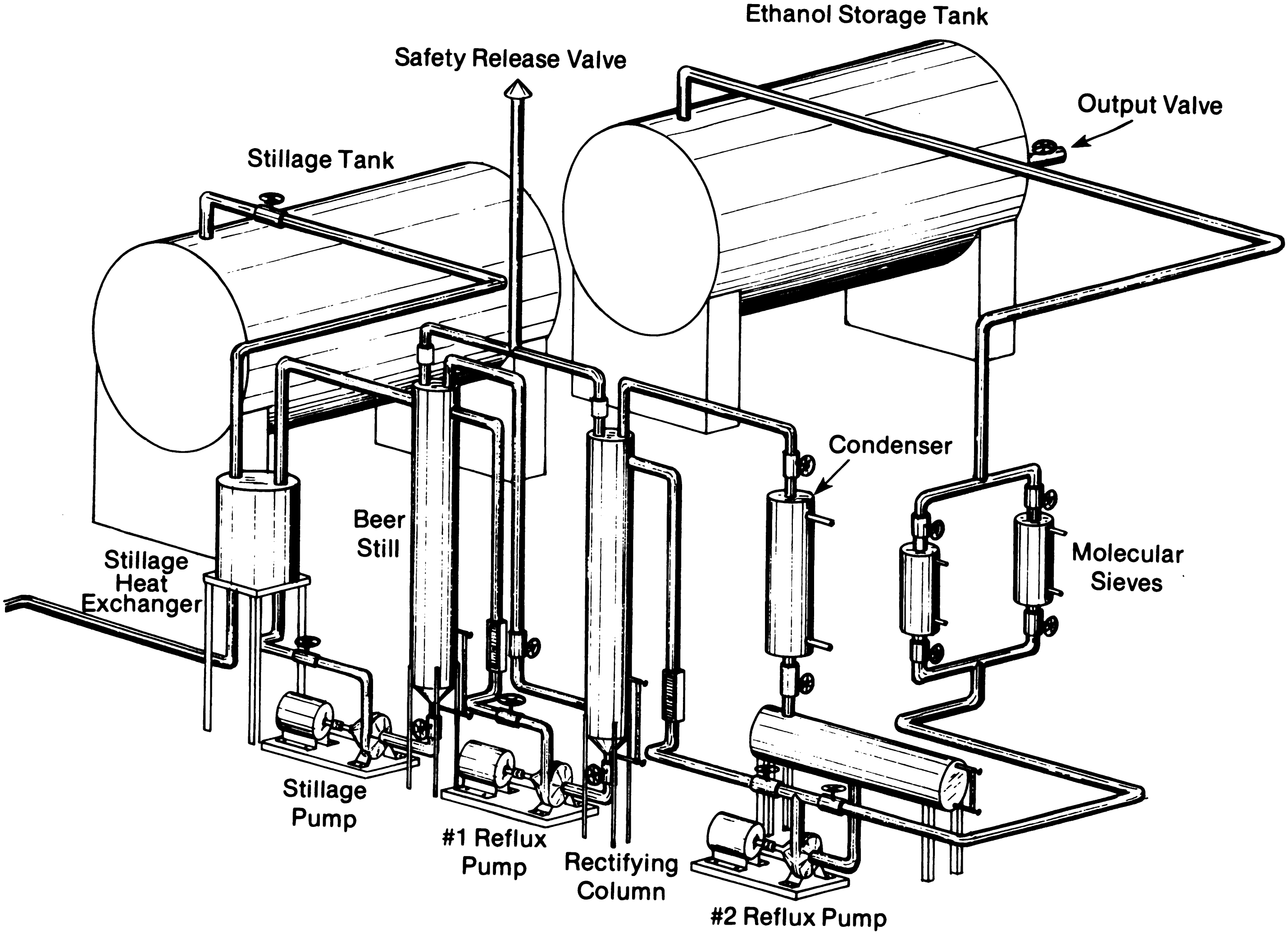

Figure III-1.2b Distillation Part of Generic Anhydrous Ethanol Plant

the fermentation mixture (called the mash or wort), the type of yeast used, the temperature, and the pH. Some of the wort may be used by the microorganisms to produce new cells, and some of the ethanol may be lost with escaping carbon dioxide. Thus, while in theory (by balancing the reaction equation) the ethanol yield should be 51% of the mass of fermentable sugar, the maximum practical yield is 48% (Roman, 1952).

The stages of ethanol production are feedstock storage, feedstock preparation (including starch-to-sugar conversion, if appropriate), fermentation, distillation, ethanol drying, ethanol storage, and coproduct treatment. Figure III-1.1 diagrams the ethanol-production process, and Figure III-1.2 depicts a sample ethanol plant.

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Ethanol Production Processes

Feedstock Preparation

Cleaning

The first step in feedstock preparation is cleaning. In the case of grains, this may be accomplished by blowing air to remove light debris and by screening to separate stones and other large debris. Root crops may require streams of high-pressure water. There are special machines for cleaning sugar beets and Jerusalem artichoke tubers (Agricultural Alcohol Blended Fuel Study Conference, 1975).

The next step is to obtain the necessary sugar from the feedstock so that fermentation may take place. How this is done depends on the type of feedstock used.

Wet Milling

Wet milling may be incorporated into the feedstock-preparation phase in large-scale production facilities. Its initial high capital costs make it inappropriate for small-scale operations. It is a process in which the protein, fiber, and starch are separated at the beginning of production. The protein may then be used for human consumption; the fiber may also be considered a coproduct; and the starch may be converted to sugar for ethanol production. The steps of wet milling are:

- The grain is soaked in a very dilute aqueous solution of sulfur dioxide.
- The hulls are ripped apart by metal grinding wheels without mashing the germ.
- The germ is separated from the rest of the grain in a centrifuge.
- The material is passed over a screen to separate the starch and protein from the fiber and hulls.
- The starch and protein are blended with water to make a slurry.
- The slurry is sent to a centrifuge, which separates the protein (gluten) from the starch.

For feedstocks such as potatoes, starch and cellulose must be reduced from their complex form to basic glucose because yeast can only act on simple sugars to produce ethanol.

Obtaining Sugar from Starch Crops

The starch in such crops as grains and potatoes must be made water soluble before it can be converted to sugar. First, the feedstock is broken down mechanically by milling, grinding, or slicing. A grain feedstock should be milled to particles between 20 and 40 U.S. standard mesh size (0.036 to 0.017 inch). Potatoes can be ground to the consistency of a milkshake. After being prepared, the long-branched chains of starch molecules are converted into glucose, a fermentable sugar. This may be done by acid or enzymatic hydrolysis. Acid hydrolysis is a one-step process in which the feedstock is mixed with a mild solution of sulfuric acid. The amount of acid used should equal three-to-seven times the mass of the starch. Hydrochloric acid equaling 0.6 to 1.4 times the mass of the starch may also be used. One problem with acid hydrolysis is that the process may continue to consume some of the glucose produced. In this case, maximum potential yields are not realized.

Enzymatic hydrolysis takes place in two steps: liquefaction, or dextrinization, and saccharification. First the prepared feedstock is mixed with water, making a slurry, and the alpha-amylase, or liquefying enzyme, is added. The slurry is heated at temperatures high enough to cause the cells to absorb water and expand. This action is called gelatinization. The liquefying enzyme breaks down the gelatinized starch molecules into dextrins, a form of sugar. The efficiency of liquefaction is a function of temperature, residence time at the appropriate temperature, rate of heat up, and the amount of available liquefying enzyme. For saccharification to begin, the temperature and pH are changed and a different enzyme (glucoamylase) is added. Saccharification breaks down the dextrins into glucose, a sugar that can be fermented by yeast. The conditions of time, pressure, temperature, and pH that enable the enzymes to work most effectively during saccharification vary from enzyme to enzyme.

Simple sugars can be extracted by either crushing or pressing sugar beets. The low-sugar bagasse and pulp which remain after pressing can be leached with water to remove residual sugars.

Obtaining Sugar from Sugar Crops

For crops that contain sugar rather than carbohydrate, such as sugarcane, sugar beets, sweet sorghum, or fruits, the feedstock may be merely crushed and pressed and the juice used for fermentation. In addition, the remaining pulp may be leached with water to get out even more of the residual sugar. Molasses, a waste material from the production of refined sugar, may also be considered a feedstock source for ethanol and can be used the same way as crushed sugarcane.

Obtaining Sugar from Cellulosic Materials

There are no commercially available small-scale processes for obtaining sugar from cellulose. There is a major emphasis, however, through current research and development work to obtain such a process because of the low cost and high availability of cellulose as a potential feedstock for alcohol fuels. There are development plans for experimental large-scale pilot plants utilizing cellulose.

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Ethanol Production Processes

Fermentation

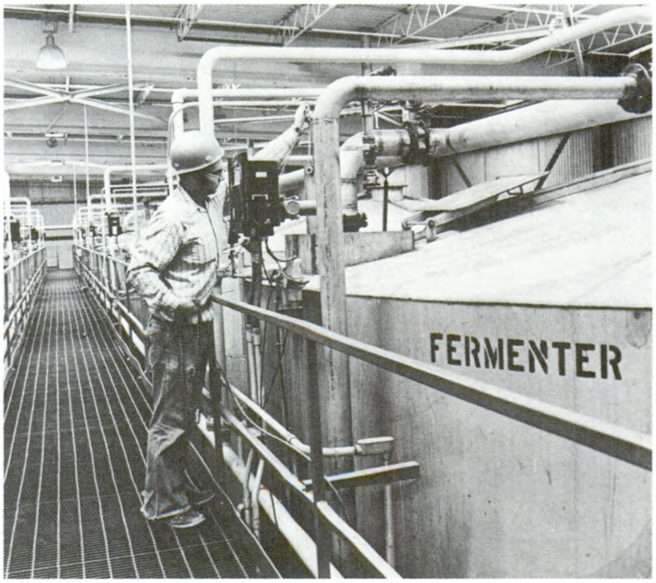
Fermentation in alcohol production is the process whereby yeast convert sugar to ethanol. The yeast consume sugar and give off ethanol as a waste product. Biologically, the producer of ethanol attempts to create the best possible environment for growing and sustaining yeast.

Chemically, the producer of ethanol attempts to maintain the right temperature and chemical conditions for the reaction that converts sugar to ethanol and carbon dioxide to proceed fastest and most completely. That reaction is:

$$\underset{\text{glucose}}{C_6H_{12}O_6} \longrightarrow \underset{\substack{\text{carbon}\\ \text{dioxide}}}{2CO_2} + \underset{\text{ethanol}}{2C_2H_5OH}$$

Yeast pass through several stages during fermentation: a *lag phase* during which they acclimate to the mash; an *exponential phase* during which they reproduce rapidly (doubling every three hours); a *stationary phase* during which ethanol is produced; and a *death phase* after the sugar has been consumed. The lag and exponential phases take place under aerobic (with oxygen) conditions, and the stationary, ethanol-producing phase occurs under anaerobic (oxygenless) conditions. Yeast need oxygen (8 ppm) initially to acclimate and to reproduce; after they assume a significant population, the oxygen in the mash drops below 1 ppm, and the yeast begin to produce ethanol.

The species *Saccharomyces cerevisiae*, a "top yeast," is the most commonly used type for ethanol production. It is a distiller's yeast—baker's yeast, the kind available from a grocery store, is not appropriate for ethanol fermentation.



An Archer Daniels Midland Company employee monitors a multitank continuous fermentation process.

Optimum Conditions for Fermentation

Yeast have a low tolerance to fluctuations in their environment. Even fluctuations within their range of viable conditions can kill or immobilize them once they have adapted to the mash. The factors that must be considered to ensure the success of fermentation are nutrition, contamination, temperature, and pH.

Nutrition

Yeast nutrition is mainly determined by the mash's water, sugar, oxygen, nitrogen, amino acid, vitamin, and mineral content. Although many mashes can supply almost all the needed nutrients with little modification, carbohydrate-rich mashes are usually more complete in terms of nutrients than mashes based on sugar crops.

Yeast require the presence of magnesium to 300 ppm, zinc to 1.0 ppm, and other minerals such as phosphate, potassium, and sulfur in small amounts. Among the vitamins required are thiamine, riboflavin, and biotin. The mash should be stirred during fermentation to suspend the nutrients and the yeast. Stirring should be done in such a way that it does not introduce oxygen into the mash.

The mash's sugar concentration should not exceed 24%. Twenty-four percent sugar concentration produces about 12% ethanol concentration, and ethanol concentrations of 12% and above are fatal to yeast. Therefore, if the initial concentration of the mash's sugar exceed 24%, some of it will be unconverted and lost.

Contamination

Yeast are susceptible to organic and inorganic contaminants that can inhibit their ethanol production or immobilize or kill them.

Inorganic contaminants are chemicals or minerals that may be introduced with the mash water through poor production procedures or if the fermentation vessel is easily pitted or corroded. The mash's hardness should be less than 80 ppm; nitrites and nitrates less than 50 ppm; copper less than 1 ppm; flouride less than 100 ppm; tin less than 360 ppm; tellurium and beryllium less than 350 ppm; and nickel less than 185 ppm.

Organic contaminants are essentially bugs. Bacterial, fungal, and viral forms can compete with the yeast for food (sugar), attack the yeast, or alter the chemical balance affecting the sugar-to-ethanol conversion. Since most competing forms can reproduce faster than yeast, they are a major threat to fermentation.

Certain contaminating organisms are likely to be encountered. Coliform bacteria inhabit soil and cling to grains and tubers and can also gain access to the fermenters through the water supply and operators. They develop quite rapidly in mashes of pH above 4, especially if the yeast do not establish themselves quickly. However, once a vigorous yeast fermentation takes hold, coliform bacteria will generally be out-competed, especially if the pH falls during fermentation.

Acetobacter species of bacteria produce acetic acid (vinegar) from ethanol. They are quite acid tolerant but need oxygen for rapid growth, so they generally only become a problem if a fermentation is arrested early for some reason. If a yeast fermentation stops and this goes undetected, these organisms could consume some of the ethanol present in the beer, especially if aerobic conditions accidentally become established due to cessation of fermentation.

Lactobacillus species of bacteria can grow under slightly anaerobic conditions and in the presence of carbon dioxide. These organisms will generally consume some of the sugar that the yeast could use to produce ethanol. Some will grow below pH 3.5.

Pediococcus species are anaerobic and have been found in connection with yeast that is being stored for reuse. They also consume, and waste, sugar.

Zymomonas species are anaerobic and can grow over a wide pH range, utilizing sugars in the mash.

So-called "wild yeasts" are those of very many species that can contaminate mashes by being introduced through the feedstock, dirt, water supply, or with operators. Since they often favor the same conditions as the culture yeast, they can grow rapidly and reduce the population of the wanted yeast. Many of them do not produce ethanol from the sugar they consume.

A good indication of contamination is an unexpected change in the mash's pH. pH will normally drop from pH 5.5 to 4.0 during fermentation: if it does not drop, or if it drops too far, organic contaminants are present. A near-certain indication of organic contamination is reduced output of ethanol from the fermenter and less-than-vigorous fermentations. Microscopic examination of the mash will reveal some of the contaminants but will most often disclose deviations in the size and shape of the culture yeast cells, an indication that the cells are having trouble competing with the contaminants. Sometimes odors will reveal contamination. Coliforms will often produce celery-like or phenolic odors, *Acetobacter* will produce the characteristic vinegar smell, and *Zymomonas* will produce an offensive rotten fruit odor quite unlike the pleasant apple-like odor of a successful fermentation.

Thorough and constant cleaning is the only reliable means to prevent recurring infections. Breweries and distilleries often use CIP (clean-in-place) systems that wash all tanks and piping with 2% caustic (sodium hydroxide) solutions, followed by water or water-acid rinses. Washing should take place at least once a day and every time a tank is emptied. Small operations can use a spray gun to spray the caustic inside tanks, and the solution can be pumped through piping, with the same pumps used to transfer product. The solution can be used more than once, provided large debris has been rinsed from tank and pipe surfaces prior to application of the solution. The final rinse should be very thorough to remove any residual caustic.

Often small operators will make the mistake of leaving traps in the piping that collect residual mash and beer. The traps serve to breed contaminants, which get washed into fermenters during mash pumping. Rinse-access ports in piping can make it easier to clear the pipes of residual organic material; sloping the pipes so that they drain is also a good idea. Simply cleaning tanks without cleaning piping and pumps is inadequate to prevent infection.

Temperature and pH

Temperature and pH control the rate of ethanol production. The rate of sugar-to-alcohol conversion increases between 80 and 97°F (27° and 36°C), is stable to about 104°F (40°C), and falls rapidly to zero at 109°F (43°C). Optimum temperature may vary slightly for different yeast strains, but is about 97°F (36°C). Since ethanol evaporation is rapid at fermentation temperature, and increases 1.5 times for a 9.5°F (5°C) temperature rise, fermentation facilities must have equipment to condense the ethanol vapor entrained in the CO_2 vapor and return it to the mash; otherwise, the fermentation temperature must be lowered to about 90°F (32°C) to avoid evaporation. Sophisticated production facilities vary the fermentation temperature with yeast phases: lower for the aerobic phases, higher during ethanol production.

Fermentation would produce about a 60°F (33°C) temperature change in 12–20 hours as a result of the sugar-to-ethanol conversion for a mash with 20% initial sugars concentration. This heat must be dissipated using cooling coils if the process is to remain within the temperature range of yeast viability. Since the amount of heat produced changes the fermentation, it must be carefully monitored by automatic sensors. Once the stationary phase is reached, a temperature fluctuation of only ±4°F (±2°C) can badly damage the yeast.

Optimal pH for fermentation is between pH 4.5 and 5.0. Yeast will grow between pH 4 and 6; they become inactive outside of pH 3–10. pH will fall naturally during fermentation from about 5.5 to 4.2 and then rise to 4.5; ph fluctuations out of this range usually indicate contamination.

Procedures and Yield

Fermentation procedures include preparing and introducing the yeast inoculum; preparing and maintaining the mash conditions; and mixing the mash while dissipating the excess heat and CO_2.

The yeast inoculum should consist of about 5–10 million cells per milliliter of mash (the number of cells per milliliter rises by a factor of 100 during the exponential phase). The necessary cells can be supplied by 0.5 to 1.0 ounce of dried yeast per 100 pounds of mash (or 4 pounds of yeast for 1000 gallons of mash). The exact amount will vary by manufacturer. The yeast may be activated by soaking for 5 to 10 minutes in a volume of tepid water equal to their weight, or they may be mixed directly into the mash. Mixing the mash at the commencement of fermentation guarantees that the 8 ppm of oxygen needed are present. No air should be introduced after the initial mixing.

More complex, commercial-scale inoculum preparations are based on preculturing. In preculturing, the yeast are acclimated to the mash environment before they are introduced into the fermenter. By doing this, the lag phase is telescoped. There are various methods for preculturing: using mash and yeast taken from an ongoing fermentation (pitching) or introducing new yeast to a media similar to the mash. In an ongoing process, part of the mash already in the exponential phase is taken from its fermenter and used to start a new fermentation. The other type of preculturing requires a separate set of clean, steel tanks devoted to growing yeast on-site. From these yeast are taken about 20% of the yeast needed for an inoculum. They are mixed with yeast nutrient and a volume of mash; after 6 to 10 hours, the yeast have multiplied 10 to 20 times and are ready to be introduced into the fermentation vessel and a full volume of mash. Thus the lag phase is eliminated, and the cells are already reproducing vigorously. The major problem with pitching and preculturing is contamination, which must be carefully monitored.

CO_2 is a by-product of the sugar-to-ethanol reaction, and it is given off in the amount of 0.5 pounds per pound of sugar fermented. CO_2 is nonpoisonous, but it drives out breathable air: in a closed room, a person could lose consciousness or even die without perceiving the change in atmosphere. To avoid this, CO_2 must constantly be vented to the outside or stored. CO_2 has value as a by-product: commercial-scale plants store, liquefy, and sell it. CO_2 can be used in food processing (for soda or as dry ice) or as a feedstock in the chemical industry.

Mash in fermenters is mixed to suspend the yeast's nutrients. In a closed vessel, mixing is not a problem because oxygen cannot be introduced. In an open fermenter, a layer of CO_2 forms over the mash and will normally prevent entry of oxygen; gentle mixing from the bottom of an open fermenter will not disturb the CO_2, and no oxygen will enter the mash.

The anticipated alcohol yield after completion of fermentation is about 47% of the original concentration of sugar. Thus, if the sugar concentration was 22%, the ethanol yield should be about 10%.

Batch vs. Continuous Fermentation

In a batch process, an amount of mash is fermented until all the sugar has been converted. The process is then stopped, the vat emptied, cleaned, and sterilized, and another batch started. In continuous fermentation, mash is added continuously (or at short intervals). Frequently, the system is a tower fermenter. The mash is pumped in at the bottom and moves through suspended yeast cells to the top, where the product is removed. The system may have several towers, with yeast propagation in the first tower and fermentation in the others. The advantages and disadvantages of these systems are:

BATCH FERMENTATION

Advantages

- Control of microbial contaminants.
- Control of ethanol yield.
- Low cost and simple for small-scale use.
- Production can be timed with availability of feedstock.

Disadvantages

- High capital requirement for large-scale use (large number of vessels).
- Low volumetric efficiency for the fermenters.
- Variations from batch to batch.

CONTINUOUS FERMENTATION

Advantages

- Highly efficient volumetric use of fermenters.
- Yeast can easily be recycled.
- More consistent product.
- Low capital and labor cost for large systems.
- Faster processing (fermentation may be completed in 6 to 12 hours).
- Efficient use of plant space.

Disadvantages

- Potential for serious microbial contamination.
- Complex—not a small-scale technology.
- Requires a continuous supply of mash.
- Requires highly skilled labor.

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Distillation

This section is taken from *Ethanol Production and Utilization for Fuel*, by Sheldon, David P. and Rider, Allen R., Lincoln, NE: Cooperative Extension Service, Institute of Agriculture and Natural Resources, University of Nebraska; October 1979; 83 pages, $2.00. Available from: Extension Publication Service, Agriculture Engineering Annex, University of Nebraska, Lincoln, NE 68583.

Distillation is the process of separating the more volatile components of a mixture from the nonvolatile or less volatile components. This is done by heating the entire mixture, which causes the more volatile components to vaporize first. These vapors are collected and cooled, causing them to condense, producing a liquid with a substantially higher concentration of the more volatile components than in the original. This liquid is called the distillate.

In general, there are two types of distillation, simple and fractional. Simple distillation is used to remove a nonvolatile substance from a solution.

Fractional distillation is used to separate liquids having different boiling points or vapor pressures. This can be done, since a mixture of two components having different boiling points will boil at a temperature between the boiling points of the individual liquids. Also, the vapor given off by boiling the mixture will contain a higher percentage of the more volatile component — that is, the one with a lower boiling point.

Fractional distillation columns can be described in terms of a few fundamental characteristics (Roberts, 1969):

The column provides a vertical path, through which the vapors pass from the distilling pot to the condenser. As the vapor from the distilling pot passes up the column, some of it condenses. The lower part of the column is maintained at a higher temperature than the upper part of the column. As the condensate drains down the column, it partially revaporizes at this higher temperature. The uncondensed vapor, together with that produced by revaporization of condensate, rises higher in the column and goes through a series of condensations and vaporizations. These amount to repeated distillations. The vapor phase produced in each step becomes richer in the more volatile component. The condensates, which drain down the column, are at each level richer in the less volatile component than the vapor with which they are in contact. Under ideal conditions, equilibrium becomes established throughout the column between the liquid and vapor phases.

The vapor phase at the top consists almost entirely of the less volatile component. The most important requirements for producing this state are (1) intimate and extensive contact between the liquid and vapor phases in the column, (2) maintenance of the proper temperature gradient along the column, (3) sufficient length of the column, and (4) sufficient difference in the boiling points of the components of the liquid mixture.

One way of providing the necessary contact between liquid and vapor phases is to place in the column some inert material providing a large surface area — for example, glass, ceramic, or metal pieces in a variety of shapes. Perforated horizontal metal plates are commonly used in plate columns (Figure III-4.1a). Columns that are filled with glass beads or other packing materials are referred to as "packed columns" (Figure III-4.1b).

Most distillation columns in commercial plants are of plate rather than packed design. Packed columns are preferred for small-scale uses (column diameter less than four feet) such as in laboratories or on farms because they are inexpensive and easy to assemble as small units. Comparing plate and packed designs:

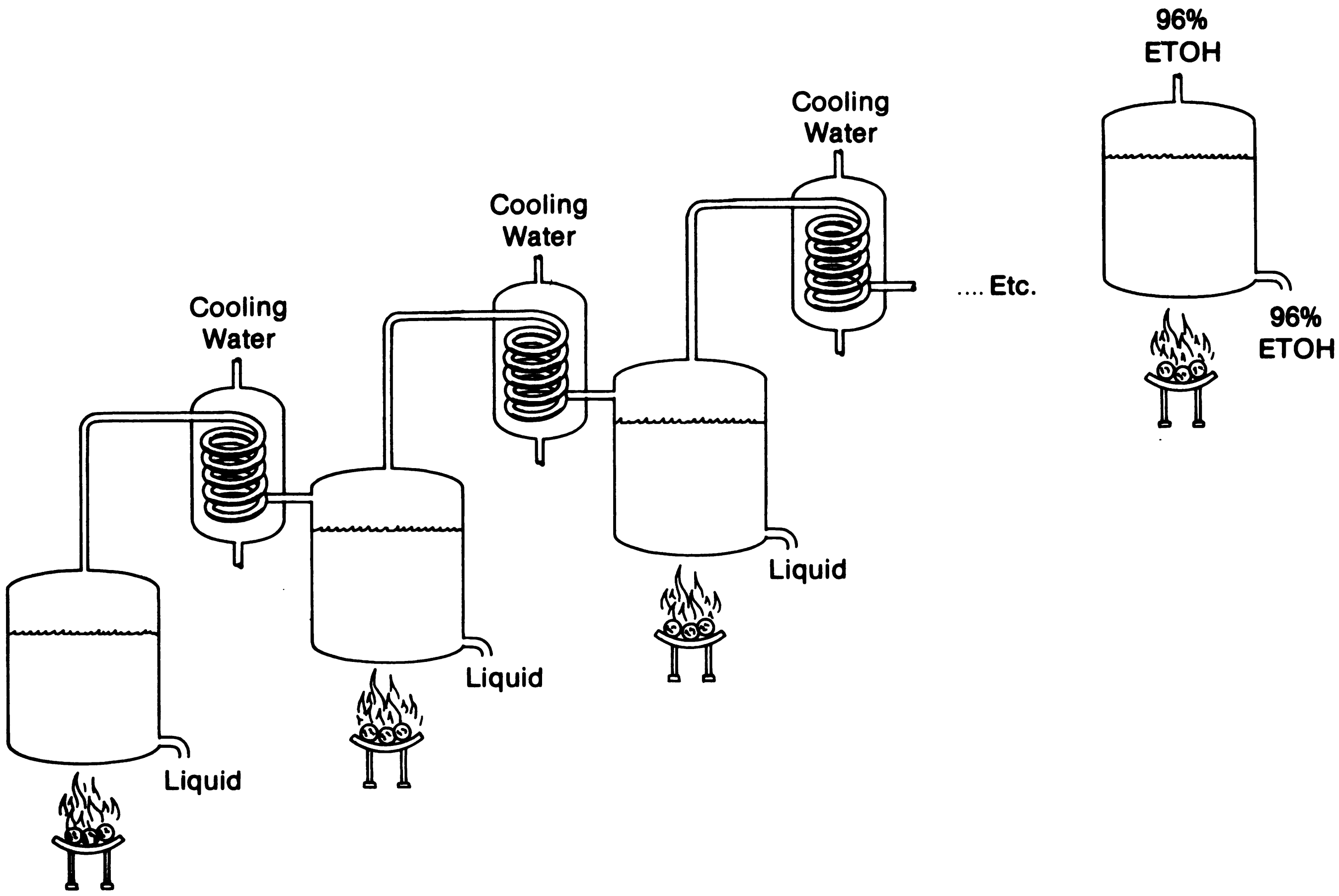

Figure III-4.1 Basic process of successive distillation to increase concentration of ethanol.

PLATE COLUMNS

- Engineering design characteristics are well known; designs are usually straightforward and reliable.
- Plate columns are easy to clean and service.
- Adjustments to handle high or low or fluctuating feed rates are simple.

PACKED COLUMNS

- Packing cannot be used in a column below the level of the liquid feed line unless the liquid is solids free. If packing were below the feed line, any solids entrained in the feed would fall and clog the packing. Packing cannot be cleaned short of removing it.
- Fusel oils (higher order alcohols) are more difficult to remove from packed columns because the oil buildup is harder to locate and to drain.
- It is hard to adjust a packed column to low or fluctuating feed rates; system inefficiency can become quite significant.
- Disruption of the countercurrent flow of liquid and vapor can occur in a poorly constructed system, totally disrupting the process.
- Packing is cheaper than plates for systems smaller than two feet in diameter.
- The vapor flow rate in a packed column is lower than in a plate column.
- Since the vapor is less agitated, it is less likely to foam.

Specific situations define the choice of these types of column. Despite their seeming disadvantage, packing can be used effectively in columns that concentrate the liquid after the solids have been eliminated.

The necessary temperature gradient from the distilling pot to the still head, in most cases, will be automatically established by the condensing vapors if the rate of distillation is properly adjusted. In some in-

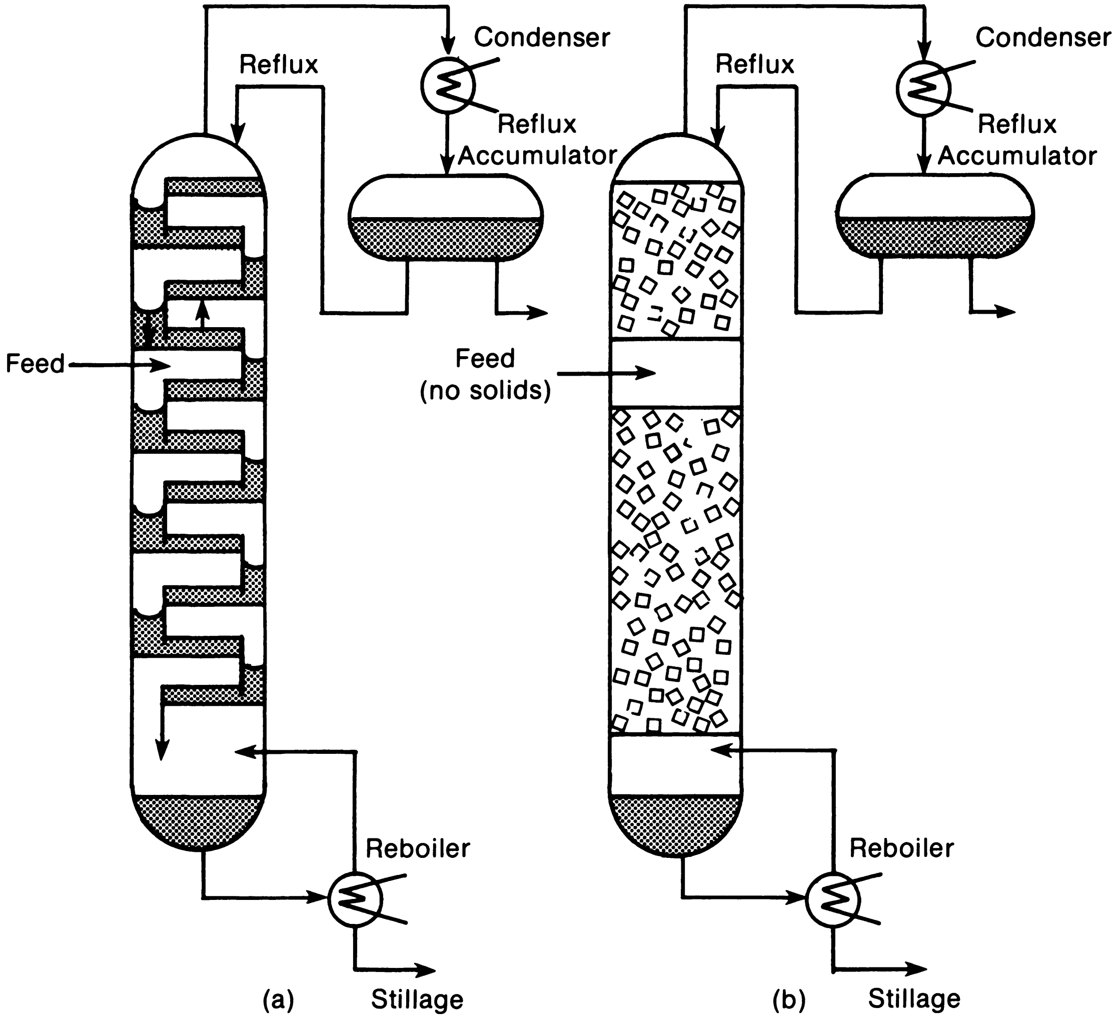

Figure III-4.2 Comparison of (a) plate and (b) packed towers (King, 1980)

stances, it may be necessary to insulate the column and/or supply heat to its upper portions.

A factor intimately related to the temperature gradient in the column is the rate of heating of the pot and the rate at which vapor is removed at the still head. If the heating is vigorous and the vapor is removed too rapidly, the whole column will heat up almost uniformly and there will be not fractionation (separation of components). On the other hand, if the pot is heated too vigorously and if vapor is removed too slowly at the top, the column will flood with returning condensate. Proper operation of a fractional distillation column requires judicious control of heating and reflux ratio (the ratio of the amount of vapor condensed and returned down the column to the amount taken off as distillate at the still head in the same time period). In general, the higher the reflux ratio, the more efficient the fractionation.

Fractional distillation is used to separate the alcohol from an alcohol-water mixture. Ethanol, which boils at about 173°F (78°C), is more volatile than water, which boils at 212°F (100°C). Depending on the relative volumes of ethanol and water in the original mixture, the boiling-point temperature will vary between these two temperatures. However, a mixture forms containing 95.6% ethanol and 4.4% water that is known as an azeotrope, or constant-boiling mixture. This mixture has a boiling point that is slightly lower than the boiling point of pure ethanol. Further, when this mixture is boiled, the vapors also contain 95.6% ethanol and 4.4% water. For this reason, ethanol cannot be made stronger than 95%, or 190-proof, by fractional distillation.

In practice, two fractional distillation columns are usually used to distill a beer containing 6% to 12% ethanol into 95% ethanol. The first, or stripping column, is used to produce a distillate containing about 50% ethanol and 50% water. This distillate is then passed to the second, or refining, column for further distillation to the 95% ethanol level.

In most instances, this will be the last distillation performed on farms. The alcohol would then be denatured and used in the 190-proof form. This may, however, cause problems in mixing the alcohol with gasoline.

If anhydrous, or 200-proof, ethanol is desired, a special distillation must be employed. One such method is azeotropic distillation.

The azeotropic distillation of an alcohol-water mixture involves using an entrainer — i.e., a liquid that forms a heterogenous azeotrope with water; this new azeotrope, having a lower boiling point than any other component, is used in the azeotropic distillation of alcohol. The process involves the following:

In an azeotropic distillation system the liquid, or feedstream, to be stripped of water is introduced into the dehydrating column at some point between the top- and bottom-most plates. The entrainer is introduced at the top of the dehydrating column, where it refluxes (flows) down the column, "entraining" (mixing with) water in the feedstream. The entrainer-water azeotrope is distilled off and passes out the top of the dehydrating column into the overhead condenser. The original feedstream, as it passes down the column, loses more and more water to the entrainer until the essentially water-free product exits at the base of the dehydrating column. The entrainer-water azeotrope enters the condenser, is cooled to a liquid, and enters the decanter, where the two liquids separate. The entrainer layer (top) is fed back to the top of the dehydrating column, where it passes down as reflux, entraining more water. The water layer (bottom), which contains a small amount of entrainer, is led to the water column, where the entrainer is distilled off as the entrainer-water azeotrope. Thus, in this azeotropic distillation system, feedstream products are dehydrated alcohol and water, the entrainer being recycled within the system.

Benzene can be the entrainer added to the 190-proof alcohol. A three-component azeotrope, or constant-boiling mixture, containing 7.5% water, 18.5% ethanol, and 74% benzene is formed. This mixture removes all of the water, all of the benzene, and some of the ethanol, but leaves pure ethanol at the bottom of the column.

As an example, if 74 pounds of benzene are added to 150 pounds of 95% ethanol, 224 pounds of mixture would be obtained. The first product, or distillate, will contain 7.5 pounds of water, 18.5 pounds of ethanol, and 74 pounds of benzene. Thus, all of the water and benzene plus some of the ethanol will have been removed from the original mixture. The second product will be 124 pounds of anhydrous ethanol, which remains in the distillation column. This alcohol is ready for denaturing and use. The distillate, when held for a short time, will form two individual layers. The top layer, representing 84% of the volume, will contain 84.5% benzene, 14.5% ethanol, and 1% water. This mixture is usually fed back into the main (anhydrous) column as the source of benzene. The bottom layer, representing 16% by volume of the distillate, contains 53% ethanol, 36% water, and 11% benzene. This mixture is then distilled in a small fractional distillation column. The distillate from this column will be the same azeotrope as was obtained from the distillation of 190-proof ethanol and benzene in the anhydrous column. An ethanol-water mixture is removed from the bottom of this small column and returned to the main refining column for distillation. With this process, nearly 100% of the benzene is recycled.

Obviously, the distillation process is a complex dynamic system, with continuous flow of components and products requiring a great deal of control and material transfer for optimum production.

References

1. Roberts, R. M., Gilbert, J. C., Rodewald, L. B., and Wingrove, A. S., 1969. "Separation and Purification of Organic Compounds." *An Introduction to Modern Experimental Organic Chemistry.* New York: Holt, Rinehart, and Winston, Inc.; pp. 20–28.
2. King, D. Judson. 1980. *Separation Processes.* New York: McGraw-Hill Book Company; p. 152.

Vehicle Fuel Use and Performance

Introduction

The use of alcohol-gasoline fuel blends in unmodified vehicles is encouraged by the Federal Government in its efforts to mitigate energy-related problems. While federal agencies are required to run their vehicles on gasohol whenever feasible, many private organizations and individuals are switching to ethanol and gasoline blends on their own. This increased interest in alcohol fuel blends has resulted in numerous large-scale fleet tests to examine the long-term effects of alcohol fuel usage.

This publication provides information on 20 ethanol-gasoline blend fuel tests on vehicular fleets in the United States. For each test, the overall effects of alcohol-gasoline blends on vehicle performance, mileage, emissions and maintenance are summarized in a convenient format. The information in each summary reflects the limited data available through September 1980.

Before October 1, 1980, an effort was carried out to identify alcohol-gasoline blend fleet-fuel tests and to compile interim or final test results. The approach involved extensive literature searches, telephone interviews, consultations with alcohol fuel and/or fleet testing experts, and analyses of available reports.

In many cases, only preliminary — and generally unpublished — results were available. Hence, both the quantity of fleet tests and the extent to which they can be discussed vary. Findings released after September 1980 are presented in the form of notes to the appropriate test summaries.

The results of these large-scale tests should be helpful in deciding whether to use commercial or other available alcohol fuel blends in different types of vehicles and engines. The principal fuel blend for most tests is gasohol — a combination of 10% ethanol and 90% unleaded gasoline — although other blends are discussed.

Test summaries are arranged alphabetically by state. Each fleet test summary contains the following information:

- test objectives,
- duration of the fleet-test program,
- miles travelled during the program (total for all vehicles),
- kinds of fuel(s) tested,
- testing (description of general procedures, analysis and data recording methodologies, special test controls),
- driveability results (notes on overall starting ability, tendency to stall, hesitation during acceleration, occurrence of knocking and pinging),
- fuel economy results (miles-per-gallon of alcohol are given and/or comparative fuel economy results relative to gasoline),
- maintenance and engine wear results (notes on engine repairs or failure attributed to the use of an alcohol fuel),
- emissions results (notes or data on engine or vehicle air pollutant emissions, generally carbon monoxide [CO], hydrocarbons [HC], and nitrogen oxides [NO_x],
- sources consulted, and
- supplementary information or future plans.

Organizations responsible for administering the fleet-tests summarized in this publication are listed below. The list is intended to be representative of the variety of fleet-testing programs conducted in the United States, and the types of organizations that typically administer such tests.

Readers are encouraged to consult the sources listed under each test summary and in the supplementary reference list at the back of this publication for more detailed and up-to-date information. Comments about this publication and new information on alcohol-gasoline blended fleet-fuel tests should be directed to the Technical Information Office, Solar Energy Research Institute, Golden, Colorado 80401.

Organizations Administering Fleet-Test Programs

Arizona Department of Transportation
Bell Telephone of Pennsylvania
California Department of General Services
Colorado State Government
Contra Costa County, California
DOE Los Alamos Scientific Laboratory, New Mexico
DOE Savannah River Plant, South Carolina
Fermi National Accelerator Center, Illinois
Illinois Bell
Illinois State Government
Los Angeles County
Los Angeles Times
Mesa City Police Department, Arizona
Nebraska Department of Roads
New Jersey State Government
New York Office of General Services
Pennsylvania Power and Light Company
Southwestern Bell Telephone Company
Tennessee Valley Authority
University of Iowa

This chapter has been extracted from the publication, *Alcohol-Gasoline Blends as Vehicular Fleet Fuels*, SERI/SP-755-1005. The complete publication is available from the Superintendent of Documents, Government Printing Office, and from the National Technical Information Service.

Available from GPO: Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402
Available from NTIS: National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161
Contact these agencies for current price and ordering information.

Summary of Performance Results

This section summarizes the experience of 20 groups from 13 different states that have tested alcohol fuel blends in their fleet vehicles under various controlled conditions. While most tests were performed using alcohol fuel blends in vehicles during normal operations, a few groups also tested a control set of vehicles on gasoline at the same time. Variables monitored include weather, vehicle type, vehicle use schedules, quality and handling of fuel (see below), driving techniques, altitude, and possible biases or preconceptions of the testing organizations or drivers. Most groups, however, accounted for or attempted to control few of these variables. In addition, not all groups kept detailed records or analyzed their results comparably. While some testing programs have been completed, some are still in progress. Nevertheless, this publication brings together much of the available information on long-term, large-scale, on-the-road experiences using these alternative fuels.

Ethanol Blends

Results from the 20 ethanol blend fleet tests were very mixed. But overall, gasohol (a mixture of 10% ethanol and 90% unleaded gasoline) was found to be an acceptable fuel from a technical standpoint.

Over half of the ethanol programs concluded that vehicle driveability — including such factors as starting ability, tendency to stall, and acceleration ability — was about the same for gasohol and gasoline, regardless of vehicle type. A few testers claimed slightly better performance using gasohol, with improved starting in cold weather, less knocking, and fewer frozen gas lines in the winter. Results from about one-fourth of the test programs indicated that gasohol caused more driveability problems than did gasoline — such as more difficult start-ups, stalling, and hesitation during acceleration.

The majority of test results showed that fuel economy was about the same for gasohol and gasoline. Some tests suggested that gasohol increased mileage, whereas others indicated lower mileage. When comparing fuel economy between gasohol and gasoline, however, the energy per gallon of fuel must be considered. Since alcohol blends have less energy per gallon, equal miles-per-gallon ratings for gasohol and gasoline denote a greater efficiency for gasohol. A possible trend suggested by a few researchers is that gasohol may lead to higher mileage in older cars with rich carburetor calibrations, but the same or slightly reduced mileage in later-model cars with lean or stoichiometric calibrations.

Another consideration pertinent to fuel economy evaluations is the quality of the fuel mixtures used. Ethanol blends obtained from various sources (e.g., storage tanks) are likely to be different because of differences in the mixing and storage techniques, and in the quality of gasoline and alcohol used. Also, the few groups which prepared their own ethanol blends for testing, may not have been able to ensure consistency between batches.

Many fleet tests confirmed that fuel filters on some vehicles needed to be replaced after a few tankfuls of gasohol because ethanol tended to dissolve accumulated dirt and deposit it in the filter. This cleaning action is generally seen as a benefit of using gasohol. To prevent problems associated with clogged filters, most mechanics suggest that the fuel filter be replaced after the first or second tankful of gasohol, especially in older vehicles.

Aside from fuel filter replacements, most vehicles using gasohol had no increased maintenance needs or problems when compared with vehicles using gasoline. A few vehicles using gasohol experienced swelling or deterioration of some engine auxiliary parts, such as rubber pump-plunger seals in carburetors, carburetor floats, accelerator-pump cups, and rubber gaskets. But these problems were not all directly traced to the use of gasohol.

One fairly consistent finding was that gasohol produced fewer emissions of two regulated pollutants than did unleaded gasoline: carbon monoxide and hydrocarbons. In most cases, carbon monoxide emission reductions were fairly dramatic — a decrease of 25% or greater with gasohol than with unleaded gasoline. This is attributed to the leaning effect of gasohol. (The leaning effect occurs when carburetors adjusted for complete combustion of gasoline are not adapted to the lower air/fuel ratio requirements of alcohol fuels. The excess air results in a lean air/fuel mixture.) Nitrogen oxide emissions were found to stay the same or decrease.

Fuel Quality and Handling

Some fleet-testing groups prepared their own alcohol fuel. When premixed blends were not used, the quality of the mixing process could not be ensured, nor could the quality of gasoline or alcohol be optimized for best performance of the final blend.

Most researchers emphasized the importance of using anhydrous alcohol (containing no water) in the alcohol/gasoline blend, because water in the fuel or storage system can cause phase separation. (In phase separation, the fuel mixture separates into two layers which have different concentrations of gasoline, alcohol, and water.) This phenomenon contributes to increased engine malfunctions and corrosion.

A few technicians had problems storing alcohol blends in former gasoline-storage tanks. The presence of water or sediment in the tanks led to phase separation or to suspended sediment in the fuel mixtures. These problems were generally solved or prevented by pumping from the bottom of the storage tank to remove water or sediment or by using a new tank. One company tried a pressurized vent on its storage tank to prevent moisture from getting in.

Disregarding economics and availability, most technicians found alcohol gasoline blends to be technically acceptable as alternative fuels, if the fuel is mixed and handled properly.

Arizona Department of Transportation, Phoenix, Arizona

Test Objectives

Evaluate the overall technical acceptability—road driveability, vehicle performance, fuel economy, exhaust emissions, fuel system and engine durability, and fuel integrity—of gasohol as an alternative fuel, through field and controlled laboratory tests.

Duration

January 1980 - January 1981.

Miles Travelled During Test

No information.

Test Fuel

10% ethanol, 90% unleaded gasoline. [Also tested 10% methanol (see "Methanol Blends" section.] Test vehicles were also run on unleaded gasoline for control data.

Testing

Records were kept on overall performance, fuel economy, corrosion, octane, emissions, driveability, engine wear, crankcase cleanliness, and vapor pressure of the fuel. Emissions were monitored in a vehicular emissions test lab.

Vehicles

Three hundred vehicles participated, including Ford, Chevrolet and Chrysler cars and pickups from model years '74-'80.

Driveability Results

The overall performance of the ethanol blend was judged adequate, although the possibility of vapor-lock during high-temperature summer operation had been anticipated. Compared with the gasoline vehicles, driveability was relatively good in the gasohol vehicles with slightly higher performance noted during acceleration.

Fuel Economy Results

Slight improvements in mileage were recorded for the gasohol vehicles compared with the gasoline vehicles.

Maintenance and Engine Wear Results

Minor corrosion of some engine metals occurred in the gasohol vehicles.

Emissions Results

Slightly lower HC emissions were recorded for the gasohol vehicles in contrast to gasoline-powered-automobile emissions. CO emissions averaged 25-90% less with gasohol than with gasoline.

Sources

Personal Communications:

1. Hauskins, John. 1980 (June 2). Unpublished memorandum to Cathy Arthur, Transportation Planner, Arizona Department of Transportation, Phoenix, AZ.
2. Hauskins, John. Research Engineer, Transportation Research Center, University of Arizona, Tempe, AZ. 1980 (Sept.) Oral communication.

Mesa City Police Department, Mesa, Arizona

Test Objectives

Monitor the effects of using gasohol in vehicles during normal operation, in terms of vehicle performance and durability.

Duration

February — June 1980.

Miles Travelled During Test

No information.

Test Fuel

10% ethanol, 90% unleaded gasoline.

Vehicles

Eighteen police cars, including '80 Malibus and '76-'78 Novas.

Testing

Drivers were questioned on driveability. Mileage was not formally monitored nor were exhaust emissions tested.

Driveability Results

Patrolmen complained that during fast acceleration the gasohol cars often "died" at thirty-five miles per hour. Brown thought the problem was due to vapor lock in warm weather.

Fuel Economy Results

No difference in fuel economy was noted for those cars on gasohol, although quantitative results were not collected to substantiate this. It was estimated that both gasohol and gasoline cars averaged 8-9 mpg.

Maintenance and Engine Wear Results

Clogged fuel filters were changed in the gasohol vehicles. Gasohol apparently clogged the carburetor and wore the rubber boots and gaskets. Three fuel pumps broke. However, this could not be directly traced to gasohol. Dirt was also occasionally found in the fuel.

Emissions Results

Exhaust emissions were not monitored.

Sources

Personal Communications:

1. Brown, Marvin. Director of Mechanical Maintenance, Mesa City Police Department, Mesa City, AZ: 1980 (Sept.) Oral communication.
2. Shroyer, Pat. Patrol Officer, 740 S. Gentry, Mesa City, AZ. 1980 (Sept.). Oral communication.

Note: Gasohol was discontinued in the Mesa City police fleet due to general dissatisfaction with its effects on driveability and maintenance.

California Department of General Services, Sacramento, California

Test Objectives

Evaluate the overall technical acceptability—road driveability, vehicle performance, fuel economy, exhaust emissions, fuel system and engine durability and fuel integrity—of gasohol as an alternative fuel, through extensive field tests (laboratory analysis of exhaust emissions only).

Duration

Sacramento state garage: June 1979—Ongoing as of September 1980. Los Angeles state garage: September 1979—Ongoing as of September 1980.

Miles Travelled During Test

No information.

Test Fuel

10% ethanol, 90% unleaded gasoline.

Vehicles

For regular gasohol usage without formal monitoring, the Department of General Services furnished 600 vehicles (50% of its motor pool), with 400 based in Sacramento and 200 in Los Angeles. In addition, special-performance test vehicles included: one test group on gasohol (43 cars), one control group on gasoline (39 cars), and another control group fueled alternately with gasohol and gasoline (36 cars). All vehicles were Pintos with the exception of one Ford Fairmont per group and all groups were composed of equal numbers of 1977 and 1978 models.

Testing

The 118 special-performance test vehicles originating out of Sacramento were tuned before starting a 12,000-mile test program. Drivers in both the gasohol and control groups filled out questionnaires after each trip without knowledge of which fuel they were using. Emissions for the test vehicles were recorded initially and then every 4,000 miles. Repairs of the test vehicles were also monitored. Preliminary results after 4,000 miles for 17 vehicles on gasoline, 37 on gasohol, and 32 on both fuels alternately, are summarized below. (Locked gas caps helped to ensure accurate fuel mileage figures.)

Driveability Results

No consistent differences were noted between the gasohol and gasoline groups.

Fuel Economy Results

Gasohol cars averaged 22.4 mpg while gasoline cars averaged 23.3 mpg (a 4% difference). EPA tests showed similar results, with gasohol producing 2% less fuel mileage than gasoline.

Maintenance and Engine Wear Results

No major repairs were required as of September 1980. Of the 118 special performance test vehicles, only four minor carburetor problems were reported: two in the gasohol group, one in the gasoline group, and one in the mixed fuel group.

Emissions Results

Test Groups	Initial Check		4,000 Mile Check	
	HC	CO	HC	CO
Gasohol group	0-40 ppm	0-0.9%	0-90 ppm	0-2.9%
Gasoline group	0-25 ppm	0-2.0%	0-25 ppm	0%
Mixed fuel group	0-60 ppm	0-2.0%	0-85 ppm	0-1.9%

No significant changes in emissions were noted for both the gasohol and gasoline groups after 4,000 miles.

Sources

Unpublished Document:

1. State Vehicle Gasohol Test Plan. 1980 (June). Sacramento, CA: Department of General Services, Fleet Administration Division. 4 pp.

Contra Costa County, Martinez, California

Test Objectives

Evaluate the overall technical acceptability—road driveability, vehicle performance, fuel economy, exhaust emissions, fuel system and engine durability and fuel integrity—of gasohol as an alternative fuel, through extensive field tests (laboratory analyses of exhaust emissions, octane rating and engine parts).

Duration

August 1, 1979 — Ongoing as of September 1980.

Test Fuel

10% ethanol, 90% unleaded gasoline.

Miles Travelled During Test

Approximately 400,000 - 600,000 miles per year.

Vehicles

Thirty vehicles were tested. The gasohol and gasoline (control) group each contained: 5 '78 Pintos, 5 '78 Ford Fairmonts and 5 '75 Plymouth Valiants.

Testing

Vehicles were used daily. Each vehicle was equipped with a locked gas cap so that drivers would neither know their fuel type nor be able to alter the mixture. No regular records were kept, however, drivers were asked to report problems and observations.

Driveability Results

No problems such as vapor lock or phase separation, etc., occurred. Gasohol vehicles experienced less pinging and more power than the gasoline-driven vehicles. Octane increased by 2.8 octane numbers in the gasohol vehicles. No gasohol-related breakdowns occurred.

Fuel Economy Results

Mileage was 2-5% lower for the gasohol vehicles than for the gasoline vehicles.

Maintenance and Engine Wear Results

Fuel filters in the gasohol cars were replaced. Results from laboratory analyses of engine parts have not yet been released.

Emissions Results

Federal emissions test procedures were under way at the time of this writing. No results have been released as of September 1980.

Sources

Personal Communication:

1. Bilbert, Bart. Public Works Department Director, County Administration Bldg., 6th floor, Martinez, CA. 94553. 1980 (Sept.). Oral communication.

Note: This effort was selected to as part of a standardized, nationwide fleet-testing program started in 1980 by the U.S. Department of Energy (DOE). This DOE Reliability Fleet Test Program will ultimately involve 13 to 15 government and business fleets totaling 1,100 cars and trucks. It tests both ethanol and methanol fuel blends and is scheduled to be completed by the end of 1982.

Los Angeles County, Los Angeles, California

Test Objectives

Evaluate the overall technical acceptability—road driveability, vehicle performance, fuel economy, exhaust emissions, fuel system and engine durability and fuel integrity—of gasohol as an alternative fuel, through extensive field tests (laboratory analyses of exhaust emissions and engine wear).

Duration

September 1979 — March 1980.

Miles Travelled During Test

No information.

Test Fuel

10% ethanol, 90% unleaded gasoline.

Vehicles

Fifty-five vehicles from model years '74 and '75 were run on gasohol, including: Matadors, Valiants, Chevrolets, and pickup trucks. Fifty-five comparable vehicles made up a gasoline control group.

Testing

Mileage records were maintained for both the gasohol and gasoline groups. Drivers were questioned on vehicle performance. Engine analyzers were used for emissions and engine-wear tests. Fuel filters were changed and engines tuned before testing began.

Driveability Results

No significant difference in driveability was reported between the gasohol and gasoline vehicles. Only two gasohol cars experienced difficulties with starting in general. Cold weather, however, caused frequent start-up problems.

Fuel Economy Results

No significant difference was noted between the gasohol and gasoline groups.

Maintenance and Engine Wear Results

The deterioration of some styrene-foam carburetor floats by ethanol was the only maintenance problem encountered. Routine fuel-filter replacements prevented clogged filter problems.

Emissions Results

Exhaust emissions from the gasohol vehicles were within California standards. CO emissions were about the same for both the gasohol and gasoline groups.

Sources

Personal Communication:

1. Fehlings, Don. Chief of Auto Division Mechanical Department, Los Angeles County, 1100 Northeastern Avenue, Los Angeles, CA. 90063. 1980 (Sept.). Oral communication.
2. Larsen, Larry. Deputy to Supervisor Baxter Ward, Suite 869, 500 W. Temple, Los Angeles, CA. 90012. 1980 (Sept.). Oral communication.

Los Angeles Times, Los Angeles, California

Test Objectives

Monitor the effects of using gasohol in vehicles during normal operation in terms of vehicle performance and durability and fuel economy.

Duration

November 1979 — February 1980.

Miles Travelled During Test

No information.

Test Fuel

10% ethanol, 90% unleaded gasoline.

Vehicles

The test fleet included 100-125 cars of all different types, model years '77 — '80.

Testing

Drivers were questioned on driveability and fuel mileage was monitored. No gasoline control group was used and emissions tests were not performed.

Driveability Results

About 20% of the cars on gasohol reported such problems as long starts or sluggishness in the morning. These were not thought to have been directly related to gasohol. The majority of cars gave no problems and overall improvement in driveability was noted. Gasohol was not used from April through October each year, because it did not meet the required summer RVP (Reid vapor pressure) standard of 9 psi.

Fuel Economy Results

The gasohol test fleet reported no change in mileage relative to expected gasoline mpg.

Maintenance and Engine Wear Results

Fuel filters were changed. No engine wear tests were conducted.

Emissions Results

Exhaust emissions were not monitored.

Sources

Personal Communication:

1. Page, Peter. Fleet Manager, Los Angeles Times, Los Angeles, CA. 1980 (Sept.). Oral communication.

Colorado State Government, Denver, Colorado

Test Objectives

Monitor the effects of using gasohol in vehicles during normal operation in terms of vehicle performance and durability and exhaust emissions.

Duration

January 1980—Ongoing as of September 1980.

Miles Travelled During Test

No information.

Test Fuel

10% ethanol, 90% unleaded gasoline.

Vehicles

The original test fleet included 62 vehicles of which most were passenger cars: '74 AMC Gremlins, '79 Dodge Aspen wagons, '75 Chevrolet Vegas, '79 Plymouth Volares, '74 AMC Hornets, '75 Ford Mavericks, '79 Chevrolet Impalas, '74 Dodge vans, and '79 Chevrolet Luvs. Since March 1980, five to six government messenger cars have also participated.

Testing

Test vehicles were run on gasohol whenever possible. Drivers were questioned on driveability, however, no mileage records were maintained. Emissions tests were conducted by the Department of Health.

Driveability Results

Overall, drivers have been satisfied and have reported no gasohol-related problems.

Fuel Economy Results

Fuel economy was not monitored.

Maintenance and Engine Wear Results

No maintenance or engine wear problems were reported as of September 1980.

Emissions Results

The Department of Health found 50% reductions in both HC and CO emissions relative to conventional levels. NO_x emissions were not evaluated.

Sources

Published Documents:

1. "Use of Fuel from Plants." 1980 (27 July). Denver Post. p. 25 (Column 3).

Personal Communication:

1. Sempien, Paul. Administration Office, Division of Central Services, 1525 Sherman Street, Room 15, Denver, CO. 80203. 1980 (Sept.). Oral communication.

Fermi National Accelerator Laboratory, Batavia, Illinois

Test Objectives

Monitor the effects of using various ethanol-based fuels in vehicles during normal operation, in terms of vehicle performance and durability.

Duration

April 1979 — Ongoing as of September 1980.

Miles Travelled During Test

1,500,000 miles as of September 1980.

Test Fuel

From April 1979 through October 1979, a 10% ethanol, 90% unleaded gasoline blend (mixed at Fermilab) was used. Since November 1979, two premixed ethanol blends have been used, including 15/85 blends of ethanol/unleaded gasoline and of ethanol/leaded gasoline.

Vehicles

The test fleet consisted of 177 DOE-owned vehicles, including: 13 compacts, one subcompact, four compact station wagons, 115 4 x 2 pickup trucks and vans, 14 4 x 4 jeeps, one ambulance, 14 large trucks (1-1/2 ton+), and 15 fire trucks.

Testing

Ethanol blends were used during normal vehicle operations. Drivers were questioned periodically on driveability and vehicles were monitored closely for engine wear and general maintenance problems.

Driveability Results

Vehicle performance was generally satisfactory with the ethanol blends and often better than that for unleaded gasoline. The octane rating of the Fermilab ethanol blend was 3-4 points higher than the unleaded gasoline used previously.

Fuel Economy Results

Fuel economy was not monitored.

Maintenance and Engine Wear Results

The first tank of gasohol generally caused hesitation problems. This was solved by replacing the fuel filters. Three measures were recommended to ensure good performance with ethanol blends: (1) an initial tuneup, (2) fuel filter replacement after the first tank of gasohol, and (3) maintaining clean storage tanks.

Emissions Results

Exhaust emissions were not monitored.

Sources

Unpublished Document:

1. Chrisman, Bruce L. 1979 (19 Oct.). "Operating Experience with Gasohol." Presented at Fifth Annual DOE-Wide, In-House Management Symposium.

Personal Communications:

1. Colson, John. Manager of Support Services, Fermilab, Batavia, IL. 60510. 1980 (Sept.). Oral communication.

2. Finks, James E. Assistant Director, Fermilab, Batavia, IL. 60510. 1980 (7 Feb.). Unpublished letter to Andrew Mravea.
3. Mravea, Andrew. Area Manager, Batavia Area Office, Department of Energy, P.O. Box 2000, Batavia, IL. 60510. 1980 (16 Jan.). Unpublished letter to Irving A. Schau, Chief, Property Management Branch.

Illinois Bell, Chicago, Illinois

Test Objectives

Evaluate the overall technical acceptability—road driveability, vehicle performance, fuel economy, exhaust emissions, fuel system and engine durability and fuel integrity—of gasohol as an alternative fuel, through extensive field tests (laboratory analysis of exhaust emissions only).

Duration

January 1979 — January 1980.

Miles Travelled During Test

No information.

Test Fuel

10% ethanol, 90% unleaded gasoline.

Vehicles

Thirty vans and trucks participated in the program.

Testing

Operational field tests were conducted using the 30 vehicles, fifteen of which were run on gasohol, with 15 control vehicles on unleaded gasoline. After six months the fuels of both groups were switched. Drivers recorded mileage data and evaluated vehicle performance. Emissions were tested via laboratory analysis.

Driveability Results

Gasohol vehicles reported better cold-weather starting than those on gasoline.

Fuel Economy Results

Mileage results were mixed. Older vehicles had better mileage with gasohol than gasoline, while newer vehicles had slightly better mileage with gasoline. Overall, gasohol achieved about 5% better mileage than did gasoline.

Maintenance and Engine Wear Results

Gasohol vehicles required no special maintenance. Fuel freezing (common with gasoline) was eliminated through the use of gasohol. The investigators concluded that gasohol's cleaner burning could lead to savings in maintenance costs through longer engine life and a reduction in the number of tune-ups.

Emissions Results

Compared to gasoline, gasohol produced lower CO and HC emissions (by 30% and 8%, respectively).

Sources

Published Document:

1. "Illinois Bell May Switch to Gasohol If Price Level Holds." 1981 (15 June). Alcohol Week. Vol. 2 (No. 24): pp. 6-7.

Unpublished Document:

1. News release. Illinois Bell. 1980 (24 Apr.). Chicago, IL: Illinois Bell News Service Division.

Personal Communication:

1. Wieler, Joseph. Illinois Bell, Chicago, IL. 1980 (Sept.). Oral communication.

Note: Following this 30-vehicle fleet test program, Illinois Bell ran similar tests on 2,500 vehicles, including proportionately more heavy vehicles. Fuel economy for gasohol-fueled vehicles averaged 4% better than for vehicles run on gasoline. Mileage was up 8% compared with the first test year (discussed above). This was attributed not only to the use of gasohol but to regular maintenance of air pressure, switching to Arco Graphite motor oil, and other factors. Illinois Bell indicated that the use of gasohol will be extended to its statewide fleet of roughly 8,000 privately owned vehicles as soon as gasohol becomes available and competitively priced.

Illinois State Government, Springfield, Illinois

Test Objectives

Evaluate the overall technical acceptability—road driveability, vehicle performance, fuel economy, exhaust emissions, fuel system and engine durability and fuel integrity—of gasohol as an alternative fuel, through extensive field tests (laboratory analysis of exhaust emissions only).

Duration

October 1977 — Ongoing as of September 1980.

Miles Travelled During Test

No information.

Test Fuel

10% ethanol, 90% unleaded gasoline.

Vehicles

The program involved over 12,000 vehicles. They included about 11,000 vehicles from the Illinois government fleet (4,500 cars, 4,700 trucks, and 1,500 off-road vehicles), and 1,500 vehicles from Illinois university systems.

Testing

All state vehicles were using gasohol by July 1, 1980. Participating drivers kept records of fuel usage and engine parts were analyzed periodically. Also from June 1978 to June 1979, controlled field tests were conducted on 11 vehicles for purposes of monitoring fuel mileage and emissions.

Driveability Results

No driveability problems were documented in spite of three very cold winters in Illinois ('77, '78, and '79).

Fuel Economy Results

In the controlled field tests the gasohol vehicles averaged 6.5% better mileage than did the gasoline vehicles.

Maintenance and Engine Wear Results

The ethanol caused minor deterioration of the rubber carburetor pump plungers. Once the plungers were replaced, no further problems were noted. Alcohol also affected the underground storage tank by dissolving accumulated rust.

Emissions Results

CO and HC emissions from the 11 gasohol controlled-test vehicles were 32% and 7.5% lower, respectively, than those from unleaded gasoline.

Sources

Personal Communication:

1. Jennings, George. Superintendent of Division of Vehicles, Department of Administrative Services, 200 E. Ash, Springfield, IL. 62706. 1980 (Sept.). Oral communication.

University of Iowa, Iowa City, Iowa

Test Objectives

Monitor the effects of using gasohol in vehicles during normal operation, in terms of vehicle performance and durability.

Duration

April 1, 1979 — Ongoing as of September 1980.

Miles Travelled During Test

No information.

Test Fuel

10% ethanol, 90% unleaded gasoline.

Vehicles

The test fleet consisted of 389 university cars, trucks, end loaders, and vans.

Testing

All vehicles used gasohol when their tanks could be filled on campus, but gasoline was used occasionally on the road. No formal mileage records were kept nor were emission tests performed. Drivers were questioned on driveability.

Driveability Results

No driveability problems were reported.

Fuel Economy Results

There was no change in mileage relative to expected gasoline mpg.

Maintenance and Engine Wear Results

No significant problems occurred. Fuel filters were changed following initial clogging.

Emissions Results

Exhaust emissions were not monitored.

Sources

Personal Communication:

1. Mellicker, Bernard. Manager of the University of Iowa Motor Pool, 603 S. Madison Street, Iowa City, IA. 1980 (Sept.). Oral communication.

Note: Plans were made to continue gasohol use in university vehicles.

Nebraska Department of Roads Lincoln, Nebraska

(2 Million Mile Road Test Program)

Test Objectives

Evaluate the overall technical acceptability—road driveability, vehicle performance, fuel economy, exhaust emissions, fuel system and engine durability and fuel integrity—of gasohol as an alternative fuel, through extensive field tests (laboratory analysis of exhaust emissions only).

Duration

December 1974 — October 1977.

Miles Travelled During Test

2 million miles.

Test Fuel

10% ethanol, 90% unleaded gasoline.

Vehicles

A total of 34 vehicles was operated throughout the state by the Nebraska Department of Roads. All vehicles were eight-cylinder, 1973-1975 models.

Testing

Gasohol was made available to the test vehicles via three Department of Roads test stations spread across Nebraska at elevations ranging from 354 to 1311 meters. This was set up to study the effects of altitude associated with gasohol use. Of the 34 vehicles, 12 ran on gasohol for the entire test, six control vehicles ran on unleaded gasoline only, eight were started on gasohol and switched midway, and eight were started on gasoline and switched midway. For each vehicle, spark plugs number three and six were removed every 90 days, examined and photographed. Compression ratios were checked, as were exhaust pipes, mufflers, cylinders, and valve-seat conditions, every 90 days. Drivers logged fuel mileage and were interviewed on the driveability of their respective vehicles. Fuel usage by the Lincoln-based gasohol and gasoline vehicles were compared at four different temperatures over a two-year period. Exhaust emissions tests were conducted on two test vehicles by the ERDA Research Center according to standard procedures.

Driveability Results

Gasohol test vehicles experienced good starting performance in the winter (to temperatures as low as -34°C), probably because of the increased volatility of gasohol. No vapor lock problems occurred in the gasohol vehicles (at temperatures as high as 38°C and altitudes up to 1524 meters). In general, gasohol caused no problems relative to starting or driveability and did not separate into layers. Power output increased with alcohol content. The average octane increased by three octane numbers over gasoline vehicles.

Fuel Economy Results

Fuel mileage was 5% better for vehicles run on gasohol than on gasoline. When expressed as miles/Btu used, gasohol vehicles (Lincoln-based models) achieved higher mileage at all temperatures than the Lincoln controls.

Maintenance and Engine Wear Results

Regular inspections of engines, valves, spark plugs, compression ratios, measurements, cylinders, etc., showed no unusual wear or deterioration of the gasohol-powered engines.

Emissions Results

The two gasohol vehicles tested produced 32% lower CO emissions than gasoline vehicles, while HC and NO_x emissions were the same.

Sources

Published Documents:

1. Anderson, E. V. 1978 (31 July). "Gasohol: Energy Mountain or Molehill?" Chemical and Engineering News. Vol. 56 (No. 31): pp. 8-15.
2. "Appendix B: Information on Fleet Activity Elsewhere in the Country." 1980 (Mar.). Report on the Testing of Alcohol/Gasoline Fuel Blends in Conventional Vehicle Fleets in New York State. Albany, NY: Office of General Services, Division of Interagency Transportation Services. 62 p.
3. Scheller, W. A. 1977 (31 Jan.). Nebraska 2 Million Mile Road Test Program - Sixth Progess Report. Lincoln, NB: University of Nebraska, Department of Chemical Engineering.
4. Scheller, William A. 1979 (Dec.). "Recalling Those 2 Million Miles on Gasohol." Gasohol U.S.A. No. 7: pp. 18-20.

Personal Communication:

1. Scheller, William A., 917 Stuart Bldg., Lincoln, NB. 1980 (Sept.). Oral communication.

New Jersey State Government, Trenton, New Jersey

Test Objectives

Evaluate the overall technical acceptability—road driveability, vehicle performance, fuel economy, exhaust emissions, fuel system and engine durability and fuel integrity—of gasohol as an alternative fuel, through extensive field tests (laboratory analyses of exhaust emissions and fuel filters).

Duration

July 1979 — Ongoing as of October 1980.

Miles Travelled During Test

No information.

Test Fuel

10% ethanol, 90% unleaded gasoline.

Vehicles

An average of fifty-three vehicles were maintained in the gasohol group and 54 in the gasoline (control) group. Vehicles included: '76 Dodge Darts, '80 Omnis, '80 Chevettes, '78 Ford Fairmonts, '74 Plymouth Dusters, '78 AMC Concords, '78 Dodge Aspens and '78 Dodge vans.

Testing

The gasohol and control groups each contained at least 32 vehicles at all times to ensure the statistical validity of the tests. Drivers were originally required to submit a report on fuel mileage and performance with each refueling or change in drivers. Since participating in DOE's Reliability Fleet Test Program, drivers have been required to submit daily reports. Vehicles were recalled every 6,000 miles for preventative maintenance checks—oil change, exhaust emissions test, special repairs—and every 18,000 miles for tune-ups (to manufacturer's specifications), unless problems required that they be performed sooner. Fuel filters from selected gasohol vehicles were sent to the manufacturer for analysis at various times during the program.

Driveability Results

During December and January, problems with hesitation, knocking, cold starts, and acceleration occurred in the gasohol vehicles. During the summer months, the performance of vehicles on gasohol and gasoline were comparable.

Fuel Economy Results

For comparable periods of operation, (March-June, 1980), gasohol vehicles averaged 19.38 mpg; those on gasoline averaged 19.95 mpg. Although the difference was not statistically significant at the 90 or 95 percent confidence levels, the researchers pointed out that the 3 percent difference in fuel economy closely corresponds to the difference in the gross energy content (Btu) of the two fuels. Older vehicles got slightly better mileage with gasohol than with gasoline due to the "leaning" effect. Newer vehicles averaged comparable mileage on gasohol and gasoline.

Maintenance and Engine Wear Results

The fuel filters from some gasohol vehicles needed to be replaced because of clogging during the early stages of the gasohol program. The manufacturer found no evidence of material degradation or other damage to the fuel filters related to the use of gasohol. Only three of 60 filters inspected were completely clogged with no remaining service life. No unusual problems or engine wear occurred in the gasohol vehicles compared with the gasoline vehicles.

Emissions Results

Results of the exhaust emissions test were not available as of October 1980.

Sources

Unpublished Documents:

1. Alternate Fuels: Summary of Alcohol Based Fuels and Their Impact on State Use. Trenton, NJ: New Jersey Department of the Treasury, Division of Purchase and Property, Energy Coordinator's Office.
2. Hills, William F. 1980 (May). Interim Report #2: Report on Central Motor Pool's Gasohol Test Program, July-March, 1979-1980. Trenton, NJ: New Jersey Department of the Treasury, Division of Purchase and Property, Energy Coordinator's Office. 33 pp.
3. Hills, William F. 1980 (5 Dec.). State of New Jersey's Gasohol Fleet Test: Summary of First Year's Test Results. Trenton, NJ: New Jersey Department of the Treasury, Division of Purchase and Property, Energy Coordinator's Office. 30 pp.
4. Interim Report #1: Report on Central Motor Pool's Gasohol Test Program. 1979 (July/Aug.). Trenton, NJ: New Jersey Department of the Treasury, Division of Purchase and Property, Energy Coordinator's Office. 36 pp.
5. Leibowitz, Donald. 1980 (1 May). The Expanded Use of Gasohol at New Jersey Central Motor Pool Facilities. Trenton, NJ: New Jersey Department of the Treasury, Division of Purchase and Property, Energy Coordinator's Office. 20 pp.

Personal Communications:

1. Hills, William F. Project Specialist, Energy Coordinator's Office, Division Purchase and Property, New Jersey Department of the Treasury, CN039, Trenton, NJ. 1980 (Sept.). Oral communication.

DOE Los Alamos Scientific Laboratory, Los Alamos, New Mexico

Test Objectives

Evaluate the overall technical acceptability—road driveability, vehicle performance, fuel economy, exhaust emissions, fuel system and engine durability, and fuel integrity—of gasohol as an alternative fuel, through field and controlled laboratory tests.

Duration

October 1979 — Ongoing as of September 1980.

Miles Travelled During Test

605,000 miles per month.

Test Fuel

10% ethanol, 90% unleaded gasoline.

Vehicles

Test vehicles included: 111 cars, 3 buses, 888 light trucks (under one ton), 50 heavy trucks and 116 special-purpose vehicles (cranes, etc.) operated by Los Alamos.

Testing

Vehicle performance and mileage were monitored during normal operation. No gasoline control group was used for this part of the test program. Exhaust emissions and engine wear were monitored by The Zia Company which operates the service stations at the Los Alamos Lab. Laboratory mileage meter tests were also conducted on vehicles randomly selected from the test fleet.

Driveability Results

The Zia Company noted comparably fewer performance problems with the gasohol cars than among gasoline-driven vehicles. For example, the following difficulties were much less frequent in the gasohol cars: cold-weather start-up problems, battery failure and frozen fuel lines. Gasohol engines also ran quieter and underwent less knocking.

Fuel Economy Results

Gasohol vehicles averaged about seven percent better fuel mileage than the gasoline vehicles in the mileage meter tests, (19 and 17 average mpg, respectively).

Maintenance and Engine Wear Results

Fuel filter replacements were 10% more common among the gasohol than among the gasoline-powered cars. Gasohol cars also had cleaner internal engine components. All problems occurred in vehicles manufactured before 1974. Twenty-four fuel tanks needed replacing and more carburetors needed to be rebuilt than was common for gasoline-fueled engines.

Emissions Results

Overall exhaust emissions were reduced approximately 10% in the gasohol-powered vehicles.

Sources

Published Documents:

1. Bond, Calvin. 1980. "Gasohol Experience." Proceedings of a Conference on Fleet Tests of Unique Automotive Fuels. San Antonio, TX; 13 August 1980. Washington, DC: U.S. Department of Energy. CONF-800891. p. 67.

Personal Communications:

1. Bond, C. Chief, Supply and Transportation Division, The Zia Company, Los Alamos, NM. 1980 (7 Feb.). Oral communication to L. Warren, Chief, Financial Management and Contracts Branch, Los Alamos Scientific Laboratory, Los Alamos, NM.

New York Office of General Services, Albany, New York

Test Objectives

Evaluate the overall technical acceptability—road driveability, vehicle performance, fuel economy, exhaust emissions, fuel system and engine durability, and fuel integrity—and economic feasibility—costs of producing alcohol blends with associated impacts on the net energy balance—as an alternative fuel, through extensive field tests and economic analyses, respectively.

Duration

May 1979 — January 1980.

Miles Travelled During Test

No information.

Test Fuel

10% ethanol, 90% unleaded gasoline.

Vehicles

The fleet consisted of 70 vehicles in the gasohol group and 35 in the unleaded gasoline control group. Vehicles included primarily passenger cars and vans and about a dozen heavy trucks and buses.

Testing

Drivers from three test sites (Albany, White Plains and Rockland County) tracked the quantity of fuel used, miles travelled and vehicle performance. Performance questionnaires covered: cold starting time, number of stalls during starting and driving, hesitation, surges, warm starting time and stalling, plus special problems encountered. Emissions were tested (CO and HC), however the methods were not sophisticated and the equipment was of questionable quality.

Driveability Results

Vehicles driven on gasohol experienced more performance-related problems than those run on unleaded gasoline. In particular, problems were encountered with cold starts and stalling and also with initial hesitation after warm-up.

Results of Driver's Responses to Selected Driveability Questions (Summary of approximately 6700 trip reports from 3 sites)	Gasohol	Unleaded Gasoline
Initial starting time:		
Less than 5 seconds	72%	86%
5-10 seconds	20%	12%
More than 10 seconds	8%	2%
Number of stalls after initial start:		
None	73%	90%
1-3 times	22%	9%
More than 3 times	5%	1%
Number of stalls after warm-up:		
None	90%	97%
1-3 times	9%	3%
More than 3 times	1%	0%

Hesitation during acceleration after warm-up:		
None	70%	83%
Sometimes	25%	15%
Always	5%	2%
Overall performance rating by drivers:		
Excellent	20%	15%
Good	66%	63%
Fair	14%	22%
Poor	0%	0%

Other specific performance results are discussed in the NYOGS report (March 1980), in addition to an analysis of why data discordances occurred between specific performance results and overall performance ratings. The findings demonstrate a subjective difference between gasohol and control vehicle drivers as well as among driver records from the three sites. The NYOGS report defines "discordance" as a situation where a vehicle received low ratings on one or more specific performance criteria, but a good or excellent overall rating.

There was general consensus that most problems could be eliminated through improved blending techniques plus minor engine adjustments.

Fuel Economy Results

Gasohol vehicles averaged 7.5 mpg, while control vehicles averaged 5.8 mpg. Two groups of vehicles which experienced a higher mpg with gasohol characteristically used only unleaded gasoline during the winter and gasohol during the summer. Vehicles generally get higher fuel economy in the summer regardless of fuel type. Some vehicles, however, showed better mpg with unleaded gasoline. The vans ('73-'78) had much higher mileage on gasohol (9.6 mpg vs. 6.6 mpg for the control group). But the heavy-weight trucks experienced a 12% drop in mileage with gasohol. The researchers noted that early fleet tests (e.g., Nebraska) showed increased mileage with gasohol, while recent controlled lab tests showed a slight decline. They theorize that while older cars with "rich" carburetor settings may get higher mileage with gasohol, newer vehicles with "lean-burn" settings are less likely to show a mileage increase.

Maintenance and Engine Wear Results

Gasohol vehicles had their fuel filters replaced. Two heavy-weight trucks had their fuel-pump gaskets replaced because the pumps swelled and caused engine malfunctions.

Emissions Results

Test methods and equipment produced inconsistent results.

Sources

Published Document:

1. Report on the Testing of Alcohol/Gasoline Fuel Blends in Conventional Vehicle Fleets in New York State. 1980 (Mar.). Albany, NY: Office of General Services, Division of Interagency Transportation Services. 62 pp. Available from: N.Y. Office of General Services, Director of Transportation Services, Bldg. 18, State Campus, Albany, NY. 12226. Free.

Note: Results of the economic analyses were unavailable at the time of this writing.

Southwestern Bell Telephone Company, Tulsa, Oklahoma

Test Objectives

Evaluate the overall technical acceptability—road driveability, vehicle performance, fuel economy, exhaust emissions, fuel system and engine durability, and fuel integrity—of gasohol as an alternative fuel, through field and controlled laboratory tests.

Duration

December 1, 1978 — March 1980.

Miles Travelled During Test

600,000 total miles.

Test Fuel

10% ethanol, 90% unleaded gasoline.

Vehicles

Fifty vehicles were run on gasohol and 50 made up a control group run on gasoline. Vehicles included 1/2- to 3/4-ton Chevrolet, Ford, and Chrysler vans, model years 1968-1979, and a few two-ton construction vehicles. Four to seven passenger cars were also in each group. Vehicles were tested in Tulsa, Oklahoma.

Testing

Testing was done in conjunction with the DOE Bartlesville Energy Technology Center (BETC). Drivers filled out questionnaires on the driveability of vehicles in the gasohol and gasoline groups. Relative to normal operating conditions, seven driveability factors were rated (normal or abnormal) in order to determine the percentage of normal conditions for each factor and overall. The factors included: cold starts, cold-start stalls, stalls after warm-up, hesitations, surges, hot starts, and hot-start stalls. A total of 25,000 daily log sheets were collected from the drivers and summarized on a monthly basis. The fuels of the two groups were reversed near the end of the test and drivers were switched for eight pairs of vehicles to analyze driver variation. Half of the fleet was also tested under laboratory conditions for emissions and fuel mileage by BETC. Each vehicle was tested on a dynamometer, once with gasohol and once with gasoline, using 1977 EPA Federal Emissions Test Procedures (see glossary). Samples of the lubricating oil were analyzed to determine engine wear.

Driveability Results

Overall, gasohol vehicles averaged 91 percent normal operation; gasoline vehicles averaged 94 percent. Driveability in all categories was lower with gasohol, but still acceptable. Gasohol vehicles experienced the most problems with cold starts, stalling and hesitation, and driveability was worse during very hot or cold temperatures. Driveability problems often appeared during the first few months of testing. Fuel phase separation occurred in several gasohol vehicle tanks and in the underground storage tank. After replacing the tank, no further phase separation was reported. It was concluded that gasohol can be an acceptable fuel if precautions are taken to ensure that the water content in the fuel system is minimized. The performance of the gasohol vehicles in this test, however, was still below the gasoline vehicles' even after the tank was replaced. Driver variation was found to be insignificant.

Fuel Economy Results

On the road, gasohol vehicles had 1.5% lower fuel mileage than gasoline vehicles. This difference was not statistically significant. The BETC lab test also reported a similar difference.

Maintenance and Engine Wear Results

Gasohol had almost no detrimental effects on engine wear or maintenance. Early in the program the gasohol storage tank was found to contain water and fine sediment which mixed with the fuel and caused phase separation and carburetor problems, respectively, in several vehicles. These problems were alleviated with the replacement of the storage tank. Poor mixing also occurred when ethanol was added to the gasoline rather than the reverse.

Emissions Results

CO	26% lower with gasohol
HC	4% lower with gasohol (not statistically significant)
NO_x	6% lower with gasohol
Formaldehyde	higher with gasohol, but still low.

Sources

Published Documents:

1. Gurney, M. D.; Allsup, J. R.; Merlotti, C. L. 1980. "Gasohol: Laboratory and Fleet Test Evaluation." Warrendale, PA: Society of Automotive Engineers. SAE Technical Paper Series No. 800892. 21 pp.

Personal Communication:

1. Beiller, Ann. Staff Specialist-Environment, Southwestern Bell, 915 Olive Street, St. Louis, MO. 63101. 1980 (Sept.). Oral communication.

Bell Telephone of Pennsylvania, Philadelphia, Pennsylvania

Test Objectives

Evaluate the overall technical acceptability—road driveability, vehicle performance, fuel economy, fuel system and engine durability, and fuel integrity—of gasohol as an alternative fuel, through field and controlled laboratory tests.

Duration

September 1979 — February 1980.

Miles Travelled During Test

No information.

Test Fuel

10% ethanol, 90% unleaded gasoline.

Vehicles

45-50 vehicles ran on gasohol. The fleet included all different makes of passenger cars and vans, model years '70-'79.

Testing

Controlled laboratory tests were performed on five vehicles, including '77-'78 Ford Chevrolet vans (6,000 lbs), to determine mileage. These vehicles were tested once on gasohol and once on gasoline daily, with the respective tests run at the same time each day on a special course. Daily records were also kept on mileage and fuel usage for a control group of 11 vehicles alternating on gasohol and gasoline each month on their regular routes. Engine wear was monitored and drivers were questioned on driveability regularly during the field testing program.

Driveability Results

No differences were noted in performance. However, during the first week up to seven vehicles experienced phase separation due to water in the ethanol. The gasohol was sent to a refinery where the water was removed and then returned to the tanks. No subsequent problems relating to water in the fuel tanks were noted.

Fuel Economy Results

At a constant 35 mph, lab-tested vehicles run on gasohol performed 5-7% better than those on gasoline in terms of mileage. At a constant 55 mph, no difference in mpg between gasohol and gasoline vehicles was noted. Fitzpatrick theorized that older vehicles with rich-tuned carburetors burned better on gasohol due to the oxygen in ethanol, but '79-'80 vehicles benefitted less from this oxygen. The 11 vehicles monitored through controlled field tests—i.e., alternate months on gasohol and gasoline—showed no meaningful mileage trends between the two fuels. The variation in routes and idling time made the results particularly inconsistent between vehicles.

Maintenance and Engine Wear Results

There was no leaching of metals in the engine, nor shrinking or swelling of plastic or rubber parts.

Emissions Results

No information.

Sources

Personal Communication:

1. Fitzpatrick, John. Bell Auto Operations Staff, Bell of Pennsylvania, 7th floor, 1 Parkway, Philadelphia, PA. 19101. 1980 (Sept.). Oral communication.

Pennsylvania Power and Light Company, Allentown, Pennsylvania

Test Objectives

Monitor the effects of using gasohol in vehicles during normal operation, in terms of vehicle performance and durability, fuel economy and exhaust emissions.

Duration

October 1979 — October 1980.

Miles Travelled During Test

195,000 miles, as of September 1980.

Test Fuel

10% ethanol, 90% unleaded gasoline, purchased from Texaco.

Vehicles

Twenty-six vehicles participated: 20 ran on gasohol and six control vehicles ran on unleaded gasoline. All vehicles were six-cylinder 1979 AMC Concords.

Testing

PP&L employees used the test vehicles on meter-reading trips. Records were kept on mileage and drivers were questioned on driveability. Engine wear and exhaust emissions were to be checked at the end of the test.

Driveability Results

The engines of some of the gasohol cars ran and idled erratically for the first eight tanksful. Johnson thought this may have been due to the presence of water in the tanks at first. Four complaints were received concerning hard starts. These, however, were shown not to be linked to the use of gasohol. Overall, no difference between the performance of gasohol and gasoline control vehicles was noted, particularly in terms of stalling, hesitation or starting.

Fuel Economy Results

No significant difference in fuel economy was observed: 11.1 mpg with gasohol, 11.2 mpg with unleaded gasoline.

Maintenance and Engine Wear Results

No maintenance problems occurred which were related to the deterioration of engine parts by ethanol. Engine wear results were not available at the time of this writing. The underground fuel storage tank had a pressurized vent installed to prevent moisture from getting in.

Emissions Results

Results of exhaust emissions test were not available as of September 1980.

Sources

Personal Communication:

1. Johnson, Robert. Research Staff Engineer, Pennsylvania Power and Light Company, 2 North 9th Street, Allentown, PA. 18101. 1980 (Sept.). Oral communication.

DOE Savannah River Plant, Aiken, South Carolina

Test Objectives

Monitor the effects of using various ethanol-based fuels in vehicles during normal operation, in terms of vehicle performance and durability.

Duration

July 1979 — Ongoing as of September 1980.

Miles Travelled During Test

No information.

Test Fuel

A 15% ethanol, 85% unleaded gasoline mixture was tested in most vehicles; a 10% ethanol blend was used in some vehicles; a 20% ethanol blend was tested on 80% of the fleet for a period of four months.

Vehicles

Nine hundred vehicles participated, including: 300 sedans, station wagons and passenger vans; 500 light trucks (pickups, panels and four-wheel drives); plus 100 medium and heavy trucks. Most were late models.

Testing

No controlled tests were conducted. Maintenance problems and performance were monitored regularly.

Driveability Results

To date the performance has been comparable for the ethanol blends and unleaded gasoline.

Fuel Economy Results

Drivers reported better mpg with the 15/85 and 10/90 blends compared with unleaded gasoline, but no statistically valid results were obtained.

Maintenance and Engine Wear Results

Replacement of fuel filters was often required after the first tank of gasohol. Many 1978 and earlier model Dodge pickup trucks had rubber pump plunger seals damaged by the ethanol, leading to hesitation during acceleration. These were replaced with neoprene seals. In several older-model pickups the ethanol caused deterioration of the fuel-line rubber hoses, which led to clogged fuel filters. In these instances, the hoses were replaced. The timing was advanced on 10 vehicles using the 15% ethanol blend. Due to the higher octane of ethanol, it was thought that advanced timing would improve the burn. No evidence of abnormal engine wear or carbon deposits on spark plugs, valves or valve seats was observed.

Emissions Results

Exhaust emissions were not monitored.

Sources

Unpublished Document:

1. Grogan, D. M. 1980 (5 Feb.). Savannah River Plant Gasohol Program. Unpublished summary report. 5 pp.

Personal Communication:

1. Grogan, D. M. 1980 (5 Feb.). Unpublished memo to J. W. Joseph, Savannah River Plant, Aiken, SC.

Tennessee Valley Authority, Land Between the Lakes, Tennessee

Test Objectives

Evaluate the overall technical acceptability—road driveability, vehicle performance, fuel economy, fuel system and engine durability, and fuel integrity—of gasohol as an alternative fuel, through field and controlled laboratory tests.

Duration

March 1979 — March 1980.

Miles Travelled During Test

2 million miles.

Test Fuel

10% ethanol, 90% unleaded gasoline.

Vehicles

The final test fleet comprised 151 vehicles, including cars, vans, and light and heavy trucks.

Testing

The miles travelled and the amount of gasohol used were recorded by the drivers. Fuel economy for the gasohol-powered vehicles was calculated and compared with historical mileage records for the same vehicles. Drivers submitted performance questionnaires only for the 151 approved test vehicles. Vehicles that underwent a change of drivers or duty assignments during the test period were excluded to ensure the statistical validity of the results. Gasohol samples were analyzed periodically by Chattanooga Central Laboratory for water content. Records on maintenance problems were kept. Data were analyzed using paired t-test statistical methodologies.

Driveability Results

Most drivers observed no difference between gasohol and gasoline in most categories, including: overall performance, engine starts in the summer, engine stalls, knocking and pinging, and acceleration. But gasohol did cause more problems in cold weather. Compared with gasoline, 28% of the drivers reported worse acceleration with gasohol; 20% said it was better; and 25% reported fewer stalls; 18% reported more stalls.

Fuel Economy Results

Vehicles averaged 3% less mileage (0.40 mpg) with gasohol than with gasoline. This was statistically significant at a 95% level of confidence. There were no apparent trends relating to vehicle age, classification, or engine size.

Maintenance and Engine Wear Results

Carburetor problems in some vehicles were caused by the swelling of the carburetor floats and/or accelerator pump cups. Floats were repaired in 50 vehicles (all Chevrolets) and six accelerator pump cups were replaced. Spark plugs were cleaner with gasohol than with gasoline. No other fuel-related problems were reported by the mechanics. Laboratory analysis of gasohol samples for water content also revealed satisfactory results.

Emissions Results

Exhaust emissions were not monitored.

Sources

Unpublished Document:

1. Gasohol Fleet Testing Project-Land Between the Lakes. 1980 (May). Chattanooga, TN: Tennessee Valley Authority, Division of Property and Service. 22 pp.

References

These references are supplementary to those listed under each test summary. Unless otherwise indicated, these publications are available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

Allsup, J.R. 1979. "Vehicle Tests with Alcohol/Gasoline Blends and the Alternative Fuels Data Bank." **Highway Vehicle Systems Contractors' Coordination Meeting. Sixteenth Summary Report.** Dearborn, MI; 24 Apr. 1979; Washington, DC: U.S. Department of Energy. CONF-7904105. pp. 502-520.

Allsup, J.R.; Gurney, M.D. 1980 (18 Dec.). "Comparisons of Gasohol and Gasoline in Laboratory and Field Trials." **Fourth International Symposium on Alcohol Fuels Technology.** San Paulo, Brazil; 5 October 1980. Bartlesville, OK: U.S. Department of Energy. CONF-801030—3. 7 pp.

Ecklund, E.E.; White, H.M. 1980 (Apr.). "Alcohol/Gasoline Reliability Fleet Tests: A U.S. Federal Project." **Third International Symposium on Alcohol Fuels Technology.** Asilomar, CA; 29 May 1979. Washington, DC: U.S. Department of Energy. CONF-790520. pp. 11-20.

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Vehicle Fuel Use and Performance

Glossary

AMC — American Motors Corporation.

ASTM D323 Test Method — A method for testing the vapor pressure of a fuel as specified by the American Society for Testing and Materials.

Btu — British thermal unit, a measure of heat energy.

CO — Carbon monoxide, a regulated air pollutant (see "Emission").

Cold Start — Starting in cold weather after the engine has cooled down to ambient temperature.

Dieseling.— The tendency for an engine to "run on" after the ignition is turned off. This happens primarily when the fuel has a poor octane number, causing inadequate resistance to preignition.

DOE — U.S. Department of Energy.

Driveability — User assessment of vehicle performance, including starting ability, tendency to stall, ease of acceleration, noise, knocking, or pinging, etc.

Dynamometer — A device for absorbing and measuring mechanical power (e.g., of a vehicle engine.) Used to measure fuel economy and exhaust emissions on a standard driving cycle in conjunction with other test equipment.

Emissions — Engine or vehicle air pollutant emissions. Emissions regulated by the EPA (which sets maximum allowable emissions standards) are carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NO_x), particulates and evaporative emissions. Unregulated emissions include aldehydes and unburned fuel.

EPA — U.S. Environmental Protection Agency.

EPA Federal Emissions Test Procedures — Guidelines for measuring emissions as well as fuel economy under standardized conditions. The vehicle is run on a dynamometer, exhaust gases are collected and analyzed, and fuel mileage is calculated.

ERDA — The now defunct U.S. Energy Research and Development Administration, replaced by the U.S. Department of Energy.

Ethanol — Ethyl, or grain, alcohol, usually made from carbohydrate-rich crops or ethylene.

Ethanol Blend — A blend of ethanol and gasoline.

Field Test — As it pertains to alcohol fuel blend fleet tests, testing or monitoring conducted on one or more vehicles during normal operation. Field tests generally require participating drivers to maintain regular records on certain parameters, such as miles driven, gallons of fuel used, and problems encountered.

Fleet Test — The operation or testing of a fleet of vehicles operated by an organization, government unit, or company. Fleet tests generally involve monitoring the effects of various modifications to vehicles (fuel, engine parts, etc.) and/or of driving conditions (altitude, urban vs. highway, etc.) during the normal operations of those vehicles. Tests may also include strictly controlled laboratory tests (e.g., chassis dynamometers) and/or road tests (specified speed, course, etc.).

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Fuel Economy — Miles travelled per gallon of fuel (miles/gallon or mpg). Note that equal mpg ratings for an alcohol blend and gasoline denote a greater efficiency for the alcohol fuel (since alcohol blends have less energy per gallon).

Gasohol — A blend of 10% anhydrous ethanol and 90% unleaded gasoline.

HC — Hydrocarbons, regulated air pollutants (see "Emissions").

Hesitation — A temporary lack of initial vehicle response to an attempt to increase speed.

Hot Start — All subsequent starts, once the motor has been deliberately shut off (does not include stalls).

Indolene — A standard reference gasoline used in comparative tests of automotive fuels; the federally specified reference fuel under the Clean Air Act of 1977.

Isopropyl Alcohol — Isopropanol or rubbing alcohol used especially as a solvent.

Knocking and Pinging — Noises caused by abnormal combustion, in particular detonation and preignition.

Leaning Effect — Alcohol blends have a lower volumetric stoichiometric air/fuel ratio than does gasoline. When alcohol blends are used in a vehicle system designed to operate on gasoline, the carburetor will meter more air than is needed, thus leaning the air/fuel mixture.

Lubrizol 541 — A ferrous metals corrosion inhibitor made by Lubrizol Corporation of Cleveland, Ohio.

Methanol — Methyl, or wood, alcohol, usually made from natural gas or coal, but can be made from biomass, especially wood.

Methanol Blend — A blend of methanol and gasoline.

mpg — Miles per gallon; i.e., fuel economy.

NO$_x$ — Nitrogen oxides, regulated air pollutants (see "Emissions"); primarily nitric oxide (NO) and nitrogen dioxide (NO_2), but include many other nitrogen oxides in minute concentrations.

Octane Number — A number that is used to indicate the relative antiknock properties of a liquid motor fuel relative to n-octane (octane number = 10) and n-heptane (octane number = 0).

Phase Separation — Separation of an alcohol/gasoline mixture containing water into two layers or phases. The upper phase contains mostly gasoline with some alcohol and water. The lower phase contains mostly alcohol and water with some gasoline. Phase separation may lead to driveability problems and corrosion of some fuel system parts due to water.

ppm — Parts per million; i.e., concentration.

psi — Pounds per square inch; see "Vapor Pressure".

RVP (Reid vapor pressure) — A measure in a test bomb of the vapor pressure of a sample of gasoline (fuel) at 100°F (37.8°C).

Soak Test — A test in which an object is immersed and left in a liquid to determine the effects of that liquid on the object.

Stall — Any occasion when the vehicle stops with the ignition on.

Stoichiometric Air Fuel (A/F) Ratio — The chemically correct A/F ratio for complete combustion without excess air or fuel. A greater volume of alcohol fuel than of gasoline must be mixed with air to get the correct stoichiometric A/F ratio.

Tertiary Butyl Alcohol (TBA) — A high-octane blending compound generally added to gasoline with methyl alcohol. TBA is soluble in gasoline and helps methanol dissolve in gasoline by acting as a solvent. A type of butanol (butyl alcohol).

Vapor Lock — An abnormal engine condition in which fuel boils in the fuel pump, carburetor float or fuel line from hot weather or excessive engine heat. The resulting fuel vapor blocks the fuel flow through the carburetor causing the engine to shut down until it cools off (thereby lowering the vapor pressure).

Vapor Pressure — A measure of the tendency of a liquid to turn into the gaseous state. The pressure of vapor in equilibrium with liquid at a specified temperature. The average vapor pressure of gasoline is 10 pounds per square inch (psi) compared with 10.7 psi for gasohol.

Appendix A

Technical Reference Data

Conversion Factors

1 U.S. liquid gallon water = 8.33 pounds (at 60°F) = 0.134 cubic foot = 231 cubic inches = 128 fluid ounces = 4 quarts = 8 pints = 3.785 liters

1 gallon of 200-proof ethanol weighs 6.6 pounds

1 barrel of crude oil = 42 gallons

1 Btu = 252 calories = heat required to raise 1 pound of water 1 degree Fahrenheit (°F)

1 calorie = 0.00397 Btu = heat required to raise 1 gram of water 1 degree Centigrade (°C)

1 liter = 1.057 U.S. liquid quarts

1 fluid ounce = 30 milliliters

1 pound = 453.6 grams

1 cubic foot = 7.48 liquid gallons = 62.36 H_2O (at 60°F)

1 acre = 43,560 square feet = 4,840 square yards

To convert from °F to °C, subtract 32 and then divide by 1.8

To convert from °C to °F, multiply by 1.8 and then add 32

Chemical Formulas

Carbon dioxide	CO_2
Carbon monoxide	CO
Ethanol	C_2H_5OH, also EtOH
Glucose, fructose	$C_6H_{12}O_6$
Hydrated lime	$Ca(OH)_2$
Hydrochloric acid	HCl
Lactic acid	$C_3H_6O_3$
Lactose, sucrose	$C_{12}H_{22}O_{11}$
Lime	CaO
Methane	CH_4
Methanol	CH_3OH
Nitrous oxide	N_2O
Sulfuric acid	H_2SO_4

Gasoline, Ethanol, Methanol Properties

	Gasoline	*Ethanol*	*Methanol*
Chemical Properties			
Formula	$C_{1.63} - C_{2.16}$	C_2H_5OH	CH_3OH
Molecular weight	varies	46.1	32.04
% carbon (by weight)	85–88	52.1	38.7
% hydrogen (by weight)	12–15	13.1	9.7
% oxygen (by weight)	indefinite	34.7	51.6
C/H ratio (by weight)	5.6–7.4	4.0	3.0
Stoichiometric air-to-fuel ratio	14.2–15.1	9.0	6.45
Physical Properties			
Specific gravity	0.70–0.78	0.794	0.79
Liquid density lb/ft³	43.6 approx.	49.3	49.3
lb/gal	5.8–6.5	6.59	
Vapor pressure			
psi at 100°F (Reid)	7–15	2.5	
psi at 70°F	0.3 approx.	0.85	
Boiling point (°F)	80–440	173	149
Freezing point (°F)	– 70 approx.	– 173	– 208
Solubility in water (ppm)	240	infinite	infinite
Solubility of water in chemical (ppm)	88	infinite	infinite
Thermal Properties			
Lower heating value			
Btu/lb	18,900 (avg.)	11,500	9,066
Btu/gal	115,400 (avg.)	73,560	59,830
Higher heating value			
Btu/lb at 68°F	20,260	12,800	10,258
Btu/gal	124,800	84,400	67,700
Heat of vaporization			
Btu/lb	150	396	506
Btu/gal	900	3,378	3,340
Octane ratings			
Research	91–105	106–108	106
Pump (RON + MON)/2	86–90	98–100	92
Flammability limits (% by volume in air)	1.4–7.6	4.3–19.0	6–36.51
Specific heat (Btu/lb-°F)	0.48	0.60	0.60
Autoignition temperature (°F)	430–500	685	880
Flash point	– 50	55	54

Abbreviations

ACS	American Chemical Society
ANSI	American National Safety Institute
ASME	American Society of Mechanical Engineers
atm	atmosphere
BOD	biological oxygen demand
Btu	British thermal unit
Btu/gal	Btu per gallon
Btu/lb	Btu per pound
BATF	Bureau of Alcohol, Tobacco and Firearms
bu	bushel
bu/acre	bushels per acre
cal	calorie
CCC	Commodity Credit Corporation
ft^3	cubic foot
m^3	cubic meters
C	degree Centigrade
F	degree Fahrenheit
K	degree Kelvin
USDA	United States Department of Agriculture
USDOL	United States Department of Labor
USDOT	United States Department of Transportation
$/gal	dollars per gallon
$/lb	dollars per pound
EDA	Economic Development Act
EtOH	ethanol
gal/acre	gallons per acre
gal/day	gallons per day
gal/year	gallons per year
g/kl	grams per kiloliter
cwt	hundredweight
IC	internal combustion
kPa	kilo Pascal
kg	kilogram
l (lowercase L)	liter
V_{max}	maximum velocity of a reaction
mM	millimolar
MBtu	million Btu
mol %	mole percent
mol wt or MW	molecular weight
MON	Motor Octane Number
NAFC	National Alcohol Fuels Commission
NFPA	National Fire Protection Association
ppb	parts per billion
ppm	parts per million
lb/hr	pounds per hour
RON	Road Octane Number
SEIDB	Solar Energy Information Data Bank
SERI	Solar Energy Research Institute
SI	spark ignition
UF	ultrafiltration
USDOE or DOE	United States Department of Energy
vol %	volume percent
wt %	weight percent

Appendix B

Information Sources

Associations and Organizations

Agriculture Council of America
1625 Eye St. N.W. Suite 708
Washington, DC 20006
202/466-3100

Alcohol-Alternative Fuel Institute
9400 Wisconsin Ave.
Bethesda, MD 20014

American Agriculture Foundation
308 Second Street, SE
Washington, DC 20003
202/544-5750

American Agricultural Movement
308 Second Street, SE
Washington, DC 20003
202/544-5750

American Farm Bureau Federation
225 Touhy Avenue
Park Ridge, IL 60068
312/399-5850

American Soybean Association
P.O. Box 27300
St. Louis, MO 63141

Beef Industry Council
National Livestock and Meat Board
444 N. Michigan Avenue
Chicago, IL 60611
312/467-5520

The Bio-Energy Council
1625 Eye Street, NW Suite 825A
Washington, DC 20006
202/822-5656

Brewers Grain Institute
1754 K Street, NW
Washington, DC 20006

Center for Renewable Resources
1001 Connecticut Ave., NW
Suite 510
Washington, DC 20036

Citizens Energy Project
1413 "K" Street NW 8th Floor
Washington, DC 20005

Corn Development Commission
Route 2
Holdrege, NE 68949

Distillers Feed Research Council
208 Air Park Drive
P.O. Box 75153
Cincinnati, OH 45202
606/371-1360

Domestic Technology International
P.O. Box 2043
Evergreen, CO 80439
303/674-1597

The Fertilizer Institute
1015 18th Street NW
Washington, DC 20036
202/466-2700

The Grain Terminal Association
1667 Snelling Avenue N
P.O. Box 43594
St. Paul, MN 55164
612/646-9433

The Grange
Route 2, Box 154
Waterloo, NE 68069
402/359-5604

International Biomass Institute
1522 K Street, NW, Suite 600
Washington, D.C. 20005
202/783-1133

Iowa Corn Promotion Board
402 West Towers
1200 35th Street
West Des Moines, IA 50265
515/225-9242

Iowa Development Commission
250 Jewett Building
Des Moines, IA 50309
515/281-5360

National Alcohol Fuel
Producers Association
1760 Reston Avenue
Reston, VA 22090
703/471-1611

National Association of
Wheat Growers
1030 15th Street, NW, Suite 1030
Washington, DC 20005
202/466-8630

National Cattlemen's Association
1001 Lincoln Street
P.O. Box 569
Denver, CO 80203
303/861-1904

National Center for
Appropriate Technology
P.O. Box 3838
Butte, MT 59701
406/494-4577

National Corn Growers
Association
815 Office Park Road Suite 201
West Des Moines, IA 50265
515/225-8840

National Farmers Organization
720 Davis Avenue
Corning, IA 50841
515/322-3131

National Grange
1616 H Street, NW
Washington, DC 20006
202/628-3507

National Livestock Producers
Association
307 Livestock Exchange Bldg.
Denver, CO 80216
303/623-2098

National Milk Producers
Federation
30 "F" Street, NW
Washington, DC 20001
202/393-8151

National Oil Jobbers Council
1707 H Street, NW 11th Floor
Washington, DC 20006
202/331-1198

National Pork Producers Council
4715 Grande Avenue
Des Moines, IA 50312
515/277-6419

Nebraska Agricultural Products
Industrial Utilization Committee
P.O. Box 94831
Lincoln, NE 68509
402/471-2941

Pork Industry Group
National Livestock and
Meat Boavd
444 N. Michigan Avenue
Chicago, IL 60611

Red River Valley Potato
Growers Association
Box 31
East Grand Forks, MN 56721
218/773-3633

Red River Valley Sugarbeet
Growers Association
1701 West View Drive
West Acres Office Park
Fargo, ND 58102
701/282-0694

Small Farm Energy Project
P.O. Box 736
Hartington, NE 68739
402/254-6893

Solar Energy Research Institute
1617 Cole Boulevard
Golden, CO 80401
303/231-1207

U.S. Beet Sugar Association
1156 15th Street, NW
Washington, DC 20005
202/296-4820

U.S. Feed Grains Council
1030 15th Street, NW, Suite 540
Washington, DC 20005
202/659-1640

The Wheat Growers
Route #1, Box 27
Hemingford, NE 69438
308/487-3794

The WIFE Organization
Osceola, NE 68651

Colleges

Alabama

Livingston University
Livingston, AL 35470
Contact: Wayne F. Canis
205/652-9661 Ext. 245

Talladega College
627 West Battle Street
Talladega, AL 35160

Contact: Richard A. Morrison
205/362-8800

Wallace State Community College
P.O. Box 250 A
Hanceville, AL 35077

Contact: Rayburn Williams
205/352-6403 Ext. 34

Arizona

Central Arizona College
Woodruff at Overfield Road
Coolige, AZ 85228
Contact: John Palmer
602/723-4141 Ext. 221

Central Arizona College
P.O. Box 97
Winkleman, AZ 85292
Contact: Glen F. Johnson
602/356-7864

College of Ganado
Ganado, AZ 86505
Contact: Jefferson R. Snider
602/755-3442 Ext. 30

Arkansas

Mississippi County Community College
Mid-South Energy Project
Box 1109
Blytheville, AR 72315
Contact: Christopher M. Benson
501/762-1020 Ext. 40

North Arkansas Community College
Pioneer Ridge
Harrison, AR 72601
Contact:
501/743-3000 Ext. 60

California

Antioch University
650 Pine Street
San Francisco, CA 94108
Contact: Brant Ingram
415/956-1688 Ext. 215

Cabrillo Community College
6500 Soquel Drive
Aptos, CA 95003
Contact: Richard Merrill
408/425-6481

California State Polytechnical University at Pomona
Pomona, CA 91768
Contact: John R. Biddle
714/598-0239

California State University at Hayward
Hayward, CA 94598
Contact: Esther Railton
451/881-3016 Ext. 3027

College of Siskiyous
800 College Avenue
Weed, CA 96094
Contact: William R. Kinkade
916/938-4463 Ext. 262

College of The Redwoods
Eureka, CA 95501
Contact: David Mills
707/443-8411 Ext. 424

East Los Angeles College
1301 Brooklyn Avenue
Monterey Park, CA 91754
Contact: Robert A. Stevenson
213/265-8855

Glendale Community College
1500 North Verdugo Road
Glendale, CA 91208
Contact: Dave Davenport
213/240-1000 Ext. 312

Indian Valley Colleges
1800 Ignacio Boulevard
Novato, CA 94947
Contact: Don Marin
415/883-2211 Ext. 200

Lake Tahoe Community College
2659 Lake Tahoe Boulevard
P.O. Box 14445
South Lake Tahoe, CA 95702
Contact: Dave Bainbridge
916/541-4660 Ext. 30

Modesto Jr. College
Modesto, CA 95350
Contact: Ron Alves
209/526-2000 Ext. 311

Saddleback Community College District
28000 Marquerite Parkway
Mission Viejo, CA 92692
Contact: John Batok
714/831-4819

San Joaquin Delta College
5151 Pacific Avenue
Stockton, CA 95207
Contact: Gary Blomgren
209/478-2011 Ext. 322

Stanford University
Stanford, CA 94305
Contact: Channing Robertson
415/497-4906

University of California at Davis
Davis, CA 95616
Contact: Paul Craig
916/752-0360

University of California at San Diego
La Jolla, CA 92093
714/452-4706

Victor Valley College
58422 Bear Valley Road
Victorville, CA 92392
Contact: Kermit E. Irby
714/245-4271 Ext. 238

West Hills Community College
300 Cherry Lane
Coalinga, CA 93210
Contact: Robert Gibson
209/935-0801 Ext. 225

Colorado

Colorado State University
Fort Collins, CO 80523
Contact: S. Karaki
303/491-8617

Lamar Community College
2401 South Main
Lamar, CO 81052
Contact: Bill Henderson
303/336-2248

Mesa College
Box 2647
Grand Junction, CO 81502
Contact: Woodrow Ramsey
303/248-1476

Pikes Peak Community College
5675 South Academy Blvd.
Colorado Springs, CO 80911
Contact: Robert J. Earle
303/576-7711 Ext. 217

University of Colorado at Boulder
Boulder, CO 80309
Contact: Dennis R. Holloway
303/492-7497

Connecticut

Central Connecticut State College
1615 Stanley Street
New Britain, CT 06050
Contact: Thattil J. Devassy
203/827-7280

Fairfield University
Fairfield, CT 06430
Contact: Victor Newton
203/255-5411 Ext. 2564

Delware

Delaware Tech. and Community
College, Terry Campus
1832 North Dupont Parkway
Dover, DE 19901
Contact: Bob Adams
302/678-5401

District of Columbia

George Washington University
725 23rd Street, NW
Washington, DC 20052
Contact: W. Jackson
202/676-6749

Florida

Brevard Community College
1519 Clearlake Road
Cocoa, FL 32922
Contact: Philip Stokes
305/632-1111 Ext. 407

Broward Community College
1000 Coconut Creek Boulevard
Pompano Beach, FL 33063
Contact: Ulmer
305/972-9100 Ext. 2460

Florida International University
Miami, FL 33199
Contact: John H. Parker
305/522-2605

Florida State University
Tallahassee, FL 32306
Contact: R. H. Davis
904/644-2867

Saint Augustine Technical Center
Collins Avenue at Delmonte Dr.
St. Augustine, FL 32084
Contact: Ken Todd
904/824-4401 Ext. 78

Stetson University
Deland, FL 32720
Contact: E.C. Coolidge
904/734-4121 Ext. 244

University of North Florida
4567 St. Johns Bluff Road
Jacksonville, FL 32216
Contact: Ray Bowman

Georgia

Georgia Institute of Technology
Atlanta, GA 30332
Contact: S. M. Jeter
404/894-3351

University of Georgia
Athens, GA 30602
Contact: B. Derrell McLendon
404/549-7527

Idaho

College of Southern Idaho
315 Falls Avenue West
Twin Falls, ID 83301
Contact: James Taylor
208/733-9554

Idaho State University
Box 8088
Pocatello, ID 83209
Contact: L. E. Corey
208/236-3975

University of Idaho
Moscow, ID 83843
Contact: James M. Cassetto
208/885-6492

Illinois

Chicago State University
95 95th Street and King Drive
Chicago, IL 60628
Contact: D. W. Appenbrink
312/995-2339

Eureka College
300 College Avenue
Eureka, IL 61520
Contact: R. J. Eichenberger
309/467-3721 Ext. 241

Illinois Wesleyan University
210 East University Street
Bloomington, IL 61701
Contact: Gary Kessler
309/556-3004

Kankakee Community College
Box 888
Kankakee, IL 60901
Contact: Kris Mathers
815/944-5385

Lake Land Community College
South Route 45
Matoon, IL 61938
Contact: Robert D. Webb
217/235-3131

Lincoln Land Community College
Springfield, IL 62708
Contact: Robert Poorman
217/786-2200

Loyola University of Chicago
820 North Michigan Avenue
Chicago, IL 60611
Contact: Raymond W. Nackoney
312/670-3000 Ext. 759

Roosevelt University
430 South Michigan
Chicago, IL 60605
Contact: M. Goran
312/341-3738

Southern Illinois University at
Carbondale
Carbondale, IL 62901
Contact: Richard E. Archer
618/453-5761 Ext. 32

University of Illinois at Urbana-Champaign
Urbana, IL 61801
Contact: Gene C. Shove
217/333-6762

Western Illinois University
Macomb, IL 61455
Contact: John Shaver
309/298-1258

Wheaton College
Wheaton, IL 60187
Contact: J. H. Kraakevik
312/682-5007

Indiana

Indiana State University
Terre Haute, IN 47809
Contact: William G. Turner
812/232-6311 Ext. 2193

Indiana Vocational Technical College at Muncie
4100 Cowan Road
Muncie, IN 47302
Contact: Jerry Bunch
317/289-2291 Ext. 33

Purdue University
West Lafayette, IN 47907
Contact: G. H. Krockover
317/493-9526

Tri-State University
Angola, IN 46703
Contact: Henry Tucker
219/665-3141 Ext. 253

Vincennes University
Vincennes, IN 47591
Contact: Daryle Riegle
812/885-4197

Iowa

Des Moines Area Community College
2006 South Ankeny Boulevard
Ankeny, IA 50021
Contact: Gordon N. Rowe
515/964-6266

Eastern Iowa Community College
2804 Eastern Avenue
Davenport, IA 52803
Contact: Robert Illingsworth
319/242-6841

Iowa Central Community College
330 Avenue M
Fort Dodge, IA 50501
Contact: James C. Royce
515/576-7201 Ext. 148

Marshall Town Community College
3700 South Center
Marshalltown, IA 50158
Contact: Dennis Kethenbeutel
515/752-7106 Ext. 45

Northwest Iowa Technical College
Highway 18 West
Sheldon, IA 51201
Contact: Larry Sturdevant
712/324-2587 Ext. 78

Scott Community College
Belmont Road
Bettendorf, IA 52722
Contact: Myron Hummel
319/359-7531 Ext. 259

University of Dubuque
2050 University Avenue
Dubuque, IA 52001
Contact: David B. Straley
319/589-3142

University of Iowa
Iowa City, IA 52242
Contact: Karl Lonngren
319/353-3696

Kansas

Colby Community College
1255 South Range
Colby, KS 67701
Contact: Gene Ostmeyer
913/462-3984

Dodge City Community College
U.S. 50 Bypass and 14th Avenue
Dodge City, KS 67801
Contact: Ronald G. Albrecht
316/225-1321 Ext. 239

Kentucky

Paducah Community College
Box 1380
Paducah, KY 42001
Contact: Donald Clemons
502/442-6131

University of Louisville
Louisville, KY 40292
Contact: Dan Ochs
502/588-6591

Louisiana

Louisiana State University and A and M College
Baton Rouge, LA 70803
Contact: Clayton Callihan
504/388-1426

Nicholls State University
P.O. Box 2031
Thibodaux, LA 70301
Contact: Carey Flowers
504/446-8111 Ext. 301

Maryland

Cecil Community College
1000 North East Road
North East, MD 21901
Contact: William Charlton
301/287-6060 Ext. 251

Harford Community College
401 Thomas Run Road
Bel Air, MD 21014
Contact: Dale Rhodes
301/836-4173

Maryland

Montgomery College
51 Mannakee Street
Rockville, MD 20850
Contact: William Davis
301/279-5232

United States Naval Academy
Annapolis, MD 21402
Contact: Chih Wu
301/267-3186

University of Maryland,
Eastern Shore
Princess, MD 21853
Contact: Gian Gupta
301/651-2200 Ext. 327

Massachusetts

Bentley College
Waltham, MA 02154
Contact: B. Aghassi
617/891-2236

Clark University
450 Main
Worchester, MA 01610
Contact: Albert Gottlieb
617/793-7439

Fitchburg State College
160 Pearl Street
Fitchburg, MA 01420
Contact: Erling Lanson
617/345-2151 Ext. 184

Holyoke Community College
303 Homestead Avenue
Holyoke, MA 01040
Contact: Andrew Ellis
413/538-7000 Ext. 430

North Adams State College
Church Street
North Adams, MA 01247
Contact: W. Seeley
413/664-4511 Ext. 457

Springfield Tech. and
Community College
One Armory Square
Springfield, MA 01105
Contact: Robert Geidz
413/781-6470

Worcester State College
486 Chandler Street
Worcester, MA 01602
Contact: Daniel E. Dick
617/752-7700Ext. 136

Michigan

Central Michigan University
Mt. Pleasant, MI 48859
Contact: Louis Ecker
517/774-3996

Delta College
Markinaw Road
University Center, MI 48710
Contact: Paul Koblas
517/686-9256

Glen Oaks Community College
Route 1 Shimmel Road
Centreville, MI 49032
Contact: Wayne Moss
616/467-9945 Ext. 217

Jackson Community College
Jackson, MI 49201
Contact: V. A. Hanson
517/787-0800 Ext. 172p

Jordan College
1460 Laughlin Street
Grand Rapids, MI 49504
Contact: Alan O. Martin
616/453-5417

Michigan State University
East Lansing, MI 48824
Contact: A. M. Dhanak
517/355-5160

Mott Community College
1401 East Court Street
Flint, MI 48503
Contact: Charles Roched
313/762-0237

Northern Michigan University
Presque Isle Avenue
410 B Cohodas Adm. Center
Marquette, MI 49855
Contact: Richard V. Allenstein
906/227-2911

Saint Clair County Community
College
323 Erie Street
Port Huron, MI 48060
Contact: Phil Zochowski
313/984-3881 Ext. 288

Wayne State University
5050 Cass
Detroit, MI 48202
Contact: Trilochan Singh
313/577-3885

Minnesota

Lakewood Community College
White Bear Lake, MN 55110
Contact: Robert Wischmann
612/770-1331 Ext. 111

Redwind Energy Education
Center
Highway 16 and 19
Red Wing, MN 55066
Contact: Pat Enz
612/388-3594 Ext. 2

Saint Cloud State University
College of Industry
Department of Industrial
Education
Saint Cloud, MN 56301
Contact: Anthony Schwaller
612/255-2118

Southwest State University
Marshall, MN 56258
Contact: Richard Spencer
507/537-7217

University of Minnesota at
Minneapolis-St. Paul
Dept. of Mechanical Engineering
111 Church St., SE
Minneapolis, MN 55455
Contact: R. J. Goldstein
612/373-3302

University of Minnesota
Technical College at Crookston
Crookston, MN 56716
Contact: Kent Freberg
218/281-6510 Ext. 265

Mississippi

NW Mississippi Jr. College
Highway 51
North Senatobia, MS 38668
Contact: William Oakley
601/562-5262

University of Mississippi
University, MS 38677
Contact: John A. Fox
601/232-7219

University of Southern Mississippi
Southern Station
Hattiesburg, MS 39401
Contact: Charles R. Brent
601/266-7212

Wood Junior College
P.O. Drawer C
Mathiston, MS 39752
Contact: Barbara Crawford
601/263-5352

Missouri

Crowder College
Neosho, MO 64850
Contact: Art Boyt
417/451-4700

Drury College
900 North Benton Avenue
Springfield, MO 65802
Contact: Howard Hufford
417/887-4894

Saint Louis Community College at Forest Park
5600 Oakland Avenue
Saint Louis, MO 63110
Contact: Paul D. Nelson
314/644-9285

Southeast Missouri State University
Cape Girardeau, MO 63701
Contact: John E. Tansil
314/651-2157

State Fairground Community College
Sedalia, MO 65301
Contact: Marvin Fielding
816/826-7100, Ext. 60

Montana

Montana College of Mineral Science Technology
Butte, MT 59701
Contact: Richard Alexander
406/792-8321 Ext. 328

Nebraska

Grand Island Education Center, CICCA
3134 West Highway 34
Grand Island, NE 68801
Contact: Marion C. Kinkade
308/384-5220 Ext. 270

Peru State College
Peru, NE 68421
Contact: Daryl Long
402/872-3815 Ext. 214

South East Community College
Milford, NE 68405
Contact: Dean Roll
402/761-2131

New Hampshire

Dartmouth College
Hanover, NH 03755
Contact: A. E. Converse
603/646-2606

New Hampshire Vocational Technical College, Manchester
1066 Front Street
Manchester, NH 03102
Contact: David Magnon

New Jersey

Bergen Community College
400 Paramus Road
Paramus, NJ 07652
Contact: Neil Ender
201/447-1500 Ext. 300

Kean College
Morris Avenue
Union, NJ 07083
Contact: Joseph Clinton
201/527-2342

Rider College
P.O. Box 6400
Lawrenceville, NJ 08638
Contact: Gerald Witt
609/896-5091

New Mexico

Navajo Community College
Box 580
Shiprock, NM 87420
Contact: Raymond Housh
505/268-5291

New York

Broome Community College
Binghamton, NY 13902
Contact: Norm Herbert
607/772-5078

Columbia University, Main Division
New York, NY 10027
Contact: Harry Gregor
212/280-4716

Cornell University
B-7 Day Hall
Ithaca, NY 14853
Contact: Albert George
607/256-7540

Genesee Community College
One College Road
Batavia, NY 14020
Contact: Ray Chaya
716/343-0055 Ext. 228

New York University
32 Washington Place, Room 42
New York, NY 10003
Contact: Marshall S. Hahn
212/598-3356

Onondaga County Community College
Syracuse, NY 13215
Contact: Andreas Paloumpis
315/469-7741

Pratt Institute
215 Ryerson Street
Brooklyn, NY 11205
Contact: Brent M. Peter
212/636-3650

Rensselaer Polytechnic Institute
Troy, NY 12181
Contact: Frederick Bordt
518/270-6543

State University of New York
at Fredonia
Fredonia, NY 14063
Contact: J. J. Connelly
716/673-3305

State University of New York,
Agricultural

State University of New York,
Agricultural and
Technical College
Canton, NY 13617
Contact: Carson A. Emhof
315/386-7313

Westchester Community College
75 Grasslands Road
Valhalla, NY 10595
Contact: Diana Lee
914/347-6914

North Carolina

Appalachian State University
101 Sanford Hall
Boone, NC 28608
Contact: Karl C. Mamola
704/262-3090

Caldwell Community College and
Technical Institute
1000 Hickory Boulevard
Hudson, NC 28638
Contact: David Monroe
704/728-4323 Ext. 239

Martin Community College
Kehukee Park Road
Williamston, NC 27892
Contact: Geoffrey Balkam
919/792-1521 Ext. 249

Pitt Community College
Box Drawer 7007
Greenville, NC 27834
Contact: Marcus King
919/756-3130 Ext. 274

Technical College of Alamance
P.O. Box 623
Haw River, NC 27258
Contact: David M. Payne
919/578-2002 Ext. 29

Vance-Granville Community
College
P.O. Box 917
Henderson, NC 27536
Contact: Daniel W. Guin
919/492-2061

Western Carolina University
Cullowhee, NC 28723
Contact: Don Wood
704/227-7397

North Dakota State School of
Science
Wahpeton, ND 58075
Contact: Claire T. Blikre
701/671-2221

North Dakota

University of North Dakota
Grand Forks, ND 58202
Contact: W. A. Dando
701/777-4588

Ohio

Bowling Green State University
Bowling Green, OH 43403
Contact: A. J. PaLumbo
419/372-2436

Cleveland State University
24th Street and Euclid Avenue
Cleveland, OH 44115
Contact: Rama S. R. Govla
216/687-2567

Miami University
High Street
Exford, OH 45056
Contact: Fuller Moore
513/529-5811

University of Akron
Buchtel Avenue
Akron, OH 44325
Contact: Jim L. Jackson
216/657-2815

Wittenberg University
Springfield, OH 45501
Contact: Nelson Sartoris
513/327-7432

Oklahoma

Panhandle State University
Box 430
Goodwell, OK 73939
Contact: Gene Reeves
405/742-2121

Oregon

Eastern Oregon State College
8th and K Streets
LaGrande, OR 97850
Contact: Paul Stephas
503/963-2171 Ext. 310

Pennsylvania

King's College
River Street
Wilkes-Barre, PA 18711
Contact: J. Rakowski
717/824-9931 Ext. 237

LeHigh County Community
College
2370 Main Street
Schnecksville, PA 18078
Contact: J. Robert Walker
215/799-2121 Ext. 1500

Mansfield State College
Mansfield, PA 16933
Contact: George Mullen
717/662-4275

South Carolina

Chesterfield-Marlboro Technical
College
P.O. Drawer 928
Cheraw, SC 29520
Contact: Donald R. Smith
803/537-5286

Horry Georgetown Technical
College
Highway 501 East
Conway, SC 29526
Contact: Wade Harper
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South Dakota

Ogalala Sioux Community College
Box 439
Pine Ridge, SD 57700
Contact: Roberta Barbalace
606/867-5110

Northern State College
Aberdeen, SD 57401
Contact: Terry Richardson
605/622-2571

South Dakota State University
Brookings, SD 57007
Contact: Paul Middaugh
605/688-4116

University of South Dakota, Main Campus
Vermillion, SD 57069
Contact: Robert W. Jones
605/677-5649

Tennessee

State Technical Institute at Knoxville
3435 Division Street,
P.O. Box 19802
Knoxville, TN 37919
Contact: Dwight Magnuson
615/637-4262

Texas

East Field College
3737 Matley Drive
Mesquite, TX 75150
Contact: W. Tim Hughes
214/756-3208

Grayson County Junior College
Denison, TX 75020
Contact: Clifford Wood
214/465-6030 Ext. 227

Navarro Jr. College
Box 1170
Corsicana, TX 75110
Contact: Darrell Raines
214/874-6501

Richland College
12800 Abrams Road
Dallas, TX 75243
Contact: J. H. Daugherty
214/746-4585

Texas A & I University
Kingsville, TX 78363
Contact: Lionel D. Hewett
512/959-2618

Texas Technical University
Lubbock, TX 79409
Contact: Steven R. Beck
806/742-3553

University of Texas at Dallas
P.O. Box 688
Richardson, TX 75080
Contact: Ervin J. Fenyves
214/690-2971

Utah

University of Utah
Salt Lake City, UT 84112
Contact: R. F. Boehm
801/581-6441

Vermont

Castleton State College
Castleton, VT 05735
Contact: J. V. Freeman
802/468-5611 Ext. 201

University of Vermont
Burlington, VT 05404
Contact: Grant Wells
802/656-2000

Virginia

James Madison University
Harrisonburg, VA 22807
Contact: Kent Moore
703/433-6338

Old Dominion University
Box 6173 Hampton Blvd.
Norfolk, VA 23508
Contact: Gary R. Crossman
804/440-3766

Radford University
Radford, VA 24142
Contact: Franklin M. Jones
703/731-5145

Virginia Polytechnic Institute and State University
Blacksburg, VA 24061
Contact: David H. Vaughan
703/961-5038

Washington

Skagit Valley College
2405 College Way
Mount Vernon, WA 98273
Contact: Douglas N. Campbell
206/428-1195

The Evergreen State College
Olympia, WA 98505
Contact: Rob Knapp
206/866-6679

Washington State University
Box 708
Chehalis, WA 98532
Contact: Larry Gueck
206/748-9121, Ext. 212

University of Washington
Seattle, WA 98195
Contact: James S. Bechtel
206/543-2730

Whatcam Community College
Northwest Road
Bellingham, WA 98225
Contact: Douglas N. Campbell
206/384-1541

West Virginia

University of Charleston
2300 MacCorkle Avenue, SE
Charleston, WV 25304
Contact: Jesse Spencer
304/346-9471 Ext. 226

West Virginia University
Morgantown, WV 26506
Contact: Paul W. DeVore
304/392-3803

Wisconsin

District One Technical Institute
Eau Claire, WI 54701
Contact: Thomas A. Dougherty
715/836-2828

Marquette University
1515 West Wisconsin Avenue
Milwaukee, WI 53233
Contact: S. V. Jaskolski
414/224-6820

University of Wisconsin at River Falls
River Falls, WI 54022
Contact: C. M. Jones
715/425-3950 Ext. 3985

University of Wisconsin at Whitewater
800 West Main Street
Whitewater, WI 53190
Contact: Carl W. Shinners
414/472-1075

Wyoming

Eastern Wyoming College
3200 West C
Torrinton, WY 82240
Contact: Charles Rogers
307/532-7111

University of Wyoming
Laramie, WY 82071
Contact: V. G. Sindt
307/766-6381

Virgin Islands

College of the Virgin Islands
St. Thomas, VI 00801
Contact: Michael Canoy

Cooperative Extension Services

Alabama

Cooperative Extension Service
Auburn University
Auburn, AL 36849
205/826-4000

Alabama A&M University
1890 Program
P.O. Box 54
Normal, AL 35762
205/859-7342

Tuskegee Institute
1890 Program
109 Extension Building
Tuskegee Institute, AL 36088
205/727-8807

Alaska

Cooperative Extension Service
University of Alaska
Fairbanks, AK 99701
907/479-7246

Arizona

Cooperative Extension Service
University of Arizona
College of Agriculture
Tucson, AZ 85721
602/626-0111

Arkansas

Cooperative Extension Service
University of Arkansas
1201 McAlmont
P.O. Box 391
Little Rock, AR 72203
501/376-6301

California

Cooperative Extension Service
University of California
2200 University Avenue
Berkeley, CA 94720
415/642-9300

Colorado

Cooperative Extension Service
Colorado State University
Fort Collins, CO 80523
303/491-1101

Connecticut

Cooperative Extension Service
University of Connecticut
College of Agriculture and Natural Resources
Storrs, CT 06268
203/486-2000

Delaware

Cooperative Extension Service
University of Delaware
College of Agricultural Sciences
Newark, DE 19711
302/738-2504

District of Columbia

D.C. Cooperative Extension Service
Univ. of the District of Columbia
1331 H Street, NW
Washington, DC 20005
202/727-2016

Florida

Cooperative Extension Service
University of Florida
Institute of Food and Agricultural Sciences
Gainesville, FL 32611
904/392-1761

Georgia

Cooperative Extension Service
University of Georgia
College of Agriculture
Athens, GA 30602
404/542-3824

Hawaii

Cooperative Extension Service
University of Hawaii at Manoa
Honolulu, HI 96822
808/948-8397

Idaho

Cooperative Extension Service
University of Idaho
College of Agriculture
Moscow, ID 83843
208/885-6639

Illinois

Cooperative Extension Service
University of Illinois
College of Agriculture
Mumford Hall
1301 West Gregory Drive
Urbana, IL 61801
217/333-1000

Indiana

Cooperative Extension Service
Purdue University
West Lafayette, IN 47907
317/749-8111

Iowa

Cooperative Extension Service
Iowa State University
Ames, IA 50011
515/294-4111

Kansas

Cooperative Extension Service
Kansas State University
Umberger Hall
Manhattan, KS 66506
913/532-5820

Kentucky

Cooperative Extension Service
University of Kentucky
College of Agriculture
Lexington, KY 40506
606/258-9000

Louisiana

Cooperative Extension Service
Knapp Hall
Louisiana State University
University Station
Baton Rouge, LA 70803
504/388-4141

Maine

Cooperative Extension Service
University of Maine
Winslow Hall
Orono, ME 04469
207/581-2211

Maryland

Cooperative Extension Service
University of Maryland
Symons Hall
College Park, MD 20742
301/454-0100

Massachusetts

Cooperative Extension Service
University of Massachusetts
Amherst, MA 01003
413/545-2766

Michigan

Cooperative Extension Service
Michigan State University
113 Agriculture Hall
East Lansing, MI 48824
517/355-1855

Minnesota

Agricultural Extension Service
University of Minnesota
St. Pual, MN 55108
612/373-1243

New Jersey

Cooperative Extension Service
Cook College
Rutgers — The State University
New Brunswick, NJ 08903
201/932-9306

New Mexico

Cooperative Extension Service
New Mexico State University
Box 3AE
Las Cruces, NM 88003
505/646-1806

New York

Cooperative Extension
Cornell University
Ithaca, NY 14853
607/256-2117

North Carolina

Agricultural Extension Service
N.C. State University
P.O. Box 5157
Raleigh, NC 27650
919/737-2812

AT&T State University
P.O. Box 21928
Greensboro, NC 27420
919/379-7956

North Dakota

Cooperative Extension Service
North Dakota State University
Fargo, ND 58105
701/237-8944

Ohio

Cooperative Extension Service
Ohio State University
2120 Fyffe Road
Columbus, OH 43210
614/422-6181

Mississippi

Cooperative Extension Service
Mississippi State University
P.O. Box 5446
Mississippi State, MS 39762
601/325-3036

Missouri

Cooperative Extension Service
University of Missouri
Columbia, MO 65211
314/882-7754

Lincoln University of Missouri
Jefferson City, MO 65101
314/751-2325

Montana

Cooperative Extension Service
Montana State University
Bozeman, MT 59715
406/994-3402

Nebraska

Nebraska Cooperative Extension Service
Division of Institute of Agriculture and Natural Resources
Agricultural Hall
Lincoln, NE 68583
402/472-7211

Nevada

Cooperative Extension Service
University of Nevada
College of Agriculture
Reno, NV 89557
702/784-6611

New Hampshire

Cooperative Extension Service
College of Life Sciences and Agriculture
Taylor Hall — University of New Hampshire
Durham, NJ 03824
603/862-1520

Oklahoma

Oklahoma Cooperative Extension Service
Oklahoma State University
139 Agricultural Hall
Stillwater, OK 74078
405/624-5400

Langston Coop Extension
P.O. Box 779
Langston, OK 73050

Oregon

Extension Service
Oregon State University
Corvallis, OR 97331
503/754-2713

Pennsylvania

Cooperative Extension Service
The Pennsylvania State Univ.
323 Agri. Admin. Building
University Park, PA 16802
814/863-0331

Rhode Island

Cooperative Extension
University of Rhode Island
Kingston, RI 02881
401/792-2476

South Carolina

Cooperative Extension Service
107 Barre Hall
Clemson University
Clemson, SC 29631
803/656-3311

South Dakota

Cooperative Extension Service
South Dakota State University
College of Agriculture
Box 2207
Brookings, SD 57007
605/688-4147

Tennessee

Agricultural Extension Service
University of Tennessee
Institute of Agriculture
P.O. Box 1071
Knoxville, TN 37901
615/974-7114

Texas

Agricultural Extension Service
Texas A&M University
College Station, TX 77843
713/845-6411

Utah

Cooperation Extension Service
Utah State University
Logan, UT 84322
801/750-2194

Vermont

Cooperative Extension Service
University of Vermont
Burlington, VA 05405
802/656-2990

Virginia

Cooperative Extension Service
Burruss Hall
Virginia Polytechnic Institute and State University
Blacksburg, VA 24061
703/951-6705

Virginia State University
Cooperative Extension Programs
Box 540
Virginia State University
Petersburg, VA 23803
804/520-6421

Washington

Cooperative Extension Service
Washington State University
College of Agriculture
Pullman, WA 99164
509/335-2511

West Virginia

Cooperative Extension Service
Center for Extension and Continuing Education
West Virginia University
Morgantown, WV 26506
304/293-5691

Wisconsin

Cooperative Extension Service
Univ. of Wisconsin-Extension
432 North Lake Street
Madison, WI 53706
608/262-9510

Wyoming

Agricultural Extension Service
University Station
Box 3354
Laramie, WY 82071
307/766-6363

Puerto Rico

Cooperative Extension Service
College of Agriculture
University of Puerto Rico
Mayaguez, PR 00708
809/833-7000

Land Grant Colleges

University of Guam
UOG Station
Mangilao, Guam 96913
734-2177

College of Virgin Islands
St. Thomas, Virgin Islands 00801
809/774-1252

Feedstock Information Sources

There are a number of ways to obtain information on the availability of feedstocks for fermentation-ethanol production. Possibilities include local farmers' organizations, regional U.S. Department of Agriculture offices, local extension offices, agricultural and specific crop associations, and brokerage firms that deal in commodity futures.

General

Distillers Feed Research Council
1435 Enquirer Building
Cincinnati, OH 45202
(513) 621–5985

Southwest Alabama Farm Co-op
Highway 80
Selma, AL
(205) 872–6227
Contact: Albert Turner

Grains

National Council of Farmer Co-ops
1800 Massachusetts Avenue NW
Washington, D.C. 20036
(202) 659–1525

Potatoes

National Potato Council
45th and Peoria
Denver, CO 80239
(303) 373–5639

Sorghum

Grain Sorghum Producers Association
1708 A 15th Street
Lubbock, TX 79401
(806) 763–4425
Contact: Elbert Harp, Executive Director

Producers Grain Corp.
P.O. Box 111
Amarillo, TX 79105
(806) 374–0331

State Alcohol Fuels Contacts

Alabama

Leonard McGann
Alabama Solar Energy Center
P.O. Box 1247
Huntsville, AL 35607

Alaska

Ken Ulz
Kobuk
P.O. Box 1599
Fairbanks, AK 99707

Arizona

Dan Shein
Arizona Energy Office
1700 W. Washington
Phoenix, AZ 85007
602/255-3632

Arkansas

Jodie Marler
Arkansas Department of Energy
960 Plaza West
Little Rock, AR 72205

California

Peter Ward
Fuels Specialist
California Energy Commission
Development Division
111 Howell Avenue
Sacramento, CA 95825
916/920-6031

Colorado

Bob Merten
Colorado Gasohol Promotion
Committee
Department of Agriculture
1525 Sherman Street, 4th Floor
Denver, CO 80203
303/866-3218

Connecticut

R. C. Hoerning
85 Roosevelt Boulevard
Enfield, CT 06082
203/677-4631

Florida

Halen Vermeers
160 SW, 17th Court #7
Miami, FL 33135
305/642-3994

Georgia

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510 Houston Street
Montezuma, GA 31603

Idaho

Ralph Woodmansee
Chairman, Gasohol Prom. Com.
325 Ron Glyn
Idaho Falls, ID 83401
208/523-6970

Illinois

John Lehmann
Illinois Department of
Agriculture
Emerson Building
State Fairgrounds
Springfield, IL 62706

Iowa

Roger Etrheim
Iowa Corn Promotion Board
200 W. Towers
1200 35th Street
W. Des Moines, IA 50265
515/255-9242

Tom Perason
Iowa Department of Commerce
250 Jewett Building
Des Moines, IA 50309

Kansas

Dean Shelor
Route 1
Mineola, KA 67865

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Bruce Sauer
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P.O. Box 118888
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Toni Morrison
1102 6th Street
New Orleans, LA 70115

Maine

Nancy Holmes
Office of Energy Resources
55 Capital Street
Augusta, ME 04330

Maryland

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Michigan Department of
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Marketing/International Trade
Division
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Minnesota

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5641 Newton Avenue S
Minneapolis, MN 55419
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Mississippi

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Laurel, MS 39440
601/425-4428

Missouri

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Jefferson City, MO 65102
314/751-3332

Montana

Georgia Brensdal
Energy Division
State of Montana
Department of National
Resources and Conservation
32 South Ewing
Helena, MT 59601
406/449-4624

Nebraska

Todd Sneller, Adm.
Nebraska Grain Alcohol
Program
Ag Products Industrial Utility
Commission
3rd Floor, Box 94831
301 Centennial Mall South
Lincoln, NE 68509
402/471-2941

New Mexico

Lee Tilman
New Mexico Alcohol Fuels Association
c/o Lee Tilman
Eastern Plains Council of Governments
Curry County Courthouse
Clovis, NM 88101
505/762-7714, 763-5591

New York

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257 Middle County Road
Smithtown, NY 11787
516/724-5300

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Dean McIlroy
North Dakota Ag Products Utilization Committee
6th Floor
Capitol Building
Bismarck, ND 58505
701/224-2232

Ag Products Industrial Utilization Committee
701/224-2232

Ohio

Jack Hill
Ohio Farm Bureau
P.O. Box 479
Columbus, OH 47215
614/461-6211

Oregon

Tom Winn
Oregon Department of Agriculture
635 Capital NE
Salem, OR 97310

Pennsylvania

Joseph M. Barron
Chief Executive Officer
Pennsylvania Gasohol Association
Reynolds-Ward Building
606 Island Avenue
McKees Rocks, PA 15136

South Carolina

Bob Kinard
SCN Center
Suite 1130
Columbus, SC 29201
803/758-7502

South Dakota

Verne Brakke
Office of Energy Policy
Capital Lake Plaza
Pierre, SD 57501
605/773-3603

Texas

Robert V. Avant, Jr.
Texas Energy and National Resources Advisory Council
200 E. 18th Room 511
Austin, TX 78701
512/475-5588

Utah

Jim Byrne
Utah Energy Office
231 East 400 Street
Salt Lake City, UT 84111

Vermont

Dick Cambio
Vermont Energy Office
State Office Building
Montpelier, VT 05602

Virginia

Irl Smith
Alcohol Fuel/Gasohol Project Coordinator
Department of Agriculture and Consumer Service
203 North Gov Street
Richmond, VA 23219
803/786-3519

Washington

Robert Sarvis
Edmond Community College
200068 Avenue W
Lynwood, WA 98036
206/771-1524

Bob Michaelson
Director of Department of Agriculture
406 General Administration Building
Olympia, WA 98504
206/753-5050

West Virginia

Clifford L. Manley
Glenville, WV 26351
304/3642-8997

Wisconsin

George Plaza
Biomass Analyst
Division of State Energy
1010 S. Webster Street
Madison, WI 53702
608/266-0985

Wyoming

Butch Keadle
Fuel Allocation Specialist
Energy Conservation Office
Capitol Hill Office Building
25th and Pioneer
Cheyenne, WY 80002
307/777-7284

Appendix C

Production Resources

Notice

The following list of persons and organizations involved in various areas of alcohol fuels production is provided for your information. These persons and organizations have represented themselves as suppliers of these services and products. Neither the U.S. Department of Energy nor the Solar Energy Research Institute recommend or vouch for these sources. We would appreciate receiving additions to or revisions of this information.

Consumer Production Guidelines

The following rules might be useful when selecting products and/or services associated with fermentation ethanol:

- Prospective buyers should buy from a reputable businessperson. Two or three references should be obtained and then carefully checked.
- Care should be taken to avoid bargain prices; a "bargain" product and/or service may come along with it. Higher cost may ensure a better quality product and service.
- Price is only one factor. Prospective buyers should investigate all aspects of the product offered.
- A guarantee or warranty should be obtained for the products purchased.
- Contracts or agreements should not be signed until obligations of the seller and purchaser are fully understood.
- Local consumer-affairs offices can provide assistance if problems arise.

It is particularly important when buying products associated with fermentation-ethanol production to understand exactly what is being purchased and what is being provided. The purchaser should ask questions. For example, Who assembles the still? Is training available to teach the purchaser how to operate the still? Are any consulting services provided with the product?

Component Manufacturers

A. O. Smith
P.O. Box 29
Kankakee, IL 60901
815/933-8241

Ace Pump Corporation
1650 Channel Avenue
Memphis, TN 38113
901/948-8514

Acem International Equipment
and Supply Co., Inc.
P.O. Box 6097
Spartanburg, SC 29304

Ad-Pro Industries, Inc.
3110 Southwest Freeway, Suite 130
Houston, TX 77098
713/523-4441

Ag-Bag Corporation
P.O. Box 418
Astoria, OR 97103
503/325-2488

Agri-Fuel
P.O. Box 26581
Denver, CO 80226
303/989-3343

Agri-Fuel Corp.
200 Market Building
Suite 961
Portland, OR 97201
502/233-6660

Agri-Stills of North America
3550 Great Northern Avenue
Springfield, IL 62707
217/787-4233

Agrihol, Inc.
Box 18
Rosholt, SD 57260
605/537-4252

Agro-City Incorporated
Route 1, Box 861
Cedar Hill, TX 75104
214/296-2401

Agrodyne
P.O. Box 934
Idaho Falls, ID 83401
208/524-1000

Agrohol Systems Incorporated
6120 Earle Brown Drive
Minneapolis, MN 55430
612/560-4282

Aidco Maine Corp.
Orr's Island, ME 04066
207/833-6700

Alco-Fuels, Inc.
5118 Valley Road
Fairfield, AL 35054
205/787-3835

Alcogas, Inc.
5200 South Quebec
Suite 201
Englewood, CO 80111
303/572-9300, 770-9667

Alcohol Fuel Works
8549 Sunset Avenue
Fair Oaks, CA 95628
916/961-2896, 988-7569

Alcohol Plant Supply Company
P.O. Box 248
Sherwood, OR 97140
503/244-3230

Alcohol Power Consultant
Rural Route
Linden, IA 50146
515/744-2086

Alcohol Production Engineering Company
7201 West Vickery Street
Fort Worth, TX 76116
817/731-4121

Alcohol Technology, Inc.
P.O. Box 1489
Rockdale, TX 76567
512/446-6777

Alcomotive, Inc.
101 South Cleveland
Farmersville, IL 62533
217/227-3227

Alltech, Inc.
271 Gold rush Road
Lexington, KY 40503
606/276-3414

Alpha Tank and Metals Mfg. Co.
5001 South 38th Street
St. Louis, MO 83116
314/481-6790

Alternate Energy Association of the Ozarks
1200 South Maryland
Springfield, MO 65807
417/869-8930, 623-4289

Alternative Fuels, Inc.
2880 Southwest 4th Avenue
Ontario, OR 97914
503/881-1317

Amber Laboratoraies
6101 North Teutonia Avenue
Milwaukee, WI 53209
414/462-3700

American Agri-Fuels Corporation
1006 Grand Avenue, 10th Floor
Suite 1010
Kansas City, MO 64106
816/221-0070

American Alloy Steel, Inc.
Dept. TR
2070 Steel Drive
Tucker, GA 30084
404/934-1681

American Homegrown Fuel Company
864-B Haight Street
San Francisco, CA 94117
415/621-6338

American Lewa, Inc.
11 Mercer Road
Natick, MA 01760
617/653-0229

Ametek
2300 West Marshall Drive
Grand Prairie, TX 75201
214/647-2626

Anheuser-Busch, Inc., Yeast Products Research
72 Pestalozzi Street
St. Louis, MO 63118
314/577-2000

Applied Technologies, Inc.,
722 East South Street
Hastings, NE 68901
402/463-0521

Archer Daniels Midland
1350 Waconia Avenue, SW
Cedar Rapids, IA 52406
319/398-0600

Arlon Industries, Inc.
P.O. Box 347
Sheldon, IA 51201

Arrow Tank Co., Inc.
16 Barnett Street
Buffalo, NY 14215

Astro Metallurgical Corporation
3225 Lincoln Way West
Wooster, OH 44691
216/264-8639

Atec Energy Corporation
1916 Old Middlefield Way
Mt. View, CA 94043
415/961-6500

Automatic Equipment
Manufacturing Company
P.O. Box P
Pender, NE 68047
402/385-3051

Automation Products, Inc.
3030 Max Roy Street
Houston, TX 77008
713/869-0361

ACR Process Corporation
602 East Green Street
Champaign, IL 61820
217/351-7510

ARI Industries, Inc.
9000 King Street
Franklin Park, IL 60131
312/671-0511

Barber-Colman Company
1300 Rock Street
Rockford, IL 61101
815/877-0241

Behlen Manufacturing Company
P.O. Box 569
Columbus, NE 68601
402/564-3111

Bell and Gossett
8200 North Austin Avenue
Morton Grove, IL 60053
312/966-3700

Beloit Corporation
Dalton, MA 01226
413/443-5621

Best Welding and Fabrication
Service, Inc.
Route L, Box 6A
Lockport, LA 70374
504/693-8656

Biocon (U.S.), Inc.
261 Midland
Lexington, KY 40507
606/254-0517

Blue Bell Equipment Company
3110 Maple Drive, NE
Atlanta, GA 30305
404/237-9678

Bohler Brothers of America, Inc.
1625 West Belt North
Houston, TX 77043
713/465-8376

Brown Fintube Company
P.O. Box 2739
Tulsa, OK 74101
918/584-2621

C. J. Wennberg, Inc.
1260 Winchester Parkway,
Suite 209
Smyrna, GA 30080
404/433-1765

Caldwell Tanks, Inc.
4000 Tower Road
Louisville, KY 40219
502/964-3361

Cellulose Catalyst Company
1714 Gervais Avenue
North St. Paul, MN 55109
612/777-8545

Central Fabricators, Inc.
408-418 Poplar Street
Cincinnati, OH 45214
513/621-1240

Chem-Pro Equipment
Corporation
27 Daniel Road
Fairfield, NJ 07006
201/575-1924

Chemapec, Inc.
230 Crossways Park Drive
Woodbury, NY 11797
516/364-2100

Chief Industries, Inc.
West Highway 30
Grand Island, NE 68801
308/382-8820

Circle Bin Sales, Inc.
Rural Route 1
New Market, IA 51646
712/585-3430

Clary Corporation
917 Parkway Dr.;
Grand Prairie, TX 75051
214/647-4156

Coaltech, Inc.
P.O. Box 1602
York, PA 17405
717/767-6717

Compost Making Enzymes
R.R. 1, Box 114
Harton, KS 66439
913/486-3302

Conameter Corporation
9 Democrat Way
Gibbsboro, NJ 08026
609/783-7675

Craisner, Inc.
P.O. Box 94662
Schaumburg, IL 60193
312/830-0060

Cross Manufacturing, Inc.
204 West Simpson
Pratt, KS 67124
316/672-7484

CCI Industries
27 West 990 Industrial Road
Barrington, IL 60010
312/381-7441

D and N Distillers
Route 2, Box 41
Breman, AL 35033
205/287-1134

Damrow Co.
196 Western Avenue
Fond du Lac, WI 54935
414/922-1500

De Laval Separators
350 Dutchess Turnpike
Poughkeepsie, NY 12602
914/452-1000

Doerr Metal Products
320 East sixth
Larned, KS 67550
316/285-2174

Double "A" Quality Products Co.
P.O. Box 1107, Highway 65 South
Albert Lea, MN 56007

Double "L" Mfg., Inc.
P.O. Box 533
American Falls, ID 83211
208/226-5592

Dwyer Instruments, Inc.
Jct. Ind. 212 and U.S. 12
Michigan City, IN 46360
219/872-9141

DCI
600 North 54th Avenue
St. Cloud, MN 56301
612/252-8200

Easy Engineering, Inc.
3353 Larimer Street
Denver, CO 80205
303/893-8936

Eaton Metal Products Company
4800 York Street
Denver, CO 80216
303/825-7204

Economy Alcohol Fuel Supplies
4853 Joyce Drive
Dayton, OH 45439
513/299-4283

Elmer G. Carlson and Associates
3624 Leavenworth Street
Omaha, NE 68105
402/345-3090

Elwood Energy, Inc.
P.O. Box 321
Plainfield, IL 60544
815/436-7463

Energy Complexes, Inc.
4200 South Louis, Suite 303
Sioux Falls, SD 57106
605/331-2555

Energy Independence
Corporation
P.O. Box 56
Montrose, MN 55363
612/675-3131

Energy Restoration, Inc.
1201 J Street, Suite 101
Lincoln, NE 68508
402/475-9237

Enterprise Steelfat, Inc.
115 West 7th Avenue
Oshkosh, WI 54901
414/235-1250

Ernst Gage Co.
250 South Livingston Avenue
Livingston, NJ 07039
201/992-1400

Ethylene Corporation
7401 Phillips Hwy.
Jacksonville, FL 32216
904/731-8290

Extech International Corporation
114 State Street
Boston, MA 02109
617/227-7090

EMCO Wheaton, Inc.
Chamberlain Blvd.
Conneaut, OH 44030
216/599-8151

Fanco, Inc.
317 East Cotton Street
Longview, TX 75606
713/757-8120

Fisher Scientific Company
711 Forbes Avenue
Pittsburgh, PA 15219
412/562-8300

Flow Technology, Inc.
4250 East Broadway Road
Phoenix, AZ 85040
602/268-8776

Fuels Development and
Manufacturing, Inc.
418 South 12th
Caldwell, ID 83605
208/459-1215, 459-1245

G. B. Fermentation
Industries, Inc.
One North Broadway
Des Plaines, IL 60016
312/827-9700

Gaston County Sales and
Service Corporation
P.O. Box 308
Stanley, NC 28164
704/263-4765

Georgia-Pacific
P.O. Box 1236
Bellingham, WA 98225
503/222-5561

Glitsch, Inc.
P.O. Box 226227
Dallas, TX 75266
214/631-3841

Gorman-Rupp Company
15601 19th Place West
Sand Springs, OK 74063
918/245-9555

Granco-Clark, Inc.
7298 North Storey Road
Belding, MI 48809
616/794-2600

Hamilton Tank Company
1520 Bender Avenue
Hamilton, OH 45011
513/863-2062

Harrison and Ellis Corporation
P.O. Box 528
Cairo, GA 31728
912/377-4482

Harwil Corporation
1548C 17th Street
Santa Monica, CA 30404
213/829-2310

Homak, Inc.
P.O. box 3242
Abilene, TX 79604
915/673-4015

Honeywell
1700 West Highway 36
Roseville, MN 55113
612/378-4178

Hot Energy Shoppe
490 West 300 South
Provo, UT 84601
801/377-8130

Hydro-Thermal Corporation
1263 North 70th Street
Milwaukee, WI 53213
414/476-7711

Independent Fuels Company
741 Merus Court
Fenton, MO 63026
314/343-0508

Industrial Boiler Company, Inc.
221 Law Street
Thomasville, GA 31792
912/226-3024

Industrial Fiberglas, Inc.
3065 West 2100
Salt Lake City, UT 84119
801/972-6658

Industrial Innovators, Inc.
P.O. Box 387
Ashford, AL 36312
205/899-3314

Ingersoll-Rand
P.O. Box 668
Hastings, NE 68901
402/463-6821

Ingersoll-Rand Air Center
5805 East 39th Avenue
Denver, CO 80207
303/399-1585

Insta-Pro
10301 Dennis Drive
Des Moines, IA 50322
515/276-4524

International Fuel Systems
P.O. Box 7232
Overland Park, KS 66207
913/341-8211

International Stills, Inc.
P.O. Box 240
Lake City, MN 55041
612/345-5368

Ionics, Inc.
P.O. Box 99
Bridgeville, PA 15017
412/343-1040

J and M Distillers
Route 2, Box 151
Maynard, MN 56260
612/367-2905

J. E. Stabley
2361 Druck Valley Road
York, PA 17402
717/755-4190

Jacobson Machine Works, Inc.
2445 Nevada Avenue, N
Minneapolis, MN 55429
612/544-3781

Jay Bee Manufacturing, Inc.
P.O. Box 986
Tyler, TX 75701
214/597-9343

Jaybee Associates, Inc.
2315 Bob Wallace Avenue
Suite 102
Huntsville, AL 35805
205/533-1021

John's Stills
6878 Kent Drive
Baker, LA 70714
504/654-3126

Jones and Hunts, Inc.
21 Pheasant Run Road
Orwigsburg, PA 17361
717/366-1035

K B K Industries, Inc.
East Highway 96
Rush Center, KS 67575
913/372-4331

Kar-Ad Manufacturing Company
1626 South Greenwood
Park Ridge, IL 60068
312/823-2419

Kargard Industries
2121 Cleveland Avenue
Marinette, WI 54143
715/735-9311

L and A Engineering and
Equipment, Inc.
4124 South Soderquist Road
Turlock, CA 95380
209/632-3191

Larry Goad and Company, Inc.
260 Old State Road
Ellsville, MO 63011
314/394-6334

Lasker Boiler and Engineering
Corporation
3201 South Wolcott Avenue
Chicago, IL 60608
312/523-3700

Lipton Steel and Metal
Products, Inc.
458 South Street
Pittsfield, MA 01201
413/499-1661

Liquid Control Corporation
7576 Freedom Avenue
North Canton, OH 44720
216/494-1313

Louisiana Milling Company
P.O. Box 15903
Baton Rouge, LA 70895
504/275-9741

Lucas engineering, Inc.
4205 Fox Street
Denver, CO 80216
303/458-7460

M and W Gear Company
Route 47 South
South Gibson City, IL 60936
217/784-4261

M—E—C Company
Box 330
Neodesha, KS 66757
316/325-2673

Mandil Corporation
Colorado Technical Center
12687 West Cedar Drive
Lakewood, CO 80229
303/989-7155

Manning and Lewis Engineering Company
675 Rahway Avenue
Union, NJ 07083
201/687-2400

Marlin Car Care, Inc.
P.O. Box 1009
Marlin, TX 76661
817/883-3491

Mason Street Fabricating Company, Inc.
1645 North Railroad Avenue
Decatur, IL 62525
217/424-2611

Maurice A. Knight Company
P.O. Box 109
Akron, OH 44309
216/724-1277

McKee Engineers and Constructors
10 South Riverside Plaza
Chicago, IL 60606
312/454-3810

Mead Instrument Corporation
One Day Lane
Riverdale, NJ 07457
201/835-5988

Metal Equipment Company
P.O. Box 153
Savannah, GA 31402
912/236-3378

Micro Motion, Inc.
7070 Winchester Circle
Boulder, CO 80301
303/530-0530

Micro-Tec Laboratories, Inc.
Route 2, Box 19
Logan, IA 51546
712/644-2193

Middle State Manufacturing, Inc.
P.O. Box 788
Columbus, NE 68601
402/564-1411

Midwest Energy Company, Inc.
700 North Lake Street, Suite 200
Mundelein, IL 60060
312/949-6360

Midwest Solvents Co., Inc.
1300 Main Street
Atchison, KS 66002

Miles Laboratories
P.O. Box 932
Elkhart, IN 46515
219/262-7176

Modern Welding Company, Inc.
2880 New Hartford Road
Owensboro, KY 42301
502/685-4404

Modular Fuel Systems
2348 FM 1960 West
Houston, TX 77068
713/537-6155

MRC Energy System
Rural Route 2, Box 399
Plymouth, IN 46563
219/784-8500

Nabal, Inc.
P.O. Box 82842
Lincoln, NE 68501
402/474-2120

National Tank and Manufacturing Co., Inc.
8201 Santa Fe Avenue
Huntington Park, CA 90255
213/583-1841

National Tank and Pipe Company
10037 Southeast Mather Road
Clackamas, OR 97015
503/656-1991

New Brunswick Scientific Co., Inc.
44 Talmadge Road
Edison, NJ 08817
201/287-1200

Niro Atomizer, Inc.
9165 Rumsey Road
Columbia, MD 21045
301/997-8700

Norton Company
P.O. Box 350
Akron, OH 44309
216/798-9240

Novo Laboratories, Inc.
59 Danbury Road
Wilton, CT 06897
203/762-2401

Oklahol, Inc.
Box 32671
Oklahoma City, OK 73123
405/722-5956

Olin Corporation
Shamrock Street
East Alton, IL 62024
618/258-2000

Oscar Krenz, Inc.
750 Potter Street
Berkeley, CA 94710
415/845-1400

Owens-Corning Fiberglas Corporation
Fiberglas Tower
Toledo, OH 43659
419/248-9000

Pak-Tronics, Inc.
4044 North Rockwell Avenue
Chicago, IL 60618
312/478-8585

Palmer Manufacturing and Tank, Inc.
P.O. Box 1195, West Highway 50
Garden City, KS 67846
316/275-7461

Energy Systems, Inc.
423 North University Avenue
Little Rock, AR 72205
501/664-3985

Peabody Tec Tank
South Industrial Park
Parsons, KS 67357
316/421-0200

Plyboard Corporation
P.O. Box 498
Brownsville, OR 97327
503/466-5177

Poly Cal Plastics, Inc.
1250 South Wilson Way, No. 3
Stockton, CA 95205
209/948-9675

Pott Industries, Inc.
611 East Marceau Street
St. Louis, MO 63111
314/638-4000

Premier Malt Products, Inc.
1037 West McKinley Avenue
Milwaukee, WI 53201
309/682-5411, 414/347-7300

Process Equipment Corporation
500 Reed Street
Belding, MI 48809
616/794-1230

Pufahl Enterprises, Ltd.
RR 2, Box 99
Milbank, SD 57252
605/432-4169

PEDCo International, Inc.
11499 Chester Road
Cincinnati, OH 45246
513/782-4500

R. B. Industries
P.O. Box 182
Riverdale, MI 48877
517/833-7584

Rad Tanks and Welding
Co., Inc.
2614 North Main SE
Hubbard, OH 44425
216/534-1184

Raymond Control Systems
315 Kirk Road
St. Charles, IL 60174
312/293-0090

Reinke Manufactuaring
Company, Inc.
P.O. Box 566
Deshler, NE 68340
402/365-7251

Richmond Engineering
Company, Inc.
P.O. Box 25189
Richmond, VA 23260
904/644-2611

Rochelle Energy Development,
Inc.
Box 356
Rochelle, IL 61068
815/562-7372

Rohm and Haas Company
Independence Mall West
Philadelphia, PA 19105
215/592-3000

Rovac Pump and Supply Co.
Troiano Industrial Park
188 Moody Road
Enfield, CT 06082
203/668-7290

Sargent-Welch Scientific
Company
7300 North Linder Avenue
Skokie, IL 60077
312/676-0172

Schmitt Energy Systems
Rural Route 2
Hawkeye, IA 52147
319/427-3479, 913/462-7531

Seven Energy Corporation
11901 West Cedar Avenue
Lakewood, CO 80226
303/989-777

Shur Stills
1607 Southeast Spokane Street
Portland, OR 97202
503/231-1130

Silver Engineering Works, Inc.
3309 Blake Street
Denver, CO 80205
303/623-0211

Sisterville Tank Works, Inc.
1942 McCoy Street
Sisterville, WV 26175
304/652-3011

Solar Energy Innovations
Corporation
54-45 44th Street
Maspeth, NY 11378
212/361-9038

Solar fuels International, Inc.
P.O. Box 311
Springfield, OR 97477
503/746-8821

Solargizer International, Inc.
2000 West 98th Street
Bloomington, MN 55431
612/888-0018

Solstice Designs, Inc.
Box 2043
Evergreen, CO 80439
303/674-1597

Stord Bartz Americas, Inc.
1 North Broadway
White Plains, NY 10601
914/949-8588

Sunquest, Inc.
2601 Northwest 74th Place
Gainesville, FL 32601
904/375-0406

Sybron Corporation
P.O. Box 365
Rochester, NY 14602

SWECO, Inc.
6033 East Bandini Boulevard
Los Angeles, CA 90051
213/726-1177

Terry G. Spragg and Associates
201 Ocean Drive
Manhattan Beach, CA 90266
213/374-0471

The Bishopric Products
Company
4413 Kings Run Drive
Cincinnati, OH 45232
513/641-0500

The Duriron Company, Inc.
Box 1145
Dayton, OH 45401
513/226-4000

The John T. Cody Corporation
4116 Dr. Greaves Road
Grandview, MO 64030
816/966-3500

The Revenoor, Inc.
P.O. Box 185
La Center, WA 98629
206/263-2200

The Virtis Company
Box V4, Route 208
Gardiner, NY 12525
914/255-5000

The World Energy Co.
Route 5, Box 251
Carthage, MO 64836

Thermax, Inc.
3 Pleasant Street
South Dartmouth, MA 02748
617/999-1231

3 T Engineering, Inc.
P.O. Box 80
Arentzville, IL 62611
217/997-2188

Tomco Division C.S.P., Inc.
30520 Lakeland Boulevard
Willowick, OH 44094
216/944-9000

Tomco Systems Equipment
Company
Rosebud Road, Route 2
Loganville, GA 30249
404/979-8000

Tri-Star Corporation
Rural Route 3, Illini Street
Vandalia, IL 62471
618/283-1666

U. S. Alcohol Corporation
6565 Carpenter Street
Marlette, MI 48453
517/635-3484

Union Pump Company
6914 Hillpoint
Parker, CO 80134
303/841-3092

United Electric Controls
Company
85 School Street
Watertown, MA 02172
617/926-1000

United International, Inc.
P.O. Box 11
Buena Vista, GA 31803
912/649-7444

Universal Food Corporation
433 East Michigan Street
Milwaukee, WI 53201
414/271-6755

Vara International, Inc.
Gulf and Western Plaza
1201 19th Place
Vero Beach, FL 32960
305/567-1320

Vendome Copper and Brass
Works, Inc.
North Shelby Street
Louisville, KY 40202
502/587-1930

Victory Still, Inc.
3317 Tait Terrace
Norfolk, VA 23513
804/855-7110

Vulcan Cincinnati, Inc.
2900 Vernon Place
Cincinnati, OH 45219
513/281-2800

Warner Fiberglass Products
P.O. Box 31
Belding, MI809
616/794-1130

Wenger Alko-Vap System
904 Oakdale
Holland, MI 49422
616/399-2436

Wenger Manufacturing, Inc.
714 Main Street
Sabetha, KS 66534
913/284-2133

Werner and Pfleiderer
Corporation
663 East Crescent Avenue
Ramsey, NJ 07446
201/327-6300

Williams and Davis Boilers, Inc.
P.O. Box AF
Hutchins, TX 75141
214/225-2356

Winbco Tank Company
1200 East Main Street
Ottumwa, IA 52501
515/683-1855

World Wide Construction
Service, Inc.
P.O. Box 8126
Wichita, KS 67208
316/942-0101

WAAS, Inc.
P.O. Box 100
Adamsville, AL 35005
205/787-3835

WOODCO Enterprises
3300 Buckeye Road
Suite 857
Atlanta, GA 30341
404/455-1610

Youngstown Steel Tank
Company P.O. Box 268
Youngstown, OH 44501
216/74304121

Engineering Firms

ACR Process Corporation
808 South Lincoln, #14
Irbana, IL 61801
217/384-8003

A. G. McKee Association
10 South Riverside Plaza
Chicago, IL 60606
312/454-3685

Alltech, Inc.
271 Goldrush Rd.
Lexington, KY 40503
606/276-3414

Alternative Energy, Ltd.
650 Pine Street
Colby, KS 67701
913/462-7531

Bartlesville Energy
Technology Center
Bartlesville, OK 74003
918/336-4268

Bechtel Corporation
50 Beale Street
15th Floor, Room B15
San Francisco, CA 94119
415/768-2971

Bohler/Vogelbusch
1625 West Belt North
Houston, Tx 77043
713/465-3373

C&I Girdler Co.
1721 South 7th Street
P.O. Box 32940
Louisville, KY 40234
502/637-8701

Center for Biology of
Natural Systems
Washington University
St. Louis, MO 63130
314/889-5317

Chamapec, Inc.
230 Crossways Park Drive
Woodbury, NY 11797
516/364-2100

Development Planning and
Research Associates
200 Research Drive
P.O. Box 727
Manhattan, KS 66502
913/539-3565

Day & Zimmerman, Inc.
1818 Market Street
Philadelphia, PA 19103
215/299-8193

Honeywell, Inc.
Corp. Tech. Center
10701 Lyndale Avenue South
Bloomington, MN 55420
612/887-4477

Hydrocarbon Research, Inc.
134 Franklin Corner Rd.
P.O. Box 6047
Lawrenceville, NJ 08648
609/896-1300

I. E. Associates
3704 11th Avenue South
Minneapolis, MN 55407
612/825-9451p

Raphael Katzen Assoc.
1050 Delta Avenue
Cincinnati, OH 45208
513/871-7500

A. G. McKee Corporation
10 South Riverside Plaza
Chicago, IL 60606
312/454-3685

PEDCo International, Inc.
11499 Chester Rd.
Cincinnati, OH 45246
513/782-4717

Power Engineering Co.
1313 S.W. 27th Avenue
Miami, FL 33145

Seven Energy Corporation
3760 Vance
Wheat Ridge, CO030
303/989-7777

Stone & Webster Engineering
Corporation
One Penn Plaza
New York, NY 10001
212/760-2000

3-T Engineers
Arenzville, IL 62611
217/997-2188

Vulcan Cincinnati, Inc.
2900 Vernon Plaza
Cincinnati, OH 45219
513/281-2800

Enzyme and Yeast Producers

Altech, Inc.
271 Goldrush Road
Lexington, KY 40503
606/276-3414

Anheuser-Busch, Inc.
721 Pestalozzi Street
St. Louis, MO 63118
314/577-2000

Aquaterra Biochemicals Corp.
Dept. TMEN
Box 496
Lancaster, Tx 75146
214/227-6960

Alco-Zyme Supply
Box 79
Halecenter, TX 79041
806/839-2273

Biocon, Inc.
261 Midland Avenue
Lexington, KY 40507
606/254-0517

Chamapec, Inc.
230 Crossways Park Drive
Woodbury, NY 11797
Contact: Rene Loser
516/364/2100

Enzyme Development
Corporation
210 Plaza
New York, NY 10001
Contact: Randy Ross
212/736-1580

Fermco Biochemicals, Inc.
2638 Delton Lane
Elk Grove Village, IL 60007
312/595-3131

G. B. Fermentation Industry,
Inc.
One North Broadway
Des Plaines, IL 60061
312/827-9700

Norbert Haverkamp
Compost Making Enzymes
Rural Route 1, Box 114
Horton, KS 66439
913/486-3302

Miles Laboratoraies, Inc.
Enzyme Products Division
P.O. Box 932
Elkhart, IN 56515
219/564-8111

National Laboratories
Development Center
Pollution Abatement Division
U.S. Army
Natick, MA 01760
Contact: Leo A. Spano
617/653-2914

Novo Laboratory, Inc.
59 Danbury Road
Wilton, CT 06897
203/762-2401

Rohm & Haas
Independence Mall West
Philadelphia, PA 19105
Contact: Bob Broadbent
215/592-2517

Schwarz Service International
Ltd.
230 Washington Street
Mt. Vernon, NY 10551
Contact: Mr. Aberdein
914/664-1100

Scientific Products co.
1120 Clay
North Kansas City, MO 64116
806/221-2533

Red Star Yeast
Fermentation Products Division
Universal Foods Corporation
433 East Michigan Street
Milwaukee, WI 53201
414/271-6755

Red Star Yeast
Fermentation Products Division
Universal Foods Corporation
433 East Michigan St.
Milwaukee, WI 53201
414/271-6755

Ethanol Producers/Distributors

Almarc
2700 Lively Boulevard
Elk Grove, IL 60007
312/766-2906

American Gasohol Refiners
P.O. Box 18767
Wichita, KS 67218
216/683-3812

Amoco Production Company
P.O. Box 5340a
Chicago, IL 60680
312/856-222

APCO Oil Corporation
Houston Natural Gas Building
Houston, TX 77002
713/658-0610

Archer Daniels Midland
Company
Box 1470
Decatur, IL 62525
217/424-5700

Encore Energy Resources,
Incorporated
11951 Mitchell Road,
Mitchell Island
Richmond, British Columbia
604/327-8394

Exxon Corporation
Exxon Research and
Engineering
Public Relations
P.O. Box 639
Linden, NJ 07036

Georgia Pacific Company
Bellingham Division
P.O. Box 1236
Bellingham, WA 98225
206/733-4410

Grain Processing Corporation
Muscatine, IA 52761
918/264-4211

Hiram Walker
31275 Northwestern Highway
Farmington Hills
Detroit, MI 48018

Marcam Industries
527 North Easton Road
Glenside, PA 19038
215/885-5400

Midwest Solvents Company
1300 Main Street
Atchison, KS 66002
913/367-1480

Milbrew, Incorporated
330 South Mill Street
Juneau, WI 53039
414/462-3700

Mode, Ronald C.
Box 682
Glen Alpine, NC 28628
704/584-1432

Publicker Industries
777 W. Putnam Avenue
Greenwich, CT 06830
203/531-4500

Quaternoin Chemical Industries
72026 Livingston Street
Oakland, CA 94604
Contact: Louis Nagel
415/535-2311

Sigmor Corporation
P.O. Box 20267
San Antonio, TX 78220
512/223-2631

Syncorp
Rt. 1, Box 301
Roberta, GA 31078
912/836-3136

Texaco, Inc.
135 East 42nd Street
New York, NY 10017
212/953-6000

TIPCO
9000 N. Pioneer Rd.
Peoria, IL 61614
309/692-6543

United States Gasohol Corp.
P.O. Box N
Lockeford, CA 95237
209/727-5511

White Flame Fuels
P.O. Box 1516
Van Buren, AR 72956
501/474-5258

Worum Chemical Company
2130 Kasoto Avenue
St. Paul, MN 55108
Contact: Mr. Ritt
612/645-9224

Molecular Sieve Manufacturers

Applied Techologies, Inc.
P.O. box 296
Hastings, NE 68901
Contact: M. W. (Bill) Locatis
402/463-0521

Coast Engineering Laboratory
13510 South Normandie
Gardena, CA 90249
213/532-7400

Farrier Industries, Inc.
Baltimore Division
4211 Shannon Drive
Baltimore, MD 21213
301/483-2300

Frontier Industrial Controls
Corporation
2695 Alcott Street
Denver, Colorado 80211
Contact: James W. Tatman
303/534-5065

Gas Drying, Inc.
P.O. Box D1
Wharton, NJ 07885
201/361-2212

Grace, W. R., & Company
Davison Chemical Division
Charles and Baltimore Streets
Baltimore, MD 21202
301/727-3900

Henderson Engineering, Inc.
701 Factory Road
Addison, IL 60101
312/543-9150

Kahn and Company
885 Wells Road
Wethersfield, CT 06109
203/529-8643

Kemp, C. M., Mfg. Company
490 Baltimore-Annapolis Blvd.
Glen Burnie, MD 21061
301/761-5100

Norton Company
P.O. Box 350
Akron, OH 44309
216/673-5860

Union Carbide Corporation
Molecular Sieve Department
Linde Division
Two Greenway Plaza East
Houston, TX 77046
713/840-5930

On-Farm Operating Plants

Don Cook
2380 Coutny Road 18 N
Craig, CO 81625
303/824-6746

Don Kriley
RD2, Box 2243
Harrisville, PA 16038
412/735-4489

David Gahimer
7-H Corporation
Terre Haute, IN 47803
812/877-1511 Ext. 227

Luke Staengel
Floud Agricultural Energy Co-op.
Floyd, VA 24091
703/745-3131

Dan Williams
1514 Bennet Road
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206/466-3973

Terry Edvalson
Oregon State College
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LaGrande, OR 97850
503/963-2171

Frank Tilley
Conklin Associated Marketing Services
P.O. Box 492
Marshalltown, IA 50158
515/752-6895

Jerry Harper
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Corinne, UT 84307
801/723-2987

Dean Roll
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Milford, NE 68857
402/761-2131

Jim Jackson
Aquarius Solar Products, Inc.
Kuna, ID 83634
208/376-3172

Jamie Jacobsen
Box 845
Paonia, CO 81428
303/527-4322

Howard Baumgartner
Unlimited Energy, Inc.
R.R. 4
Decatur, IN 46733
219/824-1353

Max Pickerill
Colby Community College
Colby, KS 67701
913/462-3984 Ext. 230

Noel Reid
Ephrata, WA 98823
509/787-2098

Norbert Haverkamp
Nature's Way, Inc.
R.R. 1, Box 114
Horton, KS 66439
913/486-3302

Cliff Friedrich
Miner Agricultural Research Institute
Route 191, Ridge Road,
Chazy, NY 12921
518/846-7121

Dennis Knobelock
Route 1
Muscoutah, IL 62258
618/566-4135

Charles Minter
15444 Miller Road
Richwood, OH 43344
614/943-3405

Floyd Hoff
Box 162
Dalton, MN 56324
218/589-8444

Plant Plans

Goosen's EtOH Fuel Book
Still Plans
The Harvester Press
P.O. Box 1669
Hendersonville, NC 28793
704/692-4809

Makin' It On the Farm
American Agriculture News
P.O. Box 100
Iredell, TX 76649
817/364-2474

Mother Earth News
P.O. Box 70
Hendersonville, NC 28739
704/693-0211

Solstice Designs, Inc.
Box 2043
Evergreen, CO 80439
303/674-1597

Appendix D

Regulations and Permits

BATF Regional Offices

Central Region
Indiana, Kentucky
Michigan, Ohio, West Virginia

Regional Regulatory Administrator
Bureau of Alcohol, Tobacco, and Firearms
550 Main Street
Cincinnati, OH 45202
Phone (513) 684-3334

Mid-Atlantic Region
Delaware, District of
Columbia, Maryland, New Jersey,
Pennsylvania, Virginia

Regional Regulatory Administrator
Bureau of Alcohol, Tobacco, and Firearms
2 Penn Center Plaza, Room 360
Philadelphia, PA 19102
Phone (215) 597-2248

Midwest Region
Illinois, Iowa, Kansas, Minnesota, Missouri,
Nebraska, North Dakota, South Dakota,
Wisconsin

Regional Regulatory Administrator
Bureau of Alcohol, Tobacco, and Firearms
230 S. Dearborn Street, 15th Floor
Chicago, IL 60604
Phone (312) 353-3883

North-Atlantic Region
Connecticut, Maine, Massachusetts,
New Hampshire, New York, Rhode Island,
Vermont, Puerto Rico, Virgin Islands

Regional Regulatory Administrator
Bureau of Alcohol, Tobacco, and Firearms
6 World Trade Center, 6th Floor
(Mail: P.O. Box 15,
Church Street Station)
New York, NY 10008
Phone (212)264-1095

Southeast Region
Alabama, Florida, Georgia, Mississippi,
North Carolina, South Carolina, Tennessee

Regional Regulatory Administrator
Bureau of Alcohol, Tobacco, and Firearms
3835 Northeast Expressway
(Mail: P.O. Box 2994)
Atlanta, GA 30301
Phone (404) 455-2670

Southwest Region
Arkansas, Colorado, Louisiana, New Mexico,
Oklahoma, Texas, Wyoming

Regional Regulatory Administrator
Bureau of Alcohol, Tobacco, and Firearms
Main Tower, Room 345
1200 Main Street
Dallas, TX 75202
Phone (214) 767-2285

Western Region
Alaska, Arizona, California, Hawaii, Idaho,
Montana, Nevada, Oregon, Utah, Washington

Regional Regulatory Administrator
Bureau of Alcohol, Tobacco, and Firearms
525 Market Street, 34th Floor
San Francisco, CA 94105
Phone (415) 556-0226

BATF REGULATIONS

The design, construction, and operation of alcohol fuel plants require attention from Federal, State, and local authorities in order to ensure maintenance of the public good. Specific aspects of alcohol fuel production relating to safety and environmental concerns have been addressed in the main body of this document; other more general requirements, such as meeting building codes and zoning regulations, are site-specific and must be complied with, based on the individual case. Again, specific to alcohol fuels, this appendix addresses BATF regulations and other regulations and permits as they concern the potential investor.

In the Energy Tax Act of 1978 (Public Law 95-618), Congress required the Secretary of the Treasury to propose legislative recommendations to facilitate fuel use of distilled spirits. In compliance with this mandate, the BATF submitted a proposal in 1979. Congress incorporated the proposed legislation, with modifications, in Public Law 96-223.

Public Law 96-223 added a new section to Subchapter B of Chapter 51 of the Internal Revenue Code of 1954. New Section 5181, Distilled Spirits for Fuel Use, provides for the establishment of distilled spirits plants solely for the purpose of producing, processing and storing, and using or distributing distilled spirits to be used exclusively for fuel use. The Secretary of the Treasury is directed to expedite all applications, establish a minimum bond, and generally encourage and promote (through regulation or otherwise) the production of alcohol for fuel purposes. The Law gives the Secretary authority to provide by regulation for the waiver of any provision of Chapter 51 (except Section 5181 or any provision requiring the payment of tax). This waiver authority may be exercised with respect to alcohol fuel plants as necessary to carry out the provisions of Section 5181.

Plants which are established for the production of alcohol for purposes other than fuel, such as beverage or other industrial use, must qualify to operate under previously existing provisions of the law. You may wish to contact BATF for further details.

The law exempts alcohol fuel plants which produce less than 10,000 proof gallons of distilled spirits annually from furnishing a bond to cover the tax liability on the spirits. Also, persons wishing to establish such plants are assured by law that their applications for permits to operate will be acted upon within 60 days after receipt of a completed application. If this limit is exceeded, the application is automatically approved.

Distilled spirits may be withdrawn from alcohol fuel plants free of tax after having been rendered unfit for beverage use. The term "rendered unfit for beverage use" is used to clearly distinguish this requirement for fuel spirits from "denaturation", which is required for spirits withdrawn from other distilled spirits plants.

A principal reason for encouraging production of distilled spirits for fuel use is that these spirits are substituted for scarce fossil fuels. Therefore, in defining distilled spirits for purposes of the alcohol fuel provisions, the law excludes distilled spirits produced from petroleum, natural gas, or coal.

Finally, Public Law 96-223 amended Section 5601 to impose criminal penalties on any person who withdraws, uses, sells, or otherwise disposes of distilled spirits produced under Section 5181 for other than fuel use.

This section addresses those portions of regulations dealing with large alcohol fuel plants (defined by BATF as more than 500,000 proof gallons of spirits per calendar year). We will cover the following permits; bonds; construction, equipment, and security; supervision; accounting for spirits; transfers and withdrawals; and transfers between plants. Our intent is to be informative, but we suggest that the Bureau be contacted for more specific interpretation and guidance where needed.

The following is a brief summary of the regulations now in force:

DEPARTMENT OF THE TREASURY

Bureau of Alcohol, Tobacco, and Firearms
(27 CFR Part 19)
T.D. ATF-71

FUEL USE OF DISTILLED SPIRITS - IMPLEMENTING A PORTION OF THE CRUDE OIL WINDFALL PROFITS TAX ACT OF 1980 (PUBLIC LAW 96-223)

AGENCY: Bureau of Alcohol, Tobacco, and Firearms, Department of the Treasury.

ACTION: Temporary rule (Treasury decision).

SUMMARY: This temporary rule implements Section 232, Alcohol Fuels, in Part III of Title II of the Crude Oil Windfall Profits Tax Act of 1980 (Public Law 96-223). The temporary rule provides for the establishment and operation of distilled spirits plants solely for producing, processing and storing, and using or distributing distilled spirits (ethyl alcohol) exclusively for fuel use. Public Law 96-223 vests the Secretary of the Treasury with authority to simplify and liberalize statutory requirements for such alcohol fuel plants. The BATF will issue final regulations only after careful consideration of the comments received on these temporary regulations.

EFFECTIVE DATE OF TEMPORARY REGULATIONS: July 1, 1980.

FOR FURTHER INFORMATION CONTACT:

John V. Jarowski, Alcohol Fuels Coordinator
Bureau of Alcohol, Tobacco, and Firearms
Washington, DC 20226
Telephone 202-566-7626

(Persons interested in applying for a permit should contact their BATF regional office. A list of addresses and telephone numbers is provided.)

SUPPLEMENTARY INFORMATION: This document contains temporary regulations implementing a portion of the Crude Oil Windfall Profits Tax Act of 1980 (Public Law 96-223). The temporary regulations provided by this document will remain in effect until superseded by final regulations on this subject.

REGULATIONS

1. New Subpart Y of 27 CFR Part 19.

Regulations applicable to alcohol fuel plants have been included in a new subpart, Subpart Y, of Part 19, Distilled Spirits Plants. Except for those portions of Subparts A through X of Part 19 which have been incorporated in the new subpart by reference, alcohol fuel plants are not subject to the provisions applicable to other distilled spirits plants. While this document provides simplified BATF regulations for alcohol fuel plants, persons wishing to establish a plant should check with other Federal (EPA), state, and local authorities as to their specific requirements.

2. Definitions.

Where necessary, terms have been defined as used in the new subpart. In some instances, BATF needed to redefine a term used elsewhere in Part 19. For instance, the term "distilled spirits", as used in Subpart Y, does not include distilled spirits produced from petroleum, natural gas, or coal. In addition, BATF introduces some new terms. For example, the term "alcohol fuel plant" means a distilled spirits plant established under Subpart Y solely for producing, processing and storing, and using or distributing distilled spirits to be used exclusively for fuel use. The term "fuel alcohol" means spirits which have been rendered unfit for beverage use as provided in Subpart Y and are eligible to be withdrawn free of tax exclusively for fuel use.

3. Permits.

Any person wishing to establish an alcohol fuel plant must first make application for and obtain an Alcohol Fuel Producer's Permit. For purposes of the type of application required (as well as for bonding and other requirements), BATF classifies alcohol fuel plants into three categories:

(a) Small plants - produce (including receipts of) not more than 10,000 proof gallons per calendar year;

(b) Medium plants - produce (including receipts of) more than 10,000 but not more than 500,000 proof gallons per calendar year; and,

(c) Large plants - produce (including receipts of) more than 500,000 proof gallons per calendar year.

These classes are based on the tax liabilities incident to the various levels of activity, as well as differences in capital expenditures and attendant technical sophistication required to set up plants of different sizes. By law, small plants are exempt from bonding and special rules apply to their applications.

In determining the level of activity at a plant for purposes of bonding and qualification, BATF considers spirits received from another plant as additional production. With respect to small plants, this approach has no effect on a proprietor who will receive no spirits from other plants. Proprietors of other small plants, however, may wish to distill less than 10,000 proof gallons of spirits per year and receive additional spirits from other plants. Those proprietors may produce and receive up to a total of 10,000 proof gallons per year and still be exempt from bonding. Counting receipts as additional production simplifies the regulations for bonds and qualification of plants.

4. Application Requirements.

Applications are filed on BATF Form 5110.74 furnished by the Bureau (See Figure B-1). For small plants, only the form needs to be filed. For medium and large plants, a bond must be placed and some additional information (to be identified in Section 6) must be provided. Also, the law requires bonds for the medium and large plants. Applications are to be submitted to the regional regulatory administrator of the BATF region in which the plant is located.

Having an application form should avoid confusion as to the information required to be submitted and serve to expedite processing of applications.

Although BATF expects numerous applications to be filed in response to the temporary regulations, BATF anticipates that permits will be issued expeditiously. With respect to the small plants in particular, action well within the 60-day statutory limitation should be possible.

In general, a permit will be issued to any person who files a completed application (together with a bond for medium and large plants). Criteria for denial of applications, and for subsequent suspension or revocation of permits in the case of false or incomplete applications, are set forth in Sections 19.936 and 19.953 of the regulations. Time permitting, BATF may conduct an investigation and on-site inspection prior to issuance of the permit.

5. Changes Affecting Permits.

Permits may not be sold or transferred. If a different person purchases or acquires control of the plant, that person must file a new application. Also, BATF issues permits to cover specified plant premises. Any change in the location or extent of plant premises requires submission of an application to the regional regulatory administrator to amend the permit. Sections 19.945 through 19.953 provide more details on changes affecting permits and administrative and procedural matters relative to permits.

6. Bonds.

Bonds give the government security against possible loss of distilled spirits tax revenue. While tax is not collected on distilled spirits for fuel use lawfully produced and used as fuel, liability for tax, by law, attaches to the spirits on creation. The proprietor generally obtains a bond from a surety or insurance company, by paying a premium based on the penal sum required for the bond.

The law exempts small plants producing (including receipts of) not more than 10,000 proof gallons per year from furnishing bonds. For medium and large plants which are required to file bonds, the penal sum required is based on the tax liability to be covered. There are two sources of this tax liability:

(a) The tax on spirits that will be produced (including spirits rendered unfit for beverage use in the process of production, as provided in Section 19.983); and,

(b) The tax on spirits that will be received by transfer in bond (see Sections 19.996 through 19.999).

In the temporary regulations, the penal sum of the bond is based on the quantity in proof gallons of spirits that will be produced (including receipts) in a calendar year.

The bond for a medium plant producing (including receipts of) between 10,000 and 20,000 proof gallons per year is $2,000. For each increase of 10,000 proof gallons (or fraction thereof) in total annual production (including receipts), the bond penal sum is increased $1,000. The maximum bond for a medium plant is $50,000 (applicable to plants producing (including receipts) between 490,000 and 500,000 proof gallons per year).

For large plants, the amount of the bond is $50,000 plus an additional $2,000 for each 10,000 proof gallons (or fraction) produced and received in excess of 500,000. The maximum bond for a large plant is $200,000. Any plant producing (including receipts) in excess of 1,240,000 proof gallons of spirits in a calendar year must furnish a bond in the amount of $200,000.

Documentation required is BATF Form 5110.56, as shown in Figure B-2.

7. Premises, Equipment, and Security.

The premises of an alcohol fuel plant include all areas where distilled spirits are produced, processed, stored, used, or held for distribution. BATF requires buildings and equipment used in alcohol fuel plant operations to be constructed and arranged to enable the proprietor to maintain security adequate to deter diversion of the spirits. Regional regulatory administrators can require additional measures if security at a plant is found to be inadequate.

8. Supervision of Operations.

Regional regulatory administrators may assign BATF officers to alcohol fuel plants to supervise operations or to conduct inspections and audits. Authorities of BATF officers to carry out their duties have been incorporated by reference in the temporary regulations. BATF officers have a right of access to plant premises at all times to perform their official duties. The regulations require proprietors to render assistance to BATF officers in performing gauges and examining equipment and containers, as necessary, to determine that all spirits are lawfully accounted for.

9. Accounting for Spirits.

The regulations require proprietors to determine and record the quantities of spirits produced, received, rendered unfit for beverage use, and used or removed from the premises. The records must be adequate to allow BATF officers to verify that the proprietor has lawfully disposed of all spirits. BATF requires no government forms or specific formats for these records. Commercial invoices, books of account, and other proprietary records are sufficient, so long as they show the information required by the regulations.

The regulations also require proprietors to file periodic reports of their operations. Frequency of reporting varies with the size of the plant: annually for small plants, semiannually for medium plants, and quarterly for large plants. The required form is BATF Form 5110.75, as shown in Figure B-3.

10. Withdrawal of Spirits.

Distilled spirits withdrawn from alcohol fuel plants may be used only for fuel purposes. Before withdrawing spirits from plant premises, the proprietor must render the spirits unfit for beverage use. The only exception to this requirement is for spirits transferred to other plants.

The regulations in Section 19.992 provide that fuel alcohol is considered unfit for beverage use when, for each 100 gallons of spirits, the proprietor has added to the spirits five gallons or more of gasoline, automotive gasoline, kerosene, deodorized kerosene, rubber hydrocarbon solvent, methyl isobutyl ketone, mixed isomers of nitropropane, any combination of the foregoing, or 5 gallons of isopropyl alcohol and 1/8-ounce of denatonium benzoate N.F. (Bitrex). BATF selected these substances based on denatured alcohol and solvent formulations currently provided by regulation or ruling, and on requests and inquiries from persons currently involved in producing alcohol fuels. Proprietors may request authorization to use substitute materials under Section 19.993 of the regulations.

Once rendered unfit for beverage use, fuel alcohol is eligible to be withdrawn free of tax. However, BATF does require proprietors to account for fuel alcohol remaining on plant premises and keep records of all sales and other dispositions of fuel alcohol.

11. Use on Premises.

Proprietors may use spirits for fuel on the premises of an alcohol fuel plant without rendering the spirits unfit for beverage use. The proprietor must record the quantities of spirits so used.

12. Transfers in Bond.

Proprietors may transfer spirits to another alcohol fuel plant. The proprietor need not render the spirits unfit for beverage use prior to transfer. Generally, liability for the tax on the spirits while in transit is the responsibility of the receiving proprietor.

The temporary regulations prescribe procedures to be followed when transferring spirits between alcohol fuel plants. A commercial invoice or shipping document is required to cover each shipment of spirits. These procedures are necessary to guard against diversion of spirits to beverage use.

Spirits also may be transferred between other distilled spirits plants and alcohol fuel plants. For such transfers, procedures and forms are prescribed in Sections 19.506 through 19.510 of the regulations.

The following are the Bureau of Alcohol, Tobacco, and Firearms regulations now in force, effective date of temporary regulations is July 1, 1980.

DEPARTMENT OF THE TREASURY

Bureau of Alcohol, Tobacco and Firearms

FUEL USE OF DISTILLED SPIRITS-IMPLEMENTING A PORTION OF THE CRUDE OIL WINDFALL PROFIT TAX ACT OF 1980

(Public Law 96-223)

AGENCY: Bureau of Alcohol, Tobacco and Firearms, Department of the Treasury

ACTION: Temporary rule (Treasury decision)

SUMMARY: This temporary rule implements Section 232, Alcohol Fuels, in Part III of Title II of the crude Oil Windfall Profit Tax Act of 1980 (P.L. 96-223). The temporary rule provides for the establishment and operation of distilled spirits plants solely for producing, processing and storing, and using or distributing distilled spirits (ethyl alcohol) exclusively for fuel use. P.L. 96-223 vests the Secretary of the Treasury with authority to simplify and liberalize statutory requirements for such alcohol fuel plants. The Bureau of Alcohol, Tobacco and Firearms (ATF) will issue final regulations only after careful consideration of the comments received on these temporary regulations.

FOR FURTHER INFORMATION CONTACT:

John V. Jarowski, Research and Regulations Branch, Bureau of Alcohol, Tobacco and Firearms, Washington, DC 20226, Telephone 202-566-7626.

(Persons interested in applying for a permit should contact their ATF regional office. A list of addresses and tele phone numbers is provided.)

SUPPLEMENTARY INFORMATION: This document contains temporary regulations implementing a portion of the Crude Oil Windfall Profit Tax Act of 1980 (Public Law 96-223). The temporary regulations provided by this document will remain in effect until superseded by final regulations on this subject. A notice of proposed rulemaking with respect to final regulations appears elsewhere in this issue of the Federal Register.

Legislative Background

In the Energy Tax Act of 1978 (P.L. 95-618) Congress required the Secretary of the Treasury to propose legislative recommendations to facilitate fuel use of distilled spirits. In compliance with this mandate, the

Bureau submitted a proposal in 1979. Congress incorporated the proposed legislation, with modifications, in P.L. 96-223.

Public Law 96-223 added a new section to Subchapter B of Chapter 51 of the Internal Revenue Code of 1954. New Section 5181, Distilled Spirits for Fuel Use, provides for the establishment of distilled spirits plants solely for the purpose of producing, processing and storing, and using or distributing distilled spirits to be used exclusively for fuel use. The Secretary of the Treasury is directed to expedite all applications, to establish a minimum bond, and to generally encourage and promote (through regulation or otherwise) the production of alcohol for fuel purposes. The law gives the Secretary authority to provide by regulation for the waiver of any provision of Chapter 51 (except section 5181 or any provision requiring the payment of tax). This waiver authority may be exercised with respect to alcohol fuel plants as necessary to carry out the provisions of Section 5181.

The law exempts alcohol fuel plants which produce not more than 10,000 proof gallons of distilled spirits annually from furnishing a bond to cover the tax liability on the spirits. Also, persons wishing to establish such plants are assured by law that their applications for permits to operate will be acted upon within 60 days or less after receipt of a completed application. If this limit is exceeded, the application is automatically approved.

Distilled spirits may be withdrawn from alcohol fuel plants free of tax after having been rendered unfit for beverage use.The term "rendered unfit for beverage use" is used to clearly distinguish this requirement for fuel spirits from "denaturation," which is required for spirits withdrawn from other distilled spirits plants.

A principal reason for encouraging production of distilled spirits for fuel use is that these spirits are substituted for scarce fossil fuels. Therefore, in defining distilled spirits for purposes of the alcohol fuel provisions, the law excludes distilled spirits produced from petroleum, natural gas, or coal.

Finally, P.L. 96-223 amended Section 5601 to impose criminal penalties on any person who withdraws, uses, sells, or otherwise disposes of distilled spirits produced under Section 5181 for other than fuel use.

Regulations

1. **New Subpart Y of 27 CFR Part 19.** Regulations applicable to alcohol fuel plants have been included in a new subpart, Subpart Y, of Part 19, Distilled Spirits Plants. Except for those portions of Subparts A through X of Part 19 which have been incorporated in the new subpart by reference, alcohol fuel plants are not subject to the provisions applicable to other distilled spirits plants. While this document provides simplified ATF regulations for alcohol fuel plants, persons wishing to establish a plant should check with other Federal (EPA), State and local authorities as to their specific requirements.

2. **Definitions.** Where necessary, terms have been defined as used in the new subpart. In some instances, ATF needed to redefine a term used elsewhere in Part 19. For instance, the term "distilled spirits" as used in Subpart Y does not include distilled spirits produced from petroleum, natural gas, or coal. In addition, ATF introduces some new terms. For example, the term "alcohol fuel plant" means a distilled spirits plant established under Subpart Y solely for producing, processing and storing, and using or distributing distilled spirits to be used exclusively for fuel use. The term "fuel alcohol" means spirits which have been rendered unfit for beverage use as provided in Subpart Y and are eligible to be withdrawn free of tax exclusively for fuel use.

3. **Permits.** Any person wishing to establish an alcohol fuel plant must first make application for and obtain an Alcohol Fuel Producer's Permit. For purposes of the type of application required (as well as for bonding and other requirements), ATF classifies alcohol fuel plants into three categories:

(a) Small plants—producing (including receipts of) not more than 10,000 proof gallons per calendar year;

(b) Medium plants—produce (including receipts of) more than 10,000 but not more than 500,000 proof gallons percalendar year; and

(c) Large plants—produce (including receipts of) more than 500,000 proof gallons per calendar year.

These classes are based on the tax liabilities incident to the various levels of activity, as well as differences in capital expenditures and attendant technical sophistication required to set up plants of different sizes. By law, small plants are exempt from bonding and special rules apply to their applications.

In determining the level of activity at a plant for purposes of bonding and qualification, ATF considers spirits received from another plant as additional production. With respect to small plants, this approach has no effect on a proprietor who will receive no spirits from other plants. Proprietors of other small plants, however, may wish to distill less than 10,000 proof gallons of spirits per year and receive additional spirits from other plants. Those proprietors may produce and receive up to a total of 10,000 proof gallons per year and still be exempt from bonding. Counting receipts as additional production simplifies the regulations for bonds and qualification of plants.

4. **Application Requirements.** Applications are filed on a form (ATF Form 5110.74) furnished by the Bureau. For small plants, only the form needs to be filed. For medium and large plants, some additional information must be provided. Also, the law requires bonds for the medium and large plants. Applications are to be submitted to the regional regulatory administrator of the ATF region in which the plant is located.

   Having an application form should avoid confusion as to the information required to be submitted and serve to expedite processing of applications. Comments as to the design of the form, the information required, and as to whether the use of form is desirable, are specifically requested. Although ATF expects numerous applications to be filed in response to the temporary regulations, ATF anticipates that permits will be issued expeditiously. With respect to the small plants in particular, action well within the 60 day statutory limitation should be possible.

   In general, a permit will be issued to any person who files a completed application (together with a bond for medium and large plants). Criteria for denial of applications, and for subsequent suspension or revocation of permits in the case of false or incomplete applications, are set forth in Sections 19.936 and 19.953 of the regulations. Time permitting, ATF may conduct an investigation and on-site inspection prior to issuance of the permit.

5. **Changes Affecting Permits.** Permits may not be sold or transferred. If a different person purchases or acquires control of the plant, that person must file a new application. Also, ATF issues permits to cover specified plant premises. Any change in the location or extent of plant premises requires submission of an application to the regional regulatory administrator to amend the permit. Sections 19.945 through 19.953 provide more details on changes affecting permits and administrative and procedural matters relative to permits.

6. **Bonds.** Bonds give the Government security against possible loss of distilled spirits tax revenue. While tax is not collected on distilled spirits for fuel use lawfully produced and used as fuel, liability for tax, by law, attaches to the spirits on creation. The proprietor generally obtains a bond from a surety or insurance company, by paying a premium based on the penal sum required for the bond.

   The law exempts small plants producing (including receipts of) not more than 10,000 proof gallons per year from furnishing bonds. For medium and large plants which are required to file bonds, the penal sum required is based on the tax liability to be covered. There are two sources of this tax liability:

   (a) The tax on spirits that will be produced (including spirits rendered unfit for beverage use in the process of production, as provided in Sec. 19.983); and,

   (b) The tax on spirits that will be received by transfer in bond (see Sections 19.996 through 19.999).

   In the temporary regulations, the penal sum of the bond is based on the quantity in proof gallons of spirits that will be produced (including receipts) in a calendar year.

   The bond for a medium plant producing (including receipts of) between 10,000 and 20,000 proof gallons per year is $2,000. For each increase of 10,000 proof gallons (or fraction thereof) in total annual production (including receipts), the bond penal sum is increased $1,000. The maximum bond for a medium plant is $50,000 (applicable to plants producing (including receipts) between 490,000 and 500,000 proof gallons per year).

   For large plants, the amount of the bond is $50,000 plus an additional $2,000 for each 10,000 proof gallons (or fraction) produced and received in excess of 500,000. The maximum bond for a large plant is $200,000. Any plant producing (including receipts) in excess of 1,240,000 proof gallons of spirits in a calendar year must furnish a bond in the amount of $200,000.

7. **Premises, Equipment and Security.** The premises of an alcohol fuel plant includes all areas where distilled spirits are produced, processed, stored, used or held for distribution. ATF requires buildings and equipment used in alcohol fuel plant operations to be constructed and arranged to enable the proprietor to maintain security adequate to deter diversion of the spirits. Regional regulatory administrators can require additional measures if security at a plant is found to be inadequate.

8. **Supervision of Operations.** Regional regulatory administrators may assign ATF officers to alcohol fuel plants to supervise operations or to conduct inspections and audits. Authorities of ATF officers to carry out their duties have been incorporated by reference in the temporary regulations. ATF officers have a right of access to plant premises at all times to perform their official duties. The regulations require proprietors to render assistance to ATF officers in performing gauges and examining equipment and containers, as necessary to determine that all spirits are lawfully accounted for.

9. **Accounting for Spirits.** The regulations require proprietors to determine and record the quantities of spirits produced, received, and rendered unfit for beverage use, and used or removed from the premises. The records must be adequate to allow ATF officers to verify that the proprietor has disposed of all spirits lawfully. ATF requires no Government forms or specific formats for these records. Commercial invoices, books of account, and other proprietary records are sufficient, so long as they show the information required by the regulations.

   The regulations also require proprietors to file periodic reports of their operations. Frequency of reporting varies with the size of the plant: annually for small plants, semiannually for medium plants, and quarterly for large plants.

10. **Withdrawal of Spirits.** Distilled spirits withdrawn from alcohol fuel plants may be used only for fuel purposes. Before withdrawing spirits from plant premises, the proprietor must render the spirits unfit for beverage use. The only exception to this requirement is for spirits transferred to other plants.

   The regulations in Sec. 19.992 provide that fuel alcohol is considered unfit for beverage use when for each 100 gallons of spirits, the proprietor has added to the spirits five gallons or more of gasoline, automotive gasoline, kerosene, deodorized kerosene, rubber hydrocarbon solvent, methyl isobutyl ketone, mixed isomers of nitropropane, any combination of the foregoing, or 5 gallons of isopropyl alcohol and 1/8 ounce of denatonium benzoate N.F. (Bitrex). ATF selected these substances based on denatured alcohol and solvent formulations currently provided by regulation or ruling, and on requests and inquirites from persons currently involved in producing alcohol fuels. Proprietors may request authorization to use substitute materials under Sec. 19.993 of the regulations.

   Once rendered unfit for beverage use, fuel alcohol is eligible to be withdrawn free of tax. However, ATF does require proprietors to account for fuel alcohol remaining on plant premises and to keep records of all sales and other dispositions of fuel alcohol.

11. **Use on Premises.** Proprietors may use spirits for fuel on the premises of an alcohol fuel plant without rendering the spirits unfit for beverage use. The proprietor must record the quantities of spirits so used.

12. **Transfers in Bond.** Proprietors may transfer spirits to another alcohol fuel plant. The proprietor need not render the spirits unfit for beverage use prior to transfer. Generally, liability for the tax on the spirits while in transit is the responsibility of the receiving proprietor. The temporary regulations prescribe procedures to be followed when transferring spirits between alcohol fuel plants. A commercial invoice or shipping document is required to cover each shipment of spirits. These procedures are necessary to guard against diversion of spirits to beverage use.

   Spirits also may be transferred between other distilled spirits plants and alcohol fuel plants. For such transfers, procedures and forms are prescribed in Sections 19.506 through 19.510 of the regulations.

Issues for Comment

While all comments on these regulations are welcome and will receive careful consideration before final regulations are issued, ATF specifically requests comments on the following two issues.

1. **Location of Plants in dwellings.** Under existing regulations in 27 CFR Part 19, plants may not be located in any dwelling house, in any yard, shed, or enclosure connected with a dwelling house, or in certain other areas. Since ATF has not incorporated these restrictions in the temporary regulations, they do not apply to alcohol fuel plants.

   As to yards, sheds, or enclosures, ATF feels the existing restrictions would place undue constraints on farm production of alcohol fuel. For urban and suburban areas, ATF feels that local zoning ordinances, fire codes, and similar provisions will preclude establishment of plants at inappropriate locations. The alcohol fuel producer's permit does not relieve the proprietor of the obligations imposed by State or local law.

   However, ATF will consider prohibiting the establishment of plants in residential dwelling units. Accordingly, comments are requested as to whether such a prohibition is necessary or desirable.

2. **Specifications for fuel alcohol and materials authorized for use in rendering spirits unfit for beverage use.** In contrast to existing denatured alcohol regulations in 27 CFR Parts 211 and 212, the temperary regulations do not require fuel alcohol to be of any particular proof. In addition, proprietors have the option to choose among a number of materials or combinations thereof to use in rendering spirits unfit. Proprietors will decide both on the proof of the spirits and on what materials to use to render the spirits unfit, based on cost factors and on what works effectively for the particular fuel uses selected by themselves or their customers. The regulations do point out, however, that if gasoline is to be added to the spirits, unleaded gasoline may be required if the fuel alcohol will be used in certain engines.

For some uses higher proof spirits (anhydrous or nearly so) are necessary. For other uses, lower proof spirits may be adequate.

ATF gives the proprietor options in this area because, beyond the blended motor fuels (e.g., gasohol) which are coming into widespread use, there is interest in using alcohol (once rendered unfit) for fuel purposes without blending with other fuels. ATF recognizes, however, that there may be a demand for tighter controls. For this reason, ATF will consider modifying the requirements for spirits rendered unfit, including specifying minimum proof levels for fuel alcohol. Accordingly, ATF specifically requests comments on the following questions:

(a) Are minimum proof standards necessary or desirable for fuel alcohol?

(b) Should the list of materials authorized for rendering spirits unfit for beverage use be broadened to include other substances, or sould some materials or options permitted under the temporary regulations be deleted?

(c) Are more detailed specifications for rendering spirits unfit necessary? If adopted, should these specifications be geared to the end use of the fuel alcohol?

Experimental Plants

1. **General.**Many persons have obtained permits to operate experimental distilled spirits plants (Section 5312) to produce distilled spirits for fuel purposes. The majority of these operations would qualify as small alcohol fuel plants under the temporary regulations. The authorized operations for experimental plants are generally more limited than under these temporary regulations, particularly as to removal or distribution of any spirits produced. The proprietor must furnish a bond. Also, experimental distilled spirits plant permits are issued for a limited time, usually two years. In contrast to experimental distilled spirits plants, alcohol fuel plants:

(a) Hold a permit which generally continues in effect indefinitely with no renewal required:

(b) Are authorized to sell or distribute the fuel alcohol they produce;

(c) Are exempt from bonding of annual production (including receipts) totals not more than 10,000 proof gallons; and,

(d) May transfer spirits between plants. Given the advantages of operating as an alcohol fuel plant, ATF has developed a simplified procedure to convert outstanding experimental distilled spirits plant permits to alcohol fuel producer's permits, on the assumption that most proprietors will elect conversion. The proprietor of an experimental plant does not have to file an application to have the permit converted. With respect to any bond that was furnished, ATF regional offices will advise proprietors how to cancel surety bonds or secure refunds of cash or securities deposited in lieu of obtaining a surety bond.

2. **Status of Existing Experimental Plants.** Effective July 1, 1980, any person holding a permit to operate an experimental distilled spirits plant for fuel purposes will be considered as authorized to operate under these regulations. ATF regional offices are notifying all affected proprietors. Before expiration of the outstanding permit, a new alcohol fuel producer's permit will be issued to each such proprietor. Applications which are currently pending to establish experimental distilled spirits plants for fuel purposes will be treated as applications for alcohol fuel producer's permits. Proprietors who do not wish to be converted to alcohol fuel plant status should file a written request with the regional regulatory administrator.

Addresses of Regional Regulatory Administrators

Any person who wishes to apply for a permit under the regulations in this document may obtain the required forms and further information from the regional regulatory administrator of the region in which the plant will be located. A list of addresses and toll-free telephone numbers is provided in Appendix E.

Effective Date

The Energy Tax Act of 1978 (Pub. L. 95-618, 92 Stat. 3174) directed the Secretary to expedite, to the maximum extent possible, the applications of persons desiring to produce distilled sirits for fuel use, and to suggest legislative amendments which could reduce the amount of regulation to which such fuel producers would be subject. In furtherance of the first mandate, existing waiver authority under 26 U.S.C. 5312 was used to facilitate establishment of alcohol fuel plants on an experimental basis. The proposed legislative amendments have not been enacted as part of Pub. L. 96-223.

Pub. L. 96-223 gives the Secretary broad authority to waive or reduce existing regulatory requirements for plants which will produce distilled spirits exclusively for fuel use, such as, by allowing simplified application and recordkeeping procedures, and by providing reduced control and bonding requirements. In addition, an expedited application procedure (with no bond) is provided for small producers. For such producers, the law requires action on the issuance of a permit within sixty days of submission of a completed application. Pub. L. 96-223 is effective July 1, 1980.

Immediate guidance is necessary for the affected parties, both potential new applicants to produce distilled spirits for fuel purposes and persons currently operating as proprietors of experimental distilled spirits plants, to reap the benefits of the new law upon its becoming effective.

The issuance of this Treasury decision with notice and public procedure under 5 U.S.C. 553(d) is impracticable and not in the public interest, because absence of these regulations would create a serious delay in the production of alcohol fuel, inconsistent with the intent of the Energy Tax Act of 1978 (Pub. L. 95-618, 92 Stat. 3174) and the Crude Oil Windfall Profit Tax Act of 1980 (Pub. L. 96-223, 94 Stat. 229) to encourage the expeditious production of alcohol fuels. Immediate action is necessary to avoid delay and facilitate production of alcohol fuel, in implementing the Crude Oil Windfall Profit Tax Act of 1980, which is effective July 1, 1980. Accordingly, this Treasury decision becomes effective on July 1, 1980.

Authority and Issuance

These regulations are issued under the authority contained in 26 U.S.C. 5181 (94 Stat. 278) and 26 U.S.C. 7805 (68A Stat. 917, as amended).

Accordingly, Title 27 Code of Federal Regulations is amended as follows:

PART 19—DISTILLED SPIRITS PLANTS

Paragraph 1. The table of sections is amended to reflect the addition of §19.63a immediately following §19.63 and the addition of Subpart Y—Distilled Spirits for Fuel Use. As amended, the table of sections reads as follows:

Subpart D—Administrative and Miscellaneous Provisions

§19.63a Alcohol fuel plants.

Subpart Y—Distilled Spirits for Fuel Use

§19.931 Scope of subpart
§19.932 Taxes
§19.933 Status of existing experimental distilled spirits plants
§19.934 Meaning of terms

Permits

§19.935 Application for permit required
§19.936 Criteria for issuance of permit
§19.937 Small plants
§19.938 Waiver of bond requirement for small plants
§19.939 Medium plants
§19.940 Large plants
§19.942 Information already on file and supplemental information

Changes Affecting Permits

§19.945 Automatic termination of permits
§19.946 Change in type of alcohol fuel plant
§19.947 Change in name of proprietor
§19.948 Changes in officers, directors, or principal persons
§19.949 Change in proprietorship
§19.950 Continuing partnerships
§19.951 Change in location

Permanent Discontinuance of Business

§19.952 Notice of permanent discontinuance

Suspension or Revocation of Permits

§19.953 Suspension or revocation

Bonds

§19.956 Bonds
§19.957 Amount of bond
§19.958 Instructions to compute bond penal sum
§19.959 Conditions of bond
§19.960 Additional provisions with respect to bonds

Construction, Equipment and Security

§19.972 Construction and equipment
§19.973 Security
§19.974 Additional security

Supervision

§19.975 Supervision of operations

Accounting for Spirits

§19.980 Gauging
§19.981 Inventories
§19.982 Records
§19.983 Spirits rendered unfit in the production process
§19.984 Record of spirits received
§19.985 Record of spirits rendered unfit for beverage use

§19.986 Record of dispositions
§19.987 Maintenance and retention of records
§19.988 Reports

Transfers and Withdrawals

§19.989 Withdrawal free of tax
§19.990 Other uses prohibited
§19.991 Requirement for rendering spirits unfit for beverage use
§19.992 Authorized formulas for fuel alcohol
§19.993 Substitute materials
§19.994 Marks
§19.995 Container size

Transfers Between Plants

§19.996 Transfer in bond
§19.997 Consignor premises
§19.998 Reconsignment in transit
§19.999 Consignee premises

Paragraph 2. A new §19.63a is added immediately following §19.63. The new section incorporates authority to waive provisions of law and regulations with respect to alcohol fuel plants under the authoritites of the Director in Part 19. As added, §19.63a reads as follows:

§19.63a Alcohol fuel plants

Under the provisions of Subpart Y of this part, distilled spirits plants may be established solely for producing, processing and storing, and using distributing distilled spirits to be used exclusively for fuel use. To the extent the Director finds it necessary to carry out the provisions of 26 U.S.C. 5181, the Director may waive any provision of 26 U.S.C. Chapter 51 or this part (other than 26 U.S.C. 5181, this section, Subpart Y, or any provisions requiring the payment of tax).
(§232, Pub. L. 96-223, 94 Stat. 278 (26 U.S.C. 5181))

Paragraph 3. §19.505 is amended to provide for the transfer of spirits between plants qualified under 26 U.S.C. 5171 and alcohol fuellants. The statutes at large citation is also amended. As amended, §19.505 reads as follows:

§19.505 Authorized transfers.

(a) *Spirits.* Pursuant to approval of an application as provided for in §19.506, bulk spirits (including denatured spirits) may be transferred in bond between bonded premises in bulk conveyances, or by pipeline, or in bulk containers into which spirits may be filled on bonded premises. However, spirits (including denatured spirits) produced from petroleum, natural gas, or coal, may not be transferred to alcohol fuel plants. Spirits transferred in bond from alcohol fuel plants to plants qualified under 26 U.S.C. 5171 shall be accounted for separately by the consignee proprietor, and shall not subsequently be withdrawn, used, sold or otherwise disposed of for other than fuel use.

(b) * * *

(§201, Pub. L. 85-859, 72 Stat. 1362, as amended, 1380, as amended (26 U.S.C. 5212, 5362); §232, Pub. L. 96-223, 94 Stat. 278 (26 U.S.C. 5181)).

Paragraph 4. A new Subpart Y—Distilled Spirits for Fuel Use, is added to provide regulations for alcohol fuel plants. As added, Subpart Y reads as follows:

Subpart Y—Distilled Spirits for Fuel Use

§19.931 Scope of subpart.

This subpart relates to the qualification and operation of distilled spirits plants established solely for producing, processing and storing, and using or distributing distilled spirits to be used exclusively for fuel use. Except where incorporated in this subpart by reference, the provisions of Subparts A through X of this part do not apply to alcohol fuel plants (see §19.63a).
(§232, Pub. L. 96-223, 94 Stat. 278 (26 U.S.C. 5181))

§19.932 Taxes

(a) *Distilled spirits tax.* Distilled spirits may be withdrawn free of tax from the premises of an alcohol fuel plant exclusively for fuel use in accordance with this subpart. Payment of tax will be required in the case of diversion of spirits to beverage use or other unauthorized dispositions. The provisions of Subpart C of this part are applicable to distilled spirits for fuel use as follows:

(1) Imposition of tax liability (§§19.21 through 19.25);

(2) Assessment of tax (§§19.31 and 19.32); and,

(3) Claims for tax (§§19.41 and 19.44).

(b) *Still tax.* A commodity tax is imposed by 26 U.S.C. 5101 on the manufacturer for each still or condenser for distilling made by him. Manufacturers of stills are subject to a special occupational tax. However, a proprietor manufacturing stills or condensers exclusively for use in his plant or plants is exempt from these taxes. In addition, proprietors of alcohol fuel plants are exempt from the requirement of 26 U.S.C. 5105 to file an application and obtain a permit before setting up distilling apparatus. Provisions relating to stills are contained in 27 CFR Part 196.

(§201, Pub. L. 85-859, 72 Stat. 1314, as amended, 1339 (26 U.S.C. 5001, 5101, 5103); §232, Pub. L. 96-223, 94 Stat. 278 (26 U.S.C. 5181))

§19.933 Status of existing experimental distilled spirits plants

Notwithstanding any other provisions of this subpart, effective July 1, 1980, the prior application and permit of existing experimental plants for alcohol fuel production under Section 5312 will be considered as approved applications to operate under the provisions of 26 U.S.C. 5181 as alcohol fuel plants. Such existing plants may continue to operate and the operations shall be conducted pursuant to the provisions of this subpart. A new permanent permit as an alcohol fuel plant will be issued in lieu of, and prior to the expiration date of, the existing permit as an experimental plant. However, persons who wish to retain their permits under 26 U.S.C. 5312 as experimental distilled spirits plants, instead of converting to alcohol fuel plant status, may do so by filing a written request with the regional regulatory administrator.

§19.934 Meaning of terms

When used in this subpart, and in forms prescribed under this subpart, terms shall have the meaning given in this section. Words in the plural form include the singular and vice versa, and words indicating the masculine gender include the feminine. The terms "includes" and "including" do not exclude things not enumerated which are in the same general class.

Alcohol fuel plant or plant. An establishment qualified under this subpart solely for producing, processing and storing, and using or distributing distilled spirits to be used exclusively for fuel use.

Alcohol fuel producer's permit. The document issued pursuant to 26 U.S.C. 5181 authorizing the person named therein to engage in business as an alcohol fuel plant.

ATF officer. An officer or employee of the Bureau of Alcohol, Tobacco and Firearms (ATF) authorized to perform any function relating to the administration or enforcement of this subpart.

Bonded Premises. The premises of an alcohol fuel plant where distilled spirits are produced, processed and stored, and used or distributed. Premises of small alcohol fuel plants, which are exempt from bonding under §19.938, shall be treated as bonded premises for purposes of this subpart.

CFR. The Code of Federal Regulations.

Director. The Director, Bureau of Alcohol, Tobacco and Firearms, the Department of the Treasury, Washington, D.C.

Fuel alcohol. Distilled spirits which have been rendered unfit for beverage use at an alcohol fuel plant as provided in this subpart.

Gallon or wine gallon. The liquid measure equivalent to the volume of 231 cubic inches.

Person. An individual, trust, estate, partnership, association, company or corporation.

Proof. The ethyl alcohol content of a liquid at 60 degrees Fahrenheit, stated as twice the percent of ethyl alcohol by volume.

Proof gallon. A gallon of liquid at 60 degrees Fahrenheit which contains 50 percent by volume of ethyl alcohol having a specific gravity of 0.7939 at 60 degrees Fahrenheit referred to water at 60 degrees Fahrenheit as unity, or the alcoholic equivalent thereof.

Proprietor. The person qualified under this subpart to operate the alcohol fuel plant.

Region. A Bureau of Alcohol, Tobacco and Firearms region.

Regional regulatory administrator. The principal regional official responsible for administering regulations in this subpart.

Secretary. The Secretary of the Treasury or his delegate.

Spirits or distilled spirits. That substance known as ethyl alcohol, ethanol, or spirits of wine in any form (including all dilutions and mixtures thereof by whatever process produced), but not fuel alcohol unless specifically stated. For purposes of this subpart, the term does not include spirits produced from petroleum, natural gas, or coal.

This chapter. Title 27, Code of Federal Regulations, Chapter I (27 CFR Chapter I).

Transfer on bond. The transfer of spirits between alcohol fuel plants or between a distilled spirits plant qualified under 26 U.S.C. 5171 and an alcohol fuel plant.

Type of plant. The following three types of alcohol fuel plants are recognized in this subpart:

(a) *Small plant.* An alcohol fuel plant which produces -including receipts) not more than 10,000 proof gallons of spirits per calendar year.

(b) *Medium plant.* An alcohol fuel plant which produces (including receipts) more than 10,000 and not more than 500,000 proof gallons of spirits per calendar year.

(c) *Large plant.* An alcohol fuel plant which produces (including receipts) more than 500,000 proof gallons of spirits per calendar year.

U.S.C. The United States Code

Permits

§19.935 Application for permit required.
Any person wishing to establish an alcohol fuel plant shall first make application for and obtain an alcohol fuel producer's permit. Alcohol fuel producers permits are continuing. The permit continues in effect unless automatically terminated under §19.945, suspended or revoked as provided in §19.953, or voluntarily surrendered.
(§232, Pub. L. 96-223, 94 Stat. 278 (26 U.S.C. 5181))

§19.936 Criteria for issuance of permit.

In general, an alcohol fuel producer's permit will be issued to any person who completes the required application for permit and who furnishes the required bond (if any). However, the regional regulatory administrator may institute proceedings for the denial of the application, if the regional regulatory administrator determines that:

Persons wishing to establish a small plant shall apply for a permit as provided in this section. Except as provided in paragraph (d) of this section, operations may not be commenced until the permit has been issued.

(a) *The applicant (including, in the case of a corporation, any officer, director, or principal stockholder, and in the case of a partnership, a partner) is, by reason of business experience, financial standing, or trade connections, not likely to maintain operations in compliance with 26 U.S.C. Chapter 51, or regulations issued thereunder; or*

(b) *The applicant has failed to disclose any material information required, or has made any false statement, as to any material fact, in connection with the application; or*

(c) *The premises on which the applicant proposes to conduct the operations are not adequate to protect the revenue. The procedures applicable to denial of applications are set forth in 27 CFR Part 200.*
(§201, Pub. L. 85-859, 72 Stat. 1370, as amended (26 U.S.C. 5271); §232, Pub. L. 96-223, 94 Stat. 278 (26 U.S.C. 5181))

§19.937 Small plants.

Persons wishing to establish a small plant shall apply for a permit as provided in this section. Except as provided in paragraph (d) of this section, operations may not be commenced until the permit has been issued.

(a) *Application for permit.* The application (ATF Form 5110.74) shall be submitted to the regional regulatory administrator and shall set forth the following information:

(1) Name and mailing address of the applicant, and the location of the alcohol fuel plant if not apparent from the mailing address;

(2) A diagram of the plant premises and a statement as to the ownership of the premises (if the premises are not owned by the proprietor, the owner's consent to access by ATF officers must be furnished);

(3) A description of all stills and a statement of their maximum capacity;

(4) The materials from which spirits will be produced;

(5) A description of the security measures to be used to protect premises, buildings, and equipment where spirits are produced, processed, and stored; and,

(6) A statement as to the environmental impact of the proposed operation.

(b) *Receipt by the regional regulatory administrator*

(1) Notice of receipt—Within 15 days of receipt of the application, the regional regulatory administrator shall send a written notice of receipt to the applicant. The notice will include a statement as to whether the application meets the requirements of paragraph (a). If the application does not meet those requirements, the application will be returned and a new 15-day period will commence upon receipt by the regional regulatory administrator of the amended or corrected application.

(2) Failure to give notice—If the required notice of receipt is not sent, and the applicant has a receipt indicating that the regional regulatory administrator has received the application, the 45-day period provided for in paragraphs (c) and (d) will commence on the fifteenth day after the date the regional regulatory administrator received the application.

(3) Limitation—The provisions of subparagraphs (1) and (2) will apply only to the first application submitted with respect to any one small plant in any calendar quarter. However, an amended or corrected first application will not be treated as a separate application.

(c) *Determination by the regional regulatory administrator.* Within 45 days from the date the regional regulatory administrator sent the applicant a notice of receipt of a completed application, the regional regulatory administrator shall either (1) issue the permit, or (2) give notice in writing to the applicant, stating in detail the reason that a permit will not be issued. Denial of an application will not prejudice any further application for a permit made by the same applicant.

(d) *Presumption of approval.* If, within 45 days from the date of the notice to the applicant of receipt of a completed application, the regional regulatory administrator has not notified the applicant of issuance of the permit or denial of the application, the application shall be deemed to have been approved and the applicant may proceed as if a permit had been issued.

(§232, Pub. L. 96-223, 94 Stat. 278 (26 U.S.C. 5181)

§19.938 Waiver of bond requirement for small plants.

No bond is required for small plants.

(§232, Pub. L. 96-223, 94 Stat. 278 (26 U.S.C. 5181))

§19.939 Medium plants.

Any person wishing to establish a medium plant shall make application for and obtain an alcohol fuel producer's permit and furnish a bond as provided in this section. Operations may not be commenced until the application has been approved and the permit issued.

(a) Application for permit. The application (ATF Form 5110.74) shall be submitted to the regional regulatory administrator and shall set forth the following information:

(1) The information required by §19.937(a);

(2) Statement of maximum total proof gallons of spirits that will be produced and received during a calendar year;

(3) Information identifying the principal persons involved in the business and a statement as to whether the applicant or any such person has ever been convicted of a felony or misdemeanor under Federal or State law; and,

(4) Statement of the amount of funds invested in the business and the source of those funds.

(b) *Bond required.* A bond of sufficient penal sum, as prescribed in 19.958, must be submitted and approved before a permit may be issued.

(§232, Pub. L. 96-223, 94 Stat. 278 (26 U.S.C. 5181))

§19.940 Large Plants.

Any person wishing to establish a large plant shall make application for and obtain an alcohol fuel producer's permit and furnish a bond as provided in this section. Operations may not be commenced until the application has been approved and the permit issued.

(a) *Application for permit.* The application (ATF Form 5110.74) shall be submitted to the regional regulatory administrator and shall set forth the following information:

(1) The information required by §19.937(a);

(2) Statement of the maximum proof gallons of spirits that will be produced and received during a calendar year (not required if the bond is in the maximum sum);

(3) Information identifying the principal persons involved in the business and a statement as to whether the applicant or any such person has ever been convicted of a felony or misdemeanor under Federal or State law;

(4) Statement of the amount of funds invested in the business and the source of those funds; and,

(5) Statement of the type of business organization and of the persons interested in the business, supported by the items of information listed in §19.941.

(b) *Bond required.* A bond of sufficient penal sum, as prescribed in §19.958, must be submitted and approved before a permit may be issued.

(§232, Pub. L. 96-223, 94 Stat. 278 (26 U.S.C. 5181))

§19.941 Organizational documents.

The supporting information required by paragraph (a)(5) of §19.940, includes, as applicable, copies of—

(a) *Corporate documents.*

(1) Corporate charter or certificate of corporate existence or incorporation.

(2) List of directors and officers, showing their names and addresses. However, do not list officers who have no responsibilities in connection with the operation of the alcohol fuel plant.

(3) Certified extracts or digests of minutes of meetings of board of directors, authorizing certain individuals to sign for the corporation.

(4) Statement showing the number of shares of each class of stock or other evidence of ownership, authorized and outstanding, and the voting rights of the respective owners or holders.

(b) *Statement of interest.*

(1) Names and addresses of the 10 persons having the largest ownership or other interest in each of the classes of stock in the corporation, or other legal entity, and the nature and amount of the stockholding or other interest of each, whether the interest appears in the name of the interested party or in the name of another for him. If a corporation is wholly owned or controlled by another corporation, those persons of the parent corporation who meet the above standards are considered to be the persons interested in the business of the subsidiary, and the names thereof need be furnished only upon request of the regional regulatory administrator.

(2) In the case of an individual owner or partnership, the name and address of each person interested in the plant, whether the interest appears in the name of the interested party or in the name of another for that person.

(c) *Availability of additional documents.* The originals of documents required to be submitted under this section and additional items required under §19.942 such as the articles of incorporation, bylaws, State certificate authorizing operations, or articles of partnership or association (in the case of a partnership where required by State law) shall be made available to any ATF officer upon request.

(§201, Pub. L. 85-859, 72 Stat. 1349, as amended, 1370, as amended (26 U.S.C. 5172, 5271); §232, Pub. L. 96-223, 94 Stat. 278 (26 U.S.C. 5181))

§19.942 Information already on file and supplemental information

If any of the information required by §§19.937 through 19.941 is on file with the regional regulatory administrator, that information, if accurate and complete, may be incorporated by reference and made a part of the application. When required by the regional regulatory administrator, the applicant shall furnish as a part of the application for permit, additional information as may be necessary to determine whether the application should be approved.

(§232, Pub. L. 96-223, 94 Stat. 278, (26 U.S.C. 5181))

Changes Affecting Permits

§19.945 Automatic termination of permits.

(a) *Permits not transferable.* Permits issues under this subpart shall not be transferred. In the event of the lease, sale, or other transfer of such a permit, or of the authorized operations, the permit automatically terminates.

(b) *Corporations.* In the case of a corporation holding a permit under this subpart, if actual or legal control of the permittee corporation changes, directly or indirectly, whether by reason of change in stock ownership or control (in the permittee corporation or in any other corporation), by operation of law, or in any other manner, the permittee shall, within 10 days of such change, give written notice, executed under the penalties of perjury, to the regional regulatory administrator; the permit may remain in effect until the expiration of 30 days after the change, whereupon the permit will automatically terminate. However, if operations are to be continued after the change in control, and an application for a new permit is filed within 30 days of the change, then the outstanding permit may remain in effect until final action is taken on the new application. When final action is taken on the application, the outstanding permit automatically terminates.

(§201, Pub. L. 85-859, 72 Stat. 1370, as amended (26 U.S.C. 5271))

§19.946 Change in type of alcohol fuel plant.

(a) *Small plants.* If the proprietor of a small plant wishes to increase production (including receipts) to a level in excess of 10,000 proof gallons of spirits per calendar year, the proprietor shall first furnish a bond and obtain an amended permit by filing application under §§19.939 or 19.940, as applicable. Information filed with the original application for permit need not be resubmitted, but may be incorporated by reference in the new application.

(b) *Medium plants.* Where the proprietor of a medium plant intends to increase production (including receipts) above 500,000 proof gallons of spirits per calendar year, the proprietor shall first obtain an amended permit by filing an application under §19.940. A new or strengthening bond may be required (see §19.957(a)). Information already on file may be incorporated by reference in the new application.

(c) *Curtailment of activities.* Proprietors of large or medium plants who have curtailed operations to a level where they are eligible to be requalified as medium or small plants may, on approval of a letter of application by the regional regulatory administrator, be relieved from the additional requirements incident to their original qualification. In the case of a change to small plant status, termination of the bond and relief of the surety from further liability shall be as provided in Subpart H of this part.

(§201, Pub. L. 85-859, 72 Stat. 1370, as amended (26 U.S.C. 5271); §232, Pub. L. 96-223, 94 Stat. 278 (26 U.S.C. 5181))

§19.947 Change in name of proprietor.

Where there is to be a change in the individual, firm, or corporate name, the proprietor shall, within 30 days of the change, file an application to amend the permit; a new bond or consent of surety is not required.

(§101, Pub. L. 85-859, Stat. 1349, as amended, 1370, as amended (26 U.S.C. 5172, 5271); §232, Pub. L. 96-223, 94 Stat. 278 (26 U.S.C. 5181))

§19.948 Changes in officers, directors, or principal persons

Where there is any change in the list of officers, directors, or principal persons, furnished under the provisions of §§19.939, 19.940, or 19.941, the proprietor shall submit, within 30 days of any such change, a notice in letter form including the new list of officers and a statement of the changes reflected in such list.

(§232, Pub. L. 96-233, 94 Stat. 278 (26 U.S.C. 5181))

§19.949 Change in proprietorship.

(a) *General.* If there is a change in the proprietorship of a plant qualified under this part, the outgoing proprietor shall comply with the requirements of §19.952 and the successor shall, before commencing operations, apply for and obtain a permit and file the required bond (if any) in the same manner as a person qualifying as the proprietor of a new plant.

(b) *Fiduciary.* A successor to the proprietorship of a plant who is an administrator, executor, receiver, trustee, assignee or other fiduciary, shall comply with the applicable provisions of §19.186(b).

(§201. Pub. L. 85-859, 72 Stat. 1349, as amended (26 U.S.C. 5172))

§19.950 Continuing partnerships.

If under the laws of the particular State, the partnership is not terminated on death or insolvency of a partner, but continues until the winding up of the partnership affairs is completed, and the surviving partner has the exclusive right to the control and possession of the partnership assets for the purpose of liquidation and settlement, the surviving partner may continue to operate the plant under the prior qualification of the partnership. However, in the case of a large or medium plant, a consent of surety must be filed, wherein the surety and the surviving partner agree to remain liable on the bond. If the surviving partner acquires the business on completion of the settlement of the partnership, he shall qualify in his own name from the date of acquisition, as provided in §19.949(a). The rule set forth in this section shall also apply where there is more than one surviving partner.

(§201, Pub. L. 85-859, 72 Stat. 1349, as amended (26 U.S.C. 5172); §232, Pub. L. 96-223, 94 Stat. 278 (26 U.S.C. 5181))

§19.951 Change in location.

Where there is a change in the location of the plant or of the area included within the plant premises, the proprietor shall file an application to amend the permit and, if a bond is required, either a new bond or a consent of surety on ATF Form 1533 (5000.18). Operation of the plant may not be commenced at the new location prior to issuance of the amended permit.

(§201, Pub. L. 85-859, 72 Stat. 1349, as amended, 1370, as amended (26 U.S.C. 5172, 5271); §805(c), Pub. L. 96-39, 93 Stat. 276 (26 U.S.C. 5173); §232, Pub. L. 96-223, 94 Stat. 278 (26 U.S.C. 5181))

Permanent Discontinuance of Business

§19.952 Notice of permanent discontinuance.

A proprietor who permanently discontinues operations as an alcohol fuel plant shall, after completion of the operations, file a letter head notice with the regional regulatory administrator. The notice shall be accompanied (a) by the alcohol fuel producer's permit, and by the proprietor's request that such permit be canceled; (b) by a written statement disclosing, as applicable, whether (1) all spirits (including fuel alcohol) have been lawfully disposed of, and (2) any spirits are in transit to the premises; and (c) by a report covering the discontinued operations (the report shall be marked "Final Report").

(§201, Pub. L. 85-859, 72 Stat. 1349, as amended, 1370, as amended (26 U.S.C. 5172, 5271); §232, Pub. L. 96-223, 94 Stat. 278 (26 U.S.C. 5181))

Suspension or Revocation of Permits

§19.953 Suspension or revocation

Whenever the regional regulatory administrator has reason to believe that any person holding an alcohol fuel producer's permit—

(a) *Has not in good faith complied with the applicable provisions of 26 U.S.C. Chapter 51, or regulations issued thereunder, or*

(b) *Has violated conditions of the permit; or*

(c) *Has made any false statement as to any material fact in the application therefore; or*

(d) *Has failed to disclose any material information required to be furnished; or*

(e) *Has violated or conspired to violate any law of the United States relating to intoxicating liquor or has been convicted of any offense under Title 16, U.S.C. punishable as a felony or of any conspiracy to commit such offense: or*

(f) *Has not engaged in any of the operations authorized by the permit for a period of more than 2 years; the regional regulatory administrator may institute proceedings for the revocation or suspension of the permit in accordance with the procedures set forth in 27 CFR Part 200.*

(§201, Pub. L. 85-859, 72 Stat. 1370, as amended (26 U.S.C. 5271))

Bonds

§19.956 Bonds.

An operations bond is required for medium and large plants. Surety bonds may be given only with corporate sureties holding certificates of authority from, and subject to the limitations prescribed by, the Secretary as set forth in the current revision of Treasury Department Circular 570. However, in lieu of corporate surety the proprietor may pledge and deposit as surety for his bond, securities which are transferable and are guaranteed as to both interest and principal by the United States, in accordance with the provisions of 31 CFR Part 225. The regional regulatory administrator will not release such securities until liability under the bond for which they were pledged has been terminated.

(§805(c), Pub. L. 96-39,93 Stat. 276 (26 U.S.C. 5173); CH. 390, Pub. L. 80-280, 61 Stat. 648, 650 (6 U.S.C. 6, 7, 15); §232, Pub. L. 96-223, 94 Stat. 278 (26 U.S.C. 5181))

§19.957 Amount of bond.

The penal sum of the bond is based on the total quantity of distilled spirits to be produced (including receipts) during a calendar year. If the level of production and/or receipts at the plant is to be increased, and the bond shall be obtained.

(a) *Medium plants.* A medium plant which will produce (including receipts of) between 10,000 and 20,000 proof gallons of spirits per year requires a bond in the amount of $2,000. For each additional 10,000 proof gallons (or fraction thereof), the bond amount is increased $1,000. The maximum bond for a medium plant is $50,000.

(b) *Large plants.* The minimum bond for a large plant is $52,000 more than 500,000, but not more than 510,000 proof gallons annual production (including receipts)). For each additional 10,000 (or fraction) proof gallons, the amount of the bond is increased $2,000. The maximum bond for a large plant is $200,000 (more than 1,240,000 proof gallons).

(§805(c, Pub. L. 96-39, 93 Stat. 276 (26 U.S.C. 5173); §232, Pub. L. 96-233, 94 Stat. 278 (26 U.S.C. 5181))

§19.958 Instructions to compute bond penal sum.

(a) *Medium plants.* To find the required amount of your bond, estimate the total proof gallons of spirits to be produced and received in a calendar year. The amount of the bond is $1,000 for each 10,000 proof gallons (or fraction), subject to a minimum of $2,000 and a maximum of $50,000. The following table provides some examples:

Annual production and receipts in proof gallons

More than but not over	Amount of bond
10,000 to 10,000	$2,000
20,000 to 30,000	3,000
90,000 to 100,000	10,000
190,000 to 200,000	20,000
490,000 to 500,000	50,000

(b) *Large plants.* To find the required amount of your bond, estimate the total proof gallons of spirits to be produced and received in a calendar year. The amount of the bond is $50,000 plus $2,000 for each 10,000 proof gallons (or fraction) over 500,000. The following table provides some examples:

Annual production and receipts in proof gallons

More than but not over	Amount of bond
500,000 to 510,000	$52,000
510,000 to 520,000	54,000
740,000 to 750,000	100,000
990,000 to 1,000,000	150,000
1,240,000	200,000

(§805(c), Pub. L. 96-39, 93 Stat. 276 (26 U.S.C. 5173); §232, Pub. L. 96-223, 94 Stat. 278 (26 U.S.C. 5181))

§19.959 Conditions of bond.

The bond shall be conditioned on payment of all taxes (including any penalties and interest) imposed by 26 U.S.C. Chapter 51, on compliance with all requirements of law and regulations, and on payment of all penalties incurred or fines imposed for violation of any such provisions.

(§805(c), Pub. L. 96-39, 93 Stat. 276 (26 U.S.C. 5173); §232, Pub. L. 96-223, 94 Stat. 278 (26 U.S.C. 5181))

§19.960 Additional provisions with respect to bonds.

Subpart H of this part contains further provisions applicable to bonds which, where not inconsistent with this subpart, are applicable to bonds of alcohol fuel plants.

Construction, Equipment and Security

§19.972 Construction and equipment.

Buildings and enclosures where distilled spirits will be produced, processed, or stored shall be constructed and arranged to enable the proprietor to maintain security adequate to deter diversion of the spirits. Distilling equipment shall be constructed to prevent unauthorized removal of spirits, from the point where distilled spirits come into existence until production is complete and the quantity of spirits has been determined. Tanks and other vessels for containing spirits shall be equipped for locking and be constructed to allow for determining the quantities of spirits therein.

(§201, Pub. L. 85-859, 72 Stat. 1353, as amended (26 U.S.C. 5178))

§19.973 Security.

Proprietors shall provide security adequate to deter the unauthorized removal of spirits. The proprietor shall store spirits either in a building, a storage tank, or within an enclosure, which the proprietor will keep locked when operations are not being conducted.

(§201, Pub. L. 85-859, 72 Stat. 1353, as amended (26 U.S.C. 5178); §806, Pub. L. 96-39, 93 Stat. 279 (26 U.S.C. 5202))

§19.974 Additional security.

If the regional regulatory administrator finds that security is inadequate to deter diversion of the spirits, as may be evidenced by the occurrence of break-ins or by diversion of spirits to unauthorized purposes, additional security measures may be required. Such additional measures may include, but are not limited to, the following:

(a) *The erection of a fence around the plant or the alcohol storage facility;*

(b) *Flood lights;*

(c) *Alarm systems;*

(d) *Watchman services; or,*

(e) *Locked or barred windows.*

The exact additional security requirements would depend on the extent of the security problems, the volume of alcohol produced, the risk to tax revenue, and safety requirements.

(§201, Pub. L. 85-859, 72 Stat. 1353, as amended (26 U.S.C. 5178); §806, Pub. L. 96-39, 93 Stat. 279 (26 U.S.C. 5202))

Supervision

§19.975 Supervision of operations.

The regional regulatory administrator may assign ATF officers to premises of plants qualified under this subpart. The authorities of ATF officers, provided in §§19.80 through 19.84, and the requirement that proprietors keep premises accessible to and furnish facilities and assistance to ATF officers, provided in §§19.85 and 19.86, apply to plants qualified under this subpart.

(§201, Pub. L. 85-859, 72 Stat. 1320, as amended, 1357, as amended, 1358, as amended 1375, as amended (26 U.S.C. 5006, 5203, 5204, 5213))

Accounting for Spirits

§19.980 Gauging.

(a) *Equipment and method.* Proprietors shall gauge spirits by accurately determining the proof and quantity of spirits. The proof of the spirits shall be determined using a glass cylinder, hydrometer, and thermometer. However, fuel alcohol may be accounted for in wine gallons, so it is not necessary to determine the proof of fuel alcohol manufactured, on-hand, or removed. The proprietor may determine quantity either by volume or weight. A tank or receptacle with a calibrated glass scale installed, a calibrated dipstick, conversion charts, or (subject to approval by the Director) meters, may be used to determine quantity by volume. Detailed procedures for gauging spirits are provided in 27 CFR Part 13.

(b) *When Required.* Proprietors shall gauge spirits and record the results in their records at the following times:

(1) On completion of production of distilled spirits;

(2) On receipt of spirits at the plant;

(3) On addition of materials to render the spirits unfit for beverage use;

(4) Before withdrawal of spirits (including fuel alcohol) from plant premises or other disposition thereof; and,

(5) When spirits are to be inventoried.

§19.981 Inventories.

Proprietors shall take actual physical inventory of all spirits (including fuel alcohol) on bonded premises at least once during each period for which a report is required by §19.988. The results of the inventory shall be

posted in the applicable reocrds required by §19.982.
(§201, Pub. L. 85-859, 72 Stat. 1356, as amended (26 U.S.C. 5201))

§19.982 Records.

(a) *All plants.* All proprietors shall maintain records with respect to:

(1) The quantity and proof of spirits produced;

(2) The proof gallons of spirits on-hand and received;

(3) The quantities and types of materials added to render the spirits unfit for beverage use;

(4) The quantity of fuel alcohol manufactured; and,

(5) All dispositions of spirits (including fuel alcohol). Fuel alcohol may be recorded in wine gallons.

(b) *Medium and large plants.* Proprietors of medium and large plants shall also record the kind and quantity of materials used to produce spirits.

(c) *General requirements.* The records must contain sufficient information to allow ATF officers to determine the quantities of spirits produced, received, stored, or processed and to verify that all spirits have been lawfully disposed of or used. However, the proprietor need not prepare records specifically to meet the requirements of this subpart. Records which the proprietor prepares for other purposes (i.e., invoices or other commercial records) are sufficient, so long as they show all the required information.
(§807, Pub. L. 96-39, 93 Stat. 284 (26 U.S.C. 5207))

§19.983 Spirits rendered unfit in the production process.

If the proprietor renders spirits unfit for beverage use before removal from the production system, the production records shall also include the kind and quantity of materials added to each lot of spirits. In such a case, a separate record under §19.985 is not required. This paragraph applies to in-line addition of materials and to systems in which, before any spirits come off the production equipment, the proprietor adds materials for rendering the spirits unfit for beverage use to the first receptacle where spirits are to be deposited.
(§807, Pub. L. 96-39, 93 Stat. 284 (26 U.S.C. 5207); §232, Pub. L. 96-223, 94 Stat. 278 (26 U.S.C. 5181))

§19.984 Record of spirits received.

The proprietor's copy of the consignor's invoice or other document received with the shipment, on which the proprietor has noted the date of receipt and quantity received, constitutes the required record.
(§807, Pub. L. 96-39, 93 Stat. 284 (26 U.S.C. 5207))

§19.985 Record of spirits rendered unfit for beverage use.

The proprietor shall record the kind and quantity of materials added to render each lot of spirits unfit for beverage use and the quantity of fuel alcohol manufactured (which may be given in wine gallons).
(§807, Pub.L. 96-39, 93 Stat. 284 (26 U.S.C. 5207)).

§19.986 Record of dispositions.

(a) *Fuel alcohol.* For fuel alcohol distributed, used, or otherwise disposed of the proprietor shall record the—

(1) Quantity of fuel alcohol;

(2) Date of disposition; and

(3) Name and address of the person to whom distributed or, if used or otherwise disposed of by the proprietor, the purpose for which used or the nature of the other disposition (e.g., destruction or redistillation). Commercial invoices, sales slips, or similar documents are acceptable if they clearly show the required information.

(b) *Spirits.*

(1) For spirits transferred in bond to another alcohol fuel plant, the commercial invoice or other document required by §19.997 constitutes the required record. For transfers to other distilled spirits plants, the form required by §19.508 is the required record.

(2) For spirits used or otherwise disposed of (e.g., lost, destroyed, redistilled) on the premises of the alcohol fuel plant, the proprietor shall maintain a record as follows:

(i) the quantity of spirits (in proof gallons) and the date of disposition;

(ii) the purpose for which used or the nature of the other disposition.
(§807, Pub. L. 96-39, 93 Stat. 284 (26 U.S.C. 5207))

§19.987 Maintenance and retention of records.

The proprietor shall retain the records required by this subpart for a period of not less than three years from the date thereof or from the data of the last entry made

thereon, whichever is later. The records shall be kept at the plant where the operation or transaction occurs and shall be available for inspection by any ATF officer during business hours. For records maintained on data processing equipment, the provisions of §19.743 apply.
(§807, Pub. L. 96-39, 93 Stat. 284 (26 U.S.C. 5207)).

§19.988 Reports.

Proprietors shall file reports of their operations, depending on the type of plant, as follows:

Type of Plant and Reporting Periods
Small plant—Annually (December 31)
Medium plant—Semiannually (June 30 and December 31)
Large plant—Quarterly (Close of each calendar quarter)

The proprietor shall submit each required report to the regional regulatory administrator within 30 days after the close of the applicable reporting period. The report shall be submitted on a form provided for that purpose.
(§807, Pub. L. 96-39, 93 Stat. 284 (26 U.S.C. 5207))

Transfers and Withdrawals

§19.989 Withdrawal free of tax.

Fuel alcohol produced under this subpart, may be withdrawn free of tax from plant premises exclusively for fuel use.
(§201, Pub. L. 85-859, 72 Stat. 1362, as amended (26 U.S.C. 5214); §232, Pub. L. 96-223, 94 Stat. 278 (26 U.S.C. 5181))

§19.990 Other uses prohibited.

The law imposes criminal penalties on any person who withdraws, uses, sells or otherwise disposes of distilled spirits (including fuel alcohol) produced under this subpart for other than fuel use.
(§201, Pub. L. 85-859, 72 Stat. 1398, as amended (26 U.S.C. 5601); §232, Pub. L. 96-223, 94 Stat. 278 (26 U.S.C. 5181))

§19.991 Requirement for rendering spirits unfit for beverage use.

Before spirits may be withdrawn from plant premises, the spirits must contain, or the proprietor shall add, substances to render the spirits unfit for beverage use as provided in this subpart. However, spirits used for fuel on the premises of the alcohol fuel plant and spirits transferred to other plants need not be rendered unfit for beverage use.
(§232, Pub. L. 96-223, 94 Stat. 278 (26 U.S.C. 5181))

§19.992 Authorized formulas for fuel alcohol.

Spirits will be considered rendered unfit for beverage use and eligible for tax-free withdrawal as fuel alcohol, when for every 100 gallons of spirits, there has been added:

(a) *5 gallons or more of—*

   (1) Gasoline or automotive gasoline (for use in engines which require unleaded gasoline. Environmental Protection Agency regulations and manufacturer's specifications may require that unleaded gasoline be used to render the spirits unfit).

   (2) Kerosene

   (3) Deodorized kerosene

   (4) Rubber hydrocarbon solvent,

   (5) Methyl isobutyl ketone,

   (6) Mixed isomers of nitropropane, or

   (7) Any combination of (1) through (6); or,

(b) *1/8 ounce of denatonium benzoate N.F. (Bitrex) and 5 gallons of isopropyl alcohol.*
(§232, Pub. L. 96-233, 94 Stat. 278 (26 U.S.C. 5181))

§19.993 Substitute Materials.

Other materials may be used to render spirits unfit for beverage use subject to approval by the Director. A proprietor who wishes to use substitute materials to render spirits unfit for beverage use may submit a letter requesting authorization to the Director through the regional regulatory administrator. The letter should state the materials, and the quantity of each, which the proprietor proposes to add to each 100 gallons of spirits. The Director may require the proprietor to submit a sample of the proposed substitute material. The proprietor shall not use any proposed substitute material prior to its approval.
(§232, Pub. L. 96-233, 94 Stat. (26 U.S.C. 5181))

§19.994 Marks.

The proprietor shall conspicuously and permanently mark or securely label each container of fuel alcohol containing 55 gallons or less, as follows:

WARNING—FUEL ALCOHOL—MAY BE HARMFUL OR FATAL IF SWALLOWED

The mark or label shall be placed on the head or side of the container, and shall be in plain legible letters. Proprietors may place other marks or labels on containers

so long as they do not obscure the required mark.
(§232, Pub. L. 96-233, 94 Stat. 278 (26 U.S.C. 5181); §201, Pub. L. 85-859, 72 Stat. 1360, as amended (26 U.S.C. 5206))

§19.995 Container size.

Spirits, including fuel alcohol, shall not be filled at alcohol fuel plants into containers holding less than five gallons. However, smaller containers may be used for reasonable quantities of samples held or removed to a bonafide laboratory for testing or analysis, so long as the containers are marked as samples.
(§232, Pub. L. 96-223, 94 Stat. 278 (26 U.S.C. 5181))

Transfers Between Plants

§19.996 Transfer in bond.

(a) *Transfers between alcohol fuel plants.* Proprietors may remove spirits from the bonded premises of an alcohol fuel plant (including the premises of a small plant) for transfer to another alcohol fuel plant. Bulk conveyances in which spirits are transferred shall be secured with locks or seals. The spirits need not be rendered unfit for beverage use prior to transfer. Spirits so transferred may not be withdrawn, used, sold, or otherwise disposed of from the consignee plant for other than fuel use.

(b) *Transfers to or from other distilled spirits plants.* Spirits (not including spirits produced from petroleum, natural gas, or coal) may be transferred in bond from distilled spirits plants qualified under Subpart G of this part to alcohol fuel plants. Alcohol fuel plants may transfer spirits in bond to distilled spirits plants qualified under Subpart G. Spirits so transferred may not be withdrawn, used, sold, or otherwise disposed of for other than fuel use.

(c) *Transfer procedures.* The procedures in §§19.997 through 19.999 apply only to the transfers between two alcohol fuel plants. See §§19.506 through 19.510 for requirements where one plant is a distilled spirits plant qualified under subpart G of this part.
(§201, Pub. L. 85-859, 72 Stat. 1362, as amended (26 U.S.C. 5212); §232, Pub. L. 96-223, 94 Stat. 278 (26 U.S.C. 5181))

§19.997 Consignor premises.

The consignor shall prepare, in triplicate, a commercial invoice or shipping document to cover each shipment of spirits. The consignor shall enter on the document the quantity of spirits transferred, a description of the shipment (for example, number and size of drums or barrels, tank truck, etc.), the name, address, and permit number of the consignee, and the serial numbers of any seals, locks, or other devices used to secure the conveyance. The consignor shall forward the original and one copy of the document to the consignee with the shipment, and retain a copy as a record.
(§201, Pub. L. 85-859, 72 Stat. 1362, as amended (26 U.S.C. 5212))

§19.998 Reconsignment in transit.

When, prior to or on arrival at the premises of a consignee, spirits transferred in bond are found to be unsuitable for the intended purpose, were shipped in error, or, for any other bona fide reason, are not accepted by such consignee, or are not accepted by a carrier, they may be reconsigned, by the consignor, to himself, or to another qualified consignee. In such case, the bond, if any, of the proprietor to whom the spirits are reconsigned shall cover such spirits while in transit after reconsignment on his copy of the document covering the original shipment. Where the reconsignment is to another proprietor, a new document shall be prepared and prominently marked with the word "Reconsignment."
(§201, Pub. L. 85-859, 72 Stat. 1362, as amended (26 U.S.C. 5212); §232, Pub. L. 96-223, 94 Stat. 278 (26 U.S.C. 5181))

§19.999 Consignee premises.

(a) *General.* When spirits are received by transfer in bond, the proprietor shall examine each conveyance to determine whether the locks or seals, if any, are intact upon arrival at this premises. If the locks or seals are not intact, he shall immediately notify the area supervisor, before removal of any spirits from the conveyance. The consignee shall determine the quantity of spirits received and record the quantity and the date received on both copies of the document covering the shipment. The consignee shall return one receipted copy to the consignor and retain one copy as the record of receipt required by §19.984.

(b) *Portable containers.* When spirits are received in barrels, drums, or similar portable containers, the proprietor shall examine each container and unless the transfer was made in a sealed conveyance and the seals or other devices are intact on arrival, verify the contents of container. The proprietor shall record the quantity received for each container on a list, and attach a copy of the list to each copy of the invoice or other document required by §19.997 covering the shipment.

(c) *Bulk conveyances and pipelines.* When spirits are received in bulk conveyances or by pipeline, the consignee shall gauge the spirits received and record the quantity so determined on each copy of the invoice or other document covering the shipment. However, the regional regulatory administrator may waive the requirement for gauging spirits on receipt by pipeline if, because of the location of the premises, there will be no jeopardy to the revenue.

(§201, Pub. L. 85-859, 72 Stat. 1358, as amended 1362, as amended (26 U.S.C. 5204, 5212); §232, Pub. L. 96-223, 94 Stat. 278 (26 U.S.C. 5181))

Signed: May 21, 1980
G. R. Dickerson, Director
Approved: June 9, 1980
Richard J. Davis, Assistant Secretary
(Enforcement Operations)

DEPARTMENT OF TREASURY

Bureau of Alcohol, Tobacco and Firearms
27 CFT Part 19
(Notice No. 345)
Fuel Use of Distilled Spirits—Implemeting a Portion of the Crude Oil Windfall Profit Tax Act of 1980
(Public Law 96-223)

AGENCY: Bureau of Alcohol, Tobacco and Firearms, Department of the Treasury.

ACTION: Proposed rulemaking cross-reference to temporary regulations.

SUMMARY: In the Rules and Regulations portion of this Federal Register, the Bureau of Alcohol, Tobacco and Firearms (ATF) is issuing temporary regulations regarding implementation of Section 232, Alcohol Fuels, in Part III of Title II of the crude Oil Windfall Profit Tax Act of 1980 (Pub. L. 96-223). The temporary regulations also serve as a notice of proposed rulemaking for final regulations.

DATES: The effective date of the temporary regulations is July 1, 1980. Written comments must be delivered or mailed by October 20, 1980.

ADDRESS: Send comments to Chief, Regulations and Procedures Division, Bureau of Alcohol, Tobacco and Firearms, P.O. Box 385, Washington, DC 20044

Disclosure of comments: Any person may inspect the written comments or suggestions during normal business hours at the ATF Reading Room, Office of Public Affairs, Room 4407, Federal Building, 12th and Pennsylvania Avenue, NW, Washington, DC 20226.

FOR FURTHER INFORMATION CONTACT:

John V. Jarowski, Research and Regulations Branch,
Bureau of Alcohol, Tobacco and Firearms,
Washington, DC 20226,
Telephone: 202-566-7626.

SUPPLEMENTARY INFORMATION:

Public Participation: Interested persorns may submit written comments and suggestions regarding the temperary regulations. All communications received within the comment period will be considered before final regulations are issued. Any person who desires an opportunity to comment orally at a public hearing on the temperary regulations should submit a written request to the Director within the comment period. However, the Director reserves the right to determine whether public hearing should be held.

ATF plans to contact State regulatory officials to obtain their comments on these regulations. ATF seeks to coordinate Federal and State regulation of alcohol fuels in an effort to minimize conflicting or duplicative regulations.

The temporary regulations in the Rules and Regulations portion of this issue of the Federal Register revise and add new regulations in 27 CFR Part 19. For the text of the temporary regulations, see 45 FR (T.D. ATF-71) published in the Rules and Regulations portion of this issue of the Federal Register.

Signed: May 21, 1980
G. R. Dickerson, Director
Approved: June 9, 1980
Richard J. Davis, Assistant Secretary (Enforcement and Operations)

FDA AND OTHER ANIMAL FEED REGULATIONS

Most plants designed for the production of fuel alcohol from grain will be designed to produce coproducts in the form of grain residues suitable for use as animal feeds. Therefore, a substantial portion of the alcohol plant's activities will be concerned with producing and marketing these products. Most states have adopted commercial feed laws governing the production and marketing of animal feeds. In addition, the sale of feeds on an interstate basis is regulated at the federal level by various agencies, primarily the Food and Drug Administration (FDA). Thus, regulatory compliance will be an important consideration in developing the plant's animal feed operations.

The regulations in each State should be checked for particular requirements; however, the regulations in the majority of States are very similar. In many States, the State legislators have adopted all or part of the Uniform State Feed Bill.[1] These statutes incorporate by reference provisions of the Food, Drug, and Cosmetic Act and the of-

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[1] Officially adopted by the Association of American Feed Control Officials and endorsed by the American Feed Manufacturers Association and the National Feed Ingredients Association.

ficial definitions of feed ingredients as defined by the Association of American Feed Control Officials (AAFCO).

For the alcohol plant, as a manufacturer of animal feeds, ther are three primary areas of concern with regard to feed regulation-registration, adulteration, and misbranding. Registration (licensing) is in most instances quite simple and involves registering the products to be manufactured and paying the fees required. The statutory language in some states may require fee tags or stamps to be purchased and attached to the labeling used on packaged feeds or, in the case of feeds sold in bulk, to provide these tags or stamps to the buyer along with the invoice or bill of lading. The fees charged are, for the most part, nominal. They are either set at a flat rate for each product produced and sold or are based on tonnage. Some states have registrations involving a combination of a flat rate plus a tonnage fee.[2] A number of states may also require the filing of affidavits of tonnage on a regular basis in order to advise the state on the level of production at a given plant. In each state the actual mechanism of registration is usually a simple matter of following the statutory guidelines and associated regulations.[3]

After the initial registration has been completed, the primary concerns of management, to ensure continued compliance, will be in the area of quality control. From a licensing standpoint, lapses in quality control can produce charges of adulteration and misbranding. To ensure continuing compliance, most States have (by statute) provided for inspecting, sampling, and analyzing production. Discovery of a violation of the provisions of the Feed Law can result in various penalties (fines) or in detention of the feed (i.e. withholding the feed from sale or distribution).

Contamination of the feed can result in a charge of adulteration. The definition of adulteration is usually specifically provided by statute. The Uniform Feed Bill provides the following definition:

Section 7. Adulteration.

A commercial feed shall be deemed to be adulterated:

(a)(1) If it bears or contains any poisonous or deleterious substance which may render it injurious to health; but in case the substance is not an added substance, such commercial feed shall not be considered adulterated under this subsection if the quantity of such substance in such commercial feed does not ordinarily render it injurious to health; or

(2) If it bears or contains any added poisonous, added deleterious, or added nonnutritive substance which is unsafe within the meaning of Section 406 of the Federal, Food, and Cosmetic Act (other than one which is (i) a pesticide chemical in or on a raw agricultural commodity; or (ii) a food additive); or

(3) If it is, or it bears or contains any food additive which is unsafe within the meaning of Section 409 of the Federal Food, Drug, and Cosmetic Act; or

(4) If it is a raw agricultural commodity and it bears or contains a pesticide chemical which is unsafe within the meaning of Section 408(a) of the Federal Food, Drug, and Cosmetic Act: Provided, that where a pesticide chemical has been used in or on a raw agricultural commodity in conformity with an exemption granted or a tolerance prescribed under Section 408 of the Federal Food, Drug, and Cosmetic Act and such raw agricultural commodity has been subjected to processing such as canning, cooking, freezing, dehydrating, or milling, the residue of such pesticide chemical remaining in or on such processed feed shall not be deemed unsafe if such residue in or on the raw agricultural commodity has been removed to the extent possible in good manufacturing practice and the concentration of such residue in the processed feed is not greater than the tolerance prescribed for the raw agricultural commodity unless the feeding of such processed feed will result or is likely to result in a pesticide residue in the edible product of the animal, which is unsafe within the meaning of Section 408(a) of the Federal Food, Drug, and Cosmetic Act.

(5) If it is, or it bears or contains any color additive which is unsafe within the meaning of Section 706 of the Federal Food, Drug, and Cosmetic Act.

(b) If any valuable constituent has been in whole or in part omitted or abstracted therefrom or any less valuable substance substituted therefor.

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[2] For example, Wisconsin assesses $10.00 per plant per year plus $0.10 per ton inspection fee for all feed produced annually. By contrast, Georgia simply charges a flat fee of $2.00 annually per product produced.

[3] Most States have provided authority under the respective Administrative Procedures Act for the agencies to pass regulations further defining or implementing legislation and these regulations should be checked.

(c) If its composition or quality falls below or differs from that which it is purported or is represented in possess by its labeling.

(d) If it contains a drug and the methods used in or the facilities or controls used for its manufacture, processing, or packaging do not conform to current good manufacturing practice regulations promulgated by the (authorized State agency) to ensure that the drug meets the requirement of this Act as to safety and has the identity and strength and meets the quality and purity characteristics which it purports or is represented to possess. In promulgating such regulations, the (authorized State agency) shall adopt the current good manufacturing practice regulations for medicated feed premixes and for medicated feeds established under authority of the Federal Food, Drug, and Cosmetic Act, unless he determines that they are not appropriate to the conditions which exist in this State.

(e) If it contains visable weed seeds in amounts exceeding the limits which the (authorized state agency) shall establish by rule or regulation.

The above statute, in addition to the enumerated provisions, incorporates by reference two important areas of federal regualtion.

First, the feed could be adulterated by containing an added substance not on the list of substances Generally Recognized as Safe by the FDA (The GRAS List) or if it contains a substance on the GRAS List in excess of the limits prescribed for that substance in the Code of Federal Regulations (CFR). Thus, a violation could occur if a plant were to utilize a process that added a substance to the feed during the process of manufacturing which is not in compliance with the above regulations. For example, a process for drying feed residue which utilizes waste gases might produce unacceptable levels of contamination or contamination with some substance not on the GRAS List.

Second, a problem could also arise if the grain used as a substrate contained excessive levels of pesticides. The processing might not eliminate enough of the residue to bring the quantity in the final product within the acceptable limits.[4]

In addition to avoiding the charge of adulteration, quality control is essential to ensure regulatory compliance in other areas. To ensure compliance, it is necessary that a feed that purports to be a certain product must meet the definition established for that product. Failure to meet the definition or standard could result in the charge of misbranding. The Uniform State Feed Bill provides the following definition for misbranding:

Section 6. Misbranding.

A commercial feed shall be deemed to be misbranded:

(a) If its labeling is false or misleading in any particular.

(b) If it is distributed under the name of another commercial feed.

(c) If it is not labeled as required in Section 5 of this Act.

(d) If it purports to be or is represented as a commercial feed, or if it purports to contain or is represented as containing a commercial feed ingredient, unless such commercial feed or feed ingredient conforms to the definition, if any, prescribed by regulation by the (authorized state agency).

(e) If any word, statement, or other information required by or under authority of this Act to appear on the label or labeling is not prominently placed theron with such conspicuousness (as comapred with other words, statements, designs, or devices in the labeling) and in such terms as to render it likely to be read and understood by the ordinary individual under customary conditions of purchase and use.

The definitions referred to in the above statutory provisions for feed products have been established by AAFCO and are incorporated by reference.[5]

This discussion of feed regulations briefly outlines the areas of interest to investors in alcohol fuel plants. Compliance with these regulations can be achieved by properly designing and operating the plant. The grain and feed portions of the operation can be designed to minimize problems with contamination and provide adequate controls to monitor and manage product quality in order to eliminate or minimize regulatory complaince problems. By recognizing and considering these regulatory requirements during the planning and design phases, new plants can do a great deal to minimize potential problems in this area.

Limits on pesticides under Section 408 of FDCA are determined by the EPA and are set forth in the CFR's.

[5] Official and tentative definitions of feed ingredients as established by the Association of American Feed Control Officials (AAFCO) contains definitions for a wide variety of products. These include: Maize (corn products) 48.1 to 48.30; Fermentation Products 36.1 to 36.12; Distiller's Products 27.1 to 27.7.

TRANSPORTATION REGULATIONS

The surface transportation of raw materials and finished product may be regulated by State and Federal agencies, depending upon the location of the plant and its proximity to the source of materials and its markets. If the plant, material source, and the market are located in the same State, it is highly probable that only the individualistic State law will apply to regulate surface transportation, at least insofar as for-hire motor truck transportation is concerned. Some States, such as Texas, Nebraska, and South Dakota, choose to regulate truck transportation rather extensively, while others have little or no concern for regulation of the basic types of commodities flowing to and from a plant. Generally, grain transportation is not regulated, while coal and alcohol fuel are. Several States, including Florida, have recently deregulated the transporting of all commodities within their borders, while several others are actively studying deregulation proposals.

Assuming interstate commerce is involved in either obtaining materials or in reaching the market place, the nature of regulation is determined by the Interstate Commerce Commission. Currently, the truck transportation of grain is exempt (or not regulated), while, under the Motor Carrier Reform Act of 1980 (H.R. 6418), the movement of DDG will likely also be exempt. Truck movement of coal and alcohol, on the other hand, is currently regulated. In this context, lawful interstate movements of such commodities can be performed only by a carrier holding Federal ICC authority.*

Primary transportation considerations will necessarily include plant site selection vis a vis existing, visible rail facilities. This is particularly critical where a plant is to be located any distace (perhaps more than 200 or 250 miles) from the primary source of any major raw material (grain or coal).

LOCAL BUILDING CODES

Like zoning matters, the State's jurisdictional power is the basic authority under which building codes are enacted. Some State legislatures enact statewide building codes while others delegate the authority to the local governments. One or a combination of the four model building codes has been adopted by most States or municipalities. These codes (and the geographic area) dominated by their association/author are: (1) the Uniform Building Code written by the International Conference of Building Officials (adopted primarily in the West); (2) the Basic Building Code compiled by the Building Officials and Code Administrators, International, Inc. (found in the Northeast and North Central areas); (3) the Southern Standard Building Code enacted by the Southern Building Code Conference (adopted in the South); and (4) the National Building Code, developed by the National Board of Fire Underwriters. Local variations exist despite the model codes. Some municipalities have adopted selected provisions rather than the entire code. Interpretations of the same code differ from city to city.

Unlike zoning ordinanaces, most building codes apply retroactively. Three types of information are provided in most codes: definition of terms; licensing requirements; and standards. Taken together, the definitions and licensing requirements have the effect of prescribing who is authorized to conduct particular sorts of construction activity. For example, the International Association of Plumbing and Mechanical Officials Code states that only licensed plumbers may do work defined as plumbing. Many codes require that structural design plans be prepared by a state certified engineer.

Two types of code standards exist: technical specifications and performance standards. Codes prescribing technical specifications set out how, and with what materials, a building is to be constructed. Performance standards represent a more progressive and technically more flexible approach. Codes based on these standards state product requirements that do not prescribe designs and materials. For example, "the structural frame of all buildings, signs, tanks and other exposed structures shall be designed to resist the horizontal pressures due to wind in any direction. . . " Typical construction components specified in codes are structural and foundation loads and stresses, construction material, fireproofing, building height (this represents a common duplication of the zoning ordinance), and electrical installation. The developer is likely to be required to comply with the standards for structural and foundation loads and stresses, as standards set out the minimum force measure in pounds-per-square-inch that the design must bear under certain circumstances, e.g., wind or snow. The electrical code regulates the use of all electrical wiring when voltage levels are above 36 volts.

Dissatisfaction with the building inspector's denial of a permit may result in an appeal before the local board of building appeals. The common bases of appeal provided by the codes are: an incorrect interpretation of the code by the building official; the availability of an equally good or better form of construction not specified in the code; and the existence of practical difficulties in carrying out the requirements of the code. The local board members are usually appointed experts in the field of construction. The local board may uphold, modify, or reverse the building official's decision. Further appeals to the state board of building appeals or to the courts are also available.

***As a corollary to this, the rate structures on such transportation are also regulated.**

GASOLINE ALLOCATIONS

A letter containing the following information is required from the applicant interested in obtaining a gasoline allocation for gasohol:

The office that is final arbiter on increasing gasoline allocation for gasohol usage is:

Office of Hearings and Appeals
U. S. DEPARTMENT OF ENERGY
2000 M Street, N.W.
Washington, D.C. 20461
(202) 254-3008

(a) Investment

1. What is the amount of investment already made?
2. How is/was this investment financed?
3. What would be the value of the investment if approval for reallocation is not granted?
4. Provide photographs of production facilities.
5. For what purpose(s) will the investment be used—gasohol blending, ethanol production, facility construction, feedstock purchase, etc.?

(b) Alcohol

1. Where are the sources of alcohol?
2. What will be the cost of obtaining the alcohol for each source listed?
3. Supply copies of supply contracts, if any exist.
4. What is the efficiency of the alcohol production techniques(s) to be used?
5. What feedstock will be utilized in producing the alcohol?

(c) Unleaded Gasoline

1. What is the availability of unleaded gasoline in the intended marketing area?
2. List refiners in the marketing area.
3. Describe the contacts already made in attempting to obtain unleaded gasoline.
4. List your preferred supplier(s) for unleaded gasoline.
5. Of the gasoline you obtain, what percentage is unleaded?
6. What is your selling price for unleaded gasoline?
7. What quantities of unleaded gasoline do you anticipate needing in the next 12 months? Specify month-by-month.

(d) Marketing

1. Describe the intended marketing area.
2. Describe your plans for the marketing of gasohol.
3. What is the anticipated sales of gasohol for 12-month period?
4. Describe any feasibility studies showing demand for gasohol in marketing area.
5. List retailers in the marketing area that would sell gasohol. Describe any contracts that exist with them.
6. What is the expected selling price for the gasohol?

A copy of this letter of application (with confidential information deleted) should be sent to the base supplier of gasoline.

U.S. GOVERNMENT PRINTING OFFICE 1980 625 330

DEPARTMENT OF THE TREASURY BUREAU OF ALCOHOL, TOBACCO AND FIREARMS

APPLICATION AND PERMIT FOR ALCOHOL FUEL PRODUCER UNDER 26 U.S.C. 5181

INSTRUCTION SHEET FOR ATF FORM 5110.74

PLEASE READ CAREFULLY. AN INCOMPLETE OR INCORRECT APPLICATION WILL DELAY YOUR ALCOHOL FUEL PRODUCER'S PERMIT.

1. PURPOSE. The application is completed by a person (applicant) who would like to establish a plant to produce, process, and store, and use or distribute distilled spirits to be used exclusively for fuel use under 26 U.S.C. 5181. Distilled spirits means only ethanol or ethyl alcohol. The production of methanol does not require a permit from the Bureau of Alcohol, Tobacco and Firearms. The production of distilled spirits from petroleum, natural gas, or coal is not allowed by the Alcohol Fuel Producers Permit.

2. GENERAL PREPARATION. Prepare this form and any attachments in duplicate. Use separate sheets of approximately the same size as this form when necessary or as required. Identify these separate sheets with your name, and attach to form.

3. WHERE TO FILE. Submit application to the appropriate regional regulatory administrator. (A listing of their offices and the areas they are responsible for is on the reverse.)

4. TYPE OF APPLICATION. (See item 1. of application). The type of permit you need, small, medium, or large, depends on how many proof gallons of distilled spirits you intend to produce and receive by transfers from other plants during one calendar year. The number of proof gallons may be calculated by taking the proof of the spirits multiplied by the wine gallons (your standard American gallon) and dividing by 100. For example:

   50 gallons of 190° proof spirits =
   190 x 50 ÷ 100 = 95 proof gallons.

   After determining the quantity of spirits to be produced and received by transfers from other plants, check applicable box in item 1.

5. AMENDED PERMIT. Item 2. is only completed when changing or amending an existing permit.

6. INFORMATION ABOUT APPLICANT CURRENTLY ON FILE WITH REGIONAL REGULATORY ADMINISTRATOR NEED NOT BE RESUBMITTED. State in item requesting such information the type and the number of the license or permit for which the information was filed.

7. CAPACITY OF STILLS. Item 9.d. asks for the capacity of your still(s) in proof gallons. The capacity should be given as the greatest number of proof gallons of spirits that could be distilled in a 24 hour period. Capacity of column still may be shown by giving the diameter of the base and the number of plates or packing material. The capacity of a pot or kettle still may be shown by giving the volumetric (wine gallon) capacity of the pot or kettle.

8. SAMPLE DIAGRAM OF PREMISES. Item 12. requires a diagram of your plant premises. It can be drawn by hand and does not have to the drawn to scale. Below is a sample of such a diagram.

9. ITEM 15—SIGNATURE OF/FOR APPLICANT. (a) Individual owners sign for themselves; (b) partnerships have all partners sign, or have one partner who has attached an authorization to act on behalf of all the partners (unless this authorization is provided by State law); (c) corporations have an officer, director, or other person who is specifically authorized by the corporate documents sign; (d) any other person who signs on behalf of the applicant must submit ATF F 1534 (5000.8), Power of Attorney or other evidence of their authority.

10. ADDITIONAL INSTRUCTIONS FOR APPLICANT OF SMALL ALCOHOL FUEL PLANT. Complete all items on the application form. Be sure that you sign and date the form in items 15, and 16. NO ADDITIONAL INFORMATION IS REQUIRED.

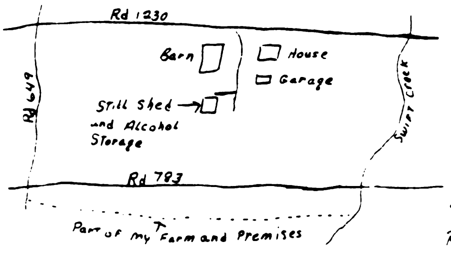
11. APPLICANT FOR PERMIT OF MEDIUM AND LARGE ALCOHOL FUEL PLANT. Complete all items on the form. Supply in duplicate the additional information and forms as stated below.
    a. The following information is requested for an individual proprietor, each partner, or each director of a corporation or similar entity and each officer of the corporation or similar entity who will have responsibilities and connection with the operations covered by the permit. In addition applicants for large plants shall show the same information for each interested person who is an individual as listed in the statement of interest in the organizational documents required by 27 CFR 19.941.
       (1) full name including middle name;
       (2) title in connection with applicants' business;
       (3) social security number;
       (4) date of birth;
       (5) place of birth; and
       (6) address of residence.
    b. A statement as to whether the applicant or any person required to be listed by the instructions above has been previously convicted of any violation of Federal or State law (other than minor traffic violations).
    c. A statement of the maximum quantity of distilled spirits to be produced and received from other plants during a calendar year.
    d. A Distilled Spirits Bond, ATF F 5110.56, as required by 27 CFR 19.956.
    e. Any other information required by the regional regulatory administrator after examination of this application.

SPECIAL INSTRUCTIONS FOR ALL APPLICANTS

12. OPERATIONS BEFORE ISSUANCE OF PERMIT. Unless otherwise specifically authorized by law or regulations, an applicant for an Alcohol Fuel Producer Permit may not engage in operations until the permit has been issued by the regional regulatory administrator.

13. STATE AND LOCAL LAWS. This permit does not allow you to operate in violation of State or local laws. Applicants should check with appropriate State and local authorities before engaging in alcohol fuel plant operations.

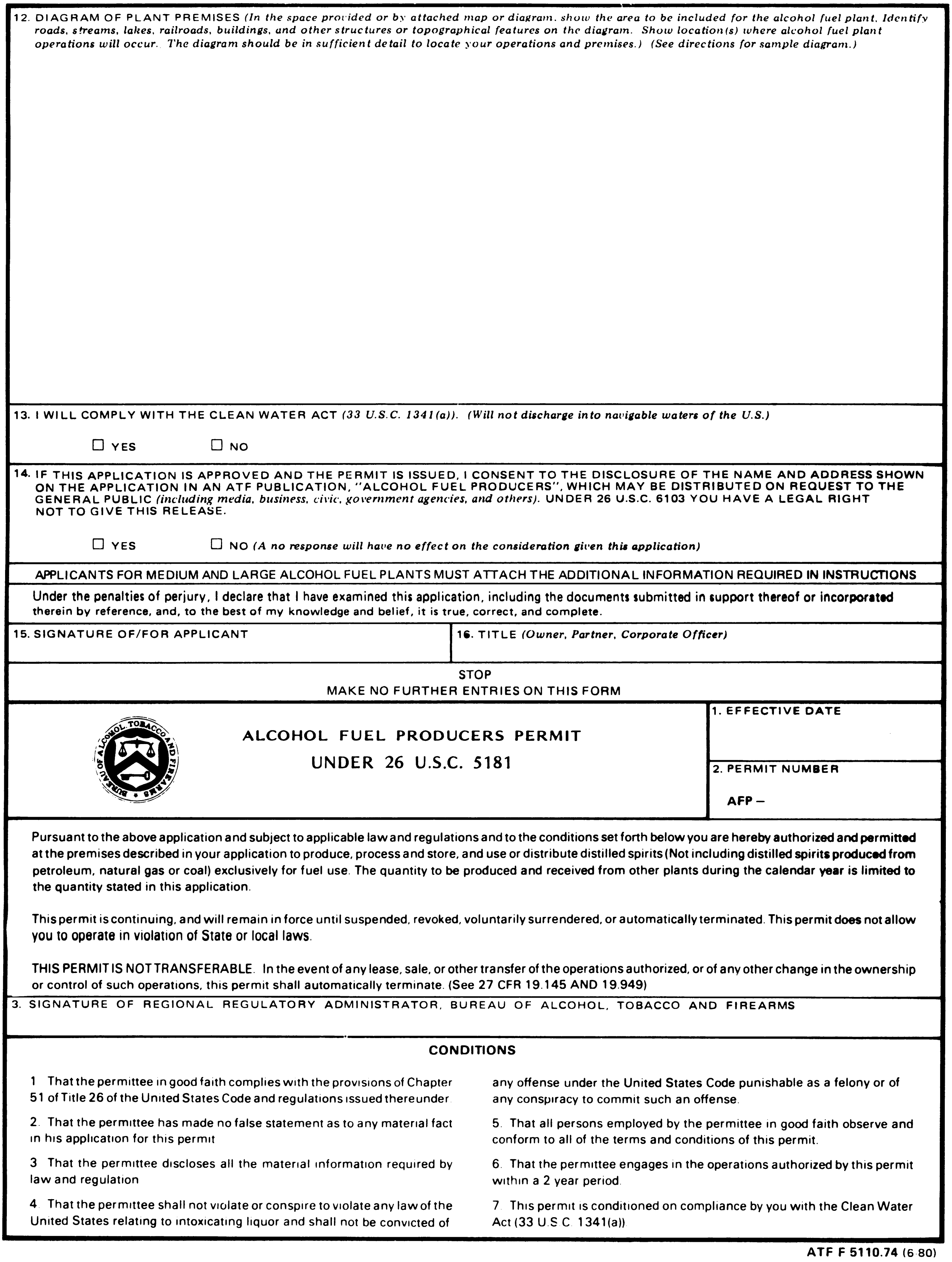
14. ATF FORMS AND REGULATIONS FOR ALCOHOL FUEL PLANTS. ATF forms and publications including regulations for alcohol fuel producers may be ordered from the ATF Distribution Center, 3800 S. Four Mile Run Drive, Arlington, VA 22206.



My farm is 1,200 acres,
1,000 acres are bounded
by Rd. 649 1230, 793 and
Swift Creek. 200 acres
are just the other side of
Rd 793.

ATF F 5110.74 (6 80)

Figure B-1.—BATF Form 5110.74



12. DIAGRAM OF PLANT PREMISES *(In the space provided or by attached map or diagram, show the area to be included for the alcohol fuel plant. Identify roads, streams, lakes, railroads, buildings, and other structures or topographical features on the diagram. Show location(s) where alcohol fuel plant operations will occur. The diagram should be in sufficient detail to locate your operations and premises.) (See directions for sample diagram.)*

13. I WILL COMPLY WITH THE CLEAN WATER ACT *(33 U.S.C. 1341(a)). (Will not discharge into navigable waters of the U.S.)*

☐ YES ☐ NO

14. IF THIS APPLICATION IS APPROVED AND THE PERMIT IS ISSUED, I CONSENT TO THE DISCLOSURE OF THE NAME AND ADDRESS SHOWN ON THE APPLICATION IN AN ATF PUBLICATION, "ALCOHOL FUEL PRODUCERS", WHICH MAY BE DISTRIBUTED ON REQUEST TO THE GENERAL PUBLIC *(including media, business, civic, government agencies, and others)*. UNDER 26 U.S.C. 6103 YOU HAVE A LEGAL RIGHT NOT TO GIVE THIS RELEASE.

☐ YES ☐ NO *(A no response will have no effect on the consideration given this application)*

APPLICANTS FOR MEDIUM AND LARGE ALCOHOL FUEL PLANTS MUST ATTACH THE ADDITIONAL INFORMATION REQUIRED IN INSTRUCTIONS

Under the penalties of perjury, I declare that I have examined this application, including the documents submitted in support thereof or incorporated therein by reference, and, to the best of my knowledge and belief, it is true, correct, and complete.

15. SIGNATURE OF/FOR APPLICANT	16. TITLE *(Owner, Partner, Corporate Officer)*

STOP
MAKE NO FURTHER ENTRIES ON THIS FORM

ALCOHOL FUEL PRODUCERS PERMIT
UNDER 26 U.S.C. 5181

1. EFFECTIVE DATE

2. PERMIT NUMBER

AFP –

Pursuant to the above application and subject to applicable law and regulations and to the conditions set forth below you are hereby authorized and permitted at the premises described in your application to produce, process and store, and use or distribute distilled spirits (Not including distilled spirits produced from petroleum, natural gas or coal) exclusively for fuel use. The quantity to be produced and received from other plants during the calendar year is limited to the quantity stated in this application.

This permit is continuing, and will remain in force until suspended, revoked, voluntarily surrendered, or automatically terminated. This permit does not allow you to operate in violation of State or local laws.

THIS PERMIT IS NOT TRANSFERABLE. In the event of any lease, sale, or other transfer of the operations authorized, or of any other change in the ownership or control of such operations, this permit shall automatically terminate. (See 27 CFR 19.145 AND 19.949)

3. SIGNATURE OF REGIONAL REGULATORY ADMINISTRATOR, BUREAU OF ALCOHOL, TOBACCO AND FIREARMS

CONDITIONS

1 That the permittee in good faith complies with the provisions of Chapter 51 of Title 26 of the United States Code and regulations issued thereunder.

2. That the permittee has made no false statement as to any material fact in his application for this permit

3 That the permittee discloses all the material information required by law and regulation

4 That the permittee shall not violate or conspire to violate any law of the United States relating to intoxicating liquor and shall not be convicted of any offense under the United States Code punishable as a felony or of any conspiracy to commit such an offense.

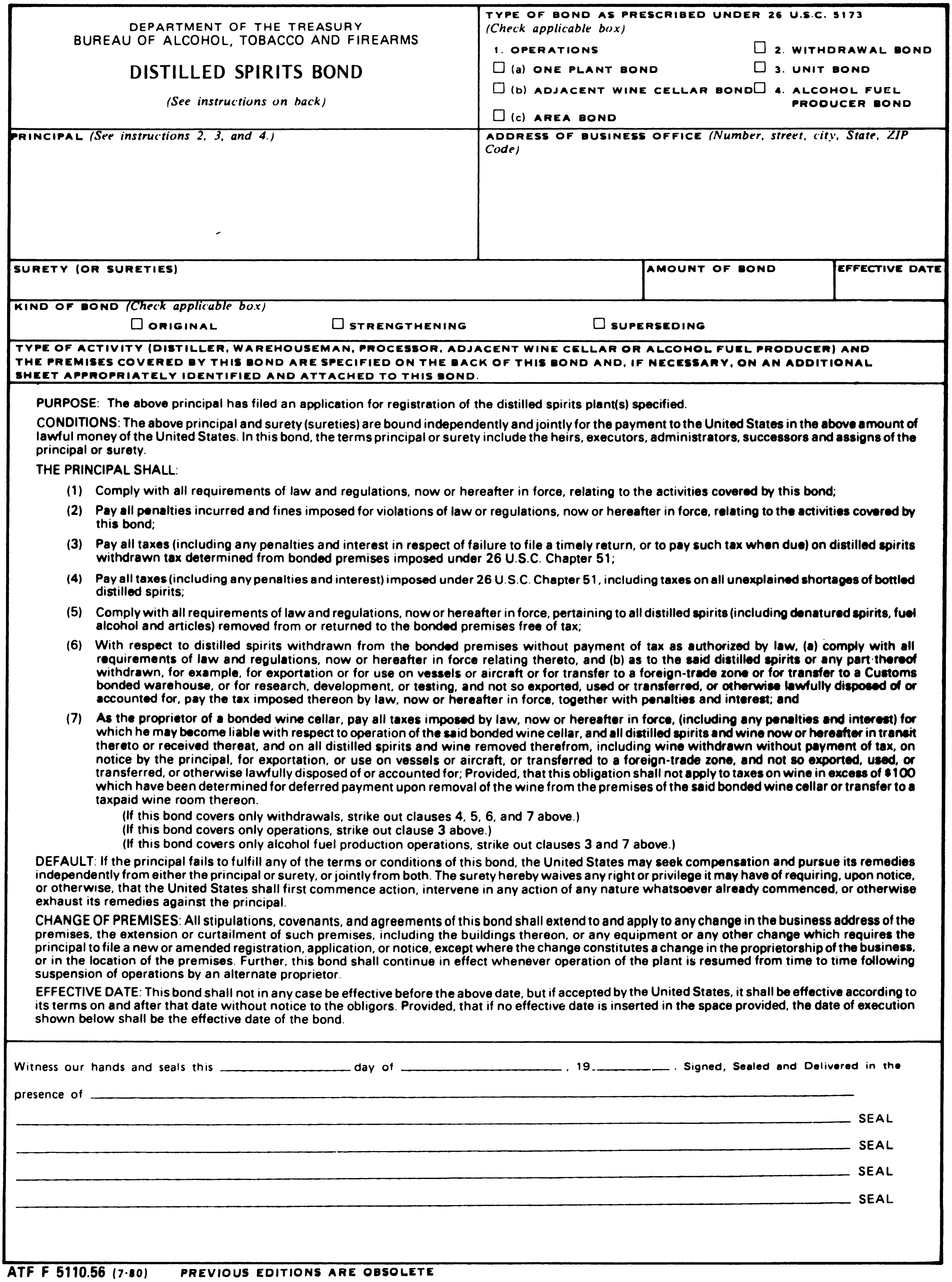
5. That all persons employed by the permittee in good faith observe and conform to all of the terms and conditions of this permit.

6. That the permittee engages in the operations authorized by this permit within a 2 year period.

7. This permit is conditioned on compliance by you with the Clean Water Act (33 U.S.C. 1341(a))

ATF F 5110.74 (6-80)

Figure B-1.—BATF Form 5110.74 (continued)



DEPARTMENT OF THE TREASURY
BUREAU OF ALCOHOL, TOBACCO AND FIREARMS

DISTILLED SPIRITS BOND

(See instructions on back)

TYPE OF BOND AS PRESCRIBED UNDER 26 U.S.C. 5173 *(Check applicable box)*

1. OPERATIONS
   ☐ (a) ONE PLANT BOND
   ☐ (b) ADJACENT WINE CELLAR BOND
   ☐ (c) AREA BOND

☐ 2. WITHDRAWAL BOND
☐ 3. UNIT BOND
☐ 4. ALCOHOL FUEL PRODUCER BOND

PRINCIPAL *(See instructions 2, 3, and 4.)*

ADDRESS OF BUSINESS OFFICE *(Number, street, city, State, ZIP Code)*

SURETY (OR SURETIES)	**AMOUNT OF BOND**	**EFFECTIVE DATE**

KIND OF BOND *(Check applicable box)*

☐ ORIGINAL ☐ STRENGTHENING ☐ SUPERSEDING

TYPE OF ACTIVITY (DISTILLER, WAREHOUSEMAN, PROCESSOR, ADJACENT WINE CELLAR OR ALCOHOL FUEL PRODUCER) AND THE PREMISES COVERED BY THIS BOND ARE SPECIFIED ON THE BACK OF THIS BOND AND, IF NECESSARY, ON AN ADDITIONAL SHEET APPROPRIATELY IDENTIFIED AND ATTACHED TO THIS BOND.

PURPOSE: The above principal has filed an application for registration of the distilled spirits plant(s) specified.

CONDITIONS: The above principal and surety (sureties) are bound independently and jointly for the payment to the United States in the above amount of lawful money of the United States. In this bond, the terms principal or surety include the heirs, executors, administrators, successors and assigns of the principal or surety.

THE PRINCIPAL SHALL:

(1) Comply with all requirements of law and regulations, now or hereafter in force, relating to the activities covered by this bond;

(2) Pay all penalties incurred and fines imposed for violations of law or regulations, now or hereafter in force, relating to the activities covered by this bond;

(3) Pay all taxes (including any penalties and interest in respect of failure to file a timely return, or to pay such tax when due) on distilled spirits withdrawn tax determined from bonded premises imposed under 26 U.S.C. Chapter 51;

(4) Pay all taxes (including any penalties and interest) imposed under 26 U.S.C. Chapter 51, including taxes on all unexplained shortages of bottled distilled spirits;

(5) Comply with all requirements of law and regulations, now or hereafter in force, pertaining to all distilled spirits (including denatured spirits, fuel alcohol and articles) removed from or returned to the bonded premises free of tax;

(6) With respect to distilled spirits withdrawn from the bonded premises without payment of tax as authorized by law, (a) comply with all requirements of law and regulations, now or hereafter in force relating thereto, and (b) as to the said distilled spirits or any part thereof withdrawn, for example, for exportation or for use on vessels or aircraft or for transfer to a foreign-trade zone or for transfer to a Customs bonded warehouse, or for research, development, or testing, and not so exported, used or transferred, or otherwise lawfully disposed of or accounted for, pay the tax imposed thereon by law, now or hereafter in force, together with penalties and interest; and

(7) As the proprietor of a bonded wine cellar, pay all taxes imposed by law, now or hereafter in force, (including any penalties and interest) for which he may become liable with respect to operation of the said bonded wine cellar, and all distilled spirits and wine now or hereafter in transit thereto or received thereat, and on all distilled spirits and wine removed therefrom, including wine withdrawn without payment of tax, on notice by the principal, for exportation, or use on vessels or aircraft, or transferred to a foreign-trade zone, and not so exported, used, or transferred, or otherwise lawfully disposed of or accounted for; Provided, that this obligation shall not apply to taxes on wine in excess of $100 which have been determined for deferred payment upon removal of the wine from the premises of the said bonded wine cellar or transfer to a taxpaid wine room thereon.

(If this bond covers only withdrawals, strike out clauses 4, 5, 6, and 7 above.)
(If this bond covers only operations, strike out clause 3 above.)
(If this bond covers only alcohol fuel production operations, strike out clauses 3 and 7 above.)

DEFAULT: If the principal fails to fulfill any of the terms or conditions of this bond, the United States may seek compensation and pursue its remedies independently from either the principal or surety, or jointly from both. The surety hereby waives any right or privilege it may have of requiring, upon notice, or otherwise, that the United States shall first commence action, intervene in any action of any nature whatsoever already commenced, or otherwise exhaust its remedies against the principal.

CHANGE OF PREMISES: All stipulations, covenants, and agreements of this bond shall extend to and apply to any change in the business address of the premises, the extension or curtailment of such premises, including the buildings thereon, or any equipment or any other change which requires the principal to file a new or amended registration, application, or notice, except where the change constitutes a change in the proprietorship of the business, or in the location of the premises. Further, this bond shall continue in effect whenever operation of the plant is resumed from time to time following suspension of operations by an alternate proprietor.

EFFECTIVE DATE: This bond shall not in any case be effective before the above date, but if accepted by the United States, it shall be effective according to its terms on and after that date without notice to the obligors. Provided, that if no effective date is inserted in the space provided, the date of execution shown below shall be the effective date of the bond.

Witness our hands and seals this ______________ day of ____________________, 19________. Signed, Sealed and Delivered in the presence of ____

____ SEAL
____ SEAL
____ SEAL
____ SEAL

ATF F 5110.56 (7-80) **PREVIOUS EDITIONS ARE OBSOLETE**

Figure B-2.—BATF Form 5110.56

NAME AND ADDRESS	REGISTRY NUMBER	OPERATIONS COVERAGE *(State activities at each premises and in the last block the amount of coverage for such activities.)*	WITHDRAWAL COVERAGE *(State amount allocated to each premises (distilled spirits plants only) and total amount.)*
			$
			$
			$
			$
			$
			$
			$
	AMOUNT OF COVERAGE	$	TOTAL $

APPROVED

SIGNATURE OF REGIONAL REGULATORY ADMINISTRATOR	REGION	DATE

INSTRUCTIONS

1. This bond shall be filed in duplicate with the Regional Regulatory Administrator, Bureau of Alcohol, Tobacco and Firearms, of the region where the premises covered by the bond are located.

2. The name, including the full given name, of each party to the bond shall be given in the heading, and each party shall sign the bond, or the bond may be executed in his name by an empowered attorney-in-fact.

3. In the case of a partnership, the firm name, followed by the names of all its members, shall be given in the heading. In executing the bond, the firm name shall be typed or written followed by the word "by" and the signatures of all partners, or the signature of any partner authorized to sign the bond for the firm, or the signature of an empowered attorney-in-fact.

4. If the principal is a corporation, the heading shall give the corporate name, the name of the State under the laws of which it is organized, and the location of the principal office. The bond shall be executed in the corporate name, immediately followed by the signature and title of the person authorized to act for the corporation.

5. If the bond is signed by an attorney-in-fact for the principal, or by one of the members for a partnership or association, or by an officer or other person for a corporation, there shall be filed with the bond an authenticated copy of the power of attorney, or a resolution of the board of direcors, or an excerpt of the bylaws, or other document, authorizing the person signing the bond to execute it for the principal, unless such authorization has been filed with the Regional Regulatory Administrator, Bureau of Alcohol, Tobacco and Firearms, in which event a statement to that effect shall be attached to the bond.

6. The signature for the surety shall be attested under corporate seal. The signature for the principal, if a corporation, shall also be attested if the corporation has a corporate seal; if the corporation has no seal, that fact should be stated. Each signature shall be made in the presence of two persons (except where corporate seals are affixed), who shall sign their names as witnesses.

7. A bond may be given with corporate surety authorized to act as surety by the Secretary of the Treasury, or by the deposit of collateral security consisting of bonds or notes of the United States. The Act of July 30, 1947 (Section 15, Title 6 U.S.C.) provides that "the phrase 'bonds or notes of the United States' shall be deemed *** to mean any public debt obligations of the United States and any bonds, notes or other obligations which are unconditionally guaranteed as to both interest and principal by the United States."

8. If any alteration or erasure is made in the bond before its execution, there shall be incorporated in the bond a statement to that effect by the principal and surety or sureties; or if any alteration or erasure is made in the bond after its execution, the consent of all parties thereto shall be written in the bond.

9. The penal sum named in the bond shall be in accordance with 27 CFR Part 19.

10. If the bond is approved, a copy shall be returned to the principal.

11. All correspondence about the filing of this bond or any subsequent action affecting this bond should be addressed to the Regional Regulatory Administrator, Bureau of Alcohol, Tobacco and Firearms with whom the bond is filed.

GPO 870 571

ATF F 5110.56 (7-80)

Figure B-2.—BATF Form 5110.56 (continued)

DEPARTMENT OF THE TREASURY BUREAU OF ALCOHOL, TOBACCO AND FIREARMS **ALCOHOL FUEL PLANT REPORT**	1. PERMIT NUMBER

GENERAL INSTRUCTIONS

1. Each proprietor of an alcohol fuel plant shall file this report of plant operations. The period covered by the report depends on the size of the alcohol fuel plant. A report is due even if no operations were conducted during the period.
2. Prepare in duplicate. Send the original to the Regional Regulatory Administrator, Bureau of Alcohol, Tobacco and Firearms. Keep the copy with your alcohol fuel plant records.
3. The report is due by the 30th day following the end of the reporting period.
4. Report spirits in proof gallons and alcohol fuel in wine gallons. Round to the nearest whole number.
5. Small and medium plants complete Parts I and II. Large plants complete Parts I and III.

WHEN TO FILE REPORTS

SMALL PLANT
1. Proprietors of small plants will prepare and file a report once a year to cover all operations for the calendar year.
2. Report is due by January 30th following the end of the calendar year.

MEDIUM PLANT
1. Proprietors of medium plants will prepare and file a report twice a year. Each report will cover all operations for period reported (January 1 thru June 30 or July 1 thru December 31) and will be due 30 days after the end of the reporting period.

LARGE PLANT
1. Proprietors of large plants will prepare and file a report 4 times a year. Reports will cover calendar quarters (example Jan - March) and reflect all transactions in that period.
2. Reports are due 30 days after the end of the reporting period.

PART - I

1.SMALL PLANTS *(Annual Report)*	2. MEDIUM PLANTS *(Semi-Annual Report)*	3. LARGE PLANTS *(Quarterly Report)*
19_____ *(Year)*	_____ *(Month)* *Through* _____ *(Month)* 19_____ *(Year)*	_____ *(Month)* *Through* _____ *(Month)* 19_____ *(Year)*

4. NAME OF PROPRIETOR *(If partnership, include name of each partner)*	5. LOCATION *(If no street show rural route)*

PART - II
FOR SMALL AND MEDIUM PLANTS ONLY

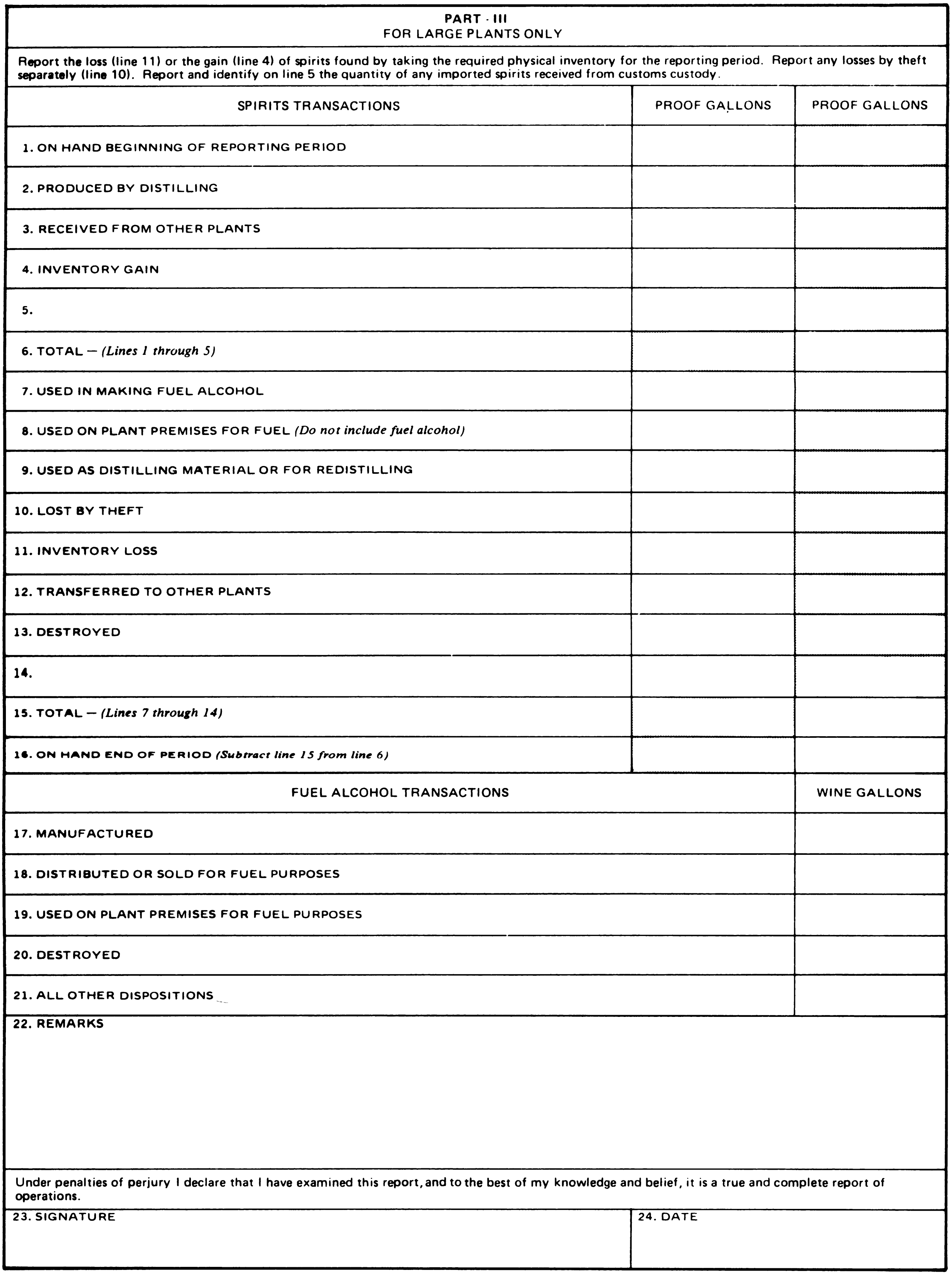
SPIRITS TRANSACTIONS	PROOF GALLONS	PROOF GALLONS
1. PRODUCED		
2. RECEIVED		
3. USED ON PREMISES FOR FUEL *(Do not include fuel alcohol)*		
4. USED IN MAKING FUEL ALCOHOL		
5. DESTROYED		
6. TRANSFERRED		
FUEL ALCOHOL TRANSACTIONS	WINE GALLONS	WINE GALLONS
7. PRODUCED *(Rendered Unfit)*		
8. USED ON PREMISES FOR FUEL		
9. TRANSFERRED		

Under penalties of perjury I declare that I have examined this report, and to the best of my knowledge and belief, it is a true and complete report of operations.

10. SIGNATURE	11. DATE

ATF F 5110.75 (7-80)

Figure B-3.—BATF Form 5110.75



PART - III
FOR LARGE PLANTS ONLY

Report the loss (line 11) or the gain (line 4) of spirits found by taking the required physical inventory for the reporting period. Report any losses by theft separately (line 10). Report and identify on line 5 the quantity of any imported spirits received from customs custody.

SPIRITS TRANSACTIONS	PROOF GALLONS	PROOF GALLONS
1. ON HAND BEGINNING OF REPORTING PERIOD		
2. PRODUCED BY DISTILLING		
3. RECEIVED FROM OTHER PLANTS		
4. INVENTORY GAIN		
5.		
6. TOTAL — *(Lines 1 through 5)*		
7. USED IN MAKING FUEL ALCOHOL		
8. USED ON PLANT PREMISES FOR FUEL *(Do not include fuel alcohol)*		
9. USED AS DISTILLING MATERIAL OR FOR REDISTILLING		
10. LOST BY THEFT		
11. INVENTORY LOSS		
12. TRANSFERRED TO OTHER PLANTS		
13. DESTROYED		
14.		
15. TOTAL — *(Lines 7 through 14)*		
16. ON HAND END OF PERIOD *(Subtract line 15 from line 6)*		

FUEL ALCOHOL TRANSACTIONS	WINE GALLONS
17. MANUFACTURED	
18. DISTRIBUTED OR SOLD FOR FUEL PURPOSES	
19. USED ON PLANT PREMISES FOR FUEL PURPOSES	
20. DESTROYED	
21. ALL OTHER DISPOSITIONS	

22. REMARKS

Under penalties of perjury I declare that I have examined this report, and to the best of my knowledge and belief, it is a true and complete report of operations.

23. SIGNATURE	24. DATE

ATF F 5110.75 (7-80)

Figure B-3.—BATF Form 5110.75 (continued)

Appendix E

Selected Additional Readings

This appendix contains selected bibliographic sources for additional information about alcohol fuels. Two comprehensive bibliographies complete with abstracts have been published by the Solar Energy Research Institute: *Alcohol Fuels Bibliography (1901-March 1980)*, SERI/SP-751-902, and *A Selected Bibliography on Alcohol Fuels (1901 Through November 1981)*, SERI/SP-290-1414. Both are available from the Document Distribution Service, SERI, 1617 Cole Boulevard, Golden, CO 80401. *Alcohol Fuels Bibliography* is also available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. Contact these agencies for current price information.

Agriculture

1. Berry, Wendell. 1978. *The Unsettling of America: Culture and Agriculture.* New York: Avon Books; pp. 1–12.

   This book provides a framework for understanding the importance of the small-scale, family-owned, integrated farm in America today and critiques modern agricultural policy.

2. Klepper, Robert et al. 1977 (Feb.). "Economic Performance and Energy Intensiveness on Organic and Conventional Farms in the Corn Belt: A Preliminary Comparison." *American Journal of Agricultural Economics.* Vol. 59: pp. 1–12.

   This article reports on a study which compared 14 matched pairs of organic and conventional corn-belt farms in the areas of crop output, net returns, energy intensiveness, and labor requirements. Initial findings indicate that large-scale, mechanized organic farming methods warrant further investigation.

3. Lappe, Frances Moore; Collins, Joseph. 1979. *Food First: Beyond the Myth of Scarcity.* New York: Ballantine Books.

   The focus of this book is a comprehensive and thoroughly referenced account of food production and distribution in the world today. The basic conclusion is that availability of food is more closely related to politics than lack of arable land and other necessary resources.

4. Lockeretz. W. et al. 1980 (Jan.-Feb.). "Maize Yields and Soil Nutrient Levels With and Without Pesticides and Standard Commercial Fertilizers." *Agronomy Journal.* Vol. 72: pp. 65–72.

   This article reports on a study comparing two groups of 26 commercial mixed grain-and-livestock farms in the western corn belt. One group used conventional fertilizers and pesticides, the other used none. Because of rising costs and uncertain supplies for agricultural chemicals it is important to establish data on production output that establishes alternatives. This study found that the difference was not statistically significant (P 90%) and that conventional yields were higher under favorable growing conditions and lower in unfavorable conditions.

5. Poos, Mary; Klopfenstein, Terry. 1979. "Nutritional Value of By-Products of Alcohol Production for Livestock Feed." *Agricultural Notebook-Livestock Letter.* Lincoln, NE: University of Nebraska, Cooperative Extension Service. Animal Science Publication 79–4. Available from: Extension Publication Service, Agricultural

Engineering Annex, University of Nebraska, Lincoln, NE 68583.

6. U.S. Department of Agriculture. 1979. *Agricultural Statistics 1979.* Washington D.C.: USDA. Stock No. SN–001–000–05775–7. Available from: GPO.

   This book presents official U.S. agricultural statistics for 1979, primarily in the form of tables and charts.

7. U.S. Department of Agriculture. 1980. *Small-Scale Fuel Alcohol Production.* Washington, D.C.: USDA. Stock No. 001–000–04124–0. Available from: GPO.

   This book plays a role in implementation of national alcohol-fuels policy by providing information on small-scale, on-farm production. The emphasis is on utilization of alcohol fuel in vehicles and use of the stillage by-product. Additional information is given on feedstocks, production processes, and costs.

Costs and Economic Issues

1. David, M.L. et al. 1978 (July). *Gasohol: Economic Feasibility Study.* Washington, DC.: USDOE. Report No. SAN 1681–T1. Available from: NTIS.
2. Janeway, Eliot. 1979 (Nov.). "Gasohol: Solution to the Gas Shortage." *The Atlantic.* Vol. 244 (No. 5): p. 62.
3. Jawetz, Pincas. 1979. "Alcohol Additives to Gasoline—An Economic Way for Extending Supplies of Fuel and for Increasing Octane Ratings." *American Chemical Society, Division of Petroleum Chemists. Preprints.* Vol. 24 (No. 3): pp. 798–800.
4. Solar Energy Research Institute. 1980. *Fuel From Farms: A Guide to Small-Scale Ethanol Production.* Golden, CO: SERI. Stock No. 061–000–00372–0. Available from: GPO.

   The first such book in support of the national alcohol fuels policy, this guide provides invaluable information on examining the potential of small-scale ethanol production. Useful decision and planning worksheets and a business plan case study are included.

5. U.S. Department of Agriculture. 1980. *Small-Scale Fuel Alcohol Production.* Washington, D.C.: USDA. Stock No. 001–000–04124–0. Available from: GPO.

   This book plays a role in implementation of national alcohol-fuels policy by providing information on small-scale, on-farm production. The emphasis is on utilization of alcohol fuel in vehicles and use of the stillage by-product. Additional information is given on feedstocks, production processes and costs.

6. U.S. National Alcohol Fuels Commission. 1980 (Apr.). *Alcohol Fuels Tax Incentives—A Summary: Alcohol Fuels Provisions of the Crude Oil Windfall Profit Tax Act.* Washington, D.C.: USNAFC. Available from: U.S. National Alcohol Fuels Commission, 412 First Street SE, Washington, D.C. 20003.

   This booklet reviews those provisions in the Crude Oil Windfall Profit Tax Act relevant to alcohol fuels including: four-cent-per-gallon excise tax exemption, income tax credits, energy investment tax credit for biomass, alcohol-fuel plant-operating permits, tax-exempt bonds for alcohol fuel from solid waste, state financing of renewable energy property, imported alcohol study, and the annual reports on alcohol fuels.

Energy Analysis

1. Alich, J.A. et al. 1978 (Jan.). "An Evaluation of the Use of Agricultural Residues as an Energy Feedstock: A Ten Site Survey." Palo Alto, CA: Stanford Research Institute—International. Report No. TID–27904/2. Available from: NTIS.
2. Commoner, Barry. 1979 (July). Testimony before U.S. Senate Committee on Agriculture, Nutrition and Forestry, Subcommittee on Agricultural Research and General Legislation on "The Potential for Energy Production by U.S. Agriculture." St. Louis, MO: Center for the Biology of Natural Systems, Washington University. Report No. CBNS–AEP–5. Available from: Center for the Biology of Natural Systems, Washington University, St. Louis, MO 63130.
3. Jawetz, Pincas. 1979. "Alcohol Additives to Gasoline—An Economic Way for Extending Supplies of Fuel and for Increasing Octane Ratings." *American Chemical Society, Division of Petroleum Chemists. Preprints.* Vol. 24 (No. 3): pp. 798–800.
4. Ladisch, Michael; Dyck, Karen. 1979 (3 Aug.). "Dehydration of Ethanol: New Approach Gives Positive Energy Balance." *Science.* Vol. 205 (No. 31): pp. 898–900.
5. Pimentel, D. et al. 1979 (2 Nov.). "Food Production and the Energy Crisis." *Science.* Vol. 182 (No. 4111): pp. 443–449.
6. Wittmuss, H. et al. 1975 (Mar.-Apr.). "Energy Requirements for Conventional Versus Minimum Tillage." *Journal of Soil and Water Conservation.* Vol. 30 (No. 2): pp. 72–75.

Available from GPO: Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402
Available from NTIS: National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161
Contact these agencies for current price and ordering information.

Feedstocks and Their Coproducts

1. Chubey, B.B.; Dorrell, D.G. 1974. "Jerusalem Artichoke, A Potential Fructose Crop for the Prairies." *Journal of the Canadian Institute of Food Science Technology*. Vol. 7 (No. 2): pp. 98–100.
2. Distillers Feed Research Council. n.d. *Distillers Feeds*. Cincinnati, OH: DFRC. Available from: Distillers Feed Research Council, 1435 Enquirer Bldg., Cincinnati, OH 45202.

   This booklet by the Distillers Feed Research Council provides a well-documented and referenced summary of the use of stillage as animal feed.
3. Distillers Feed Research Council. n.d. *Feed Formulation*. Cincinnati, OH: DFRC. Available from: Distillers Feed Research Council, 1435 Enquirer Bldg., Cincinnati, OH 45202.

   The purpose of this pamphlet is to provide information on distillers dried grains, distillers dried grains with solubles, distillers dried solubles, and condensed distillers solubles in order to produce better formula feeds for animals.
4. Paturau, J.M. 1969. *By-Products of the Cane Sugar Industry*. Amsterdam: Elsevier Publishing Company.

   As well as a complete discussion on production, this book provides a comprehensive examination of those coproducts of ethanol fermentation when molasses is used as the feedstock.
5. Solar Energy Research Institute. 1980. *Fuel From Farms: A Guide to Small-Scale Ethanol Production*. Golden, CO: SERI. Stock No. 061–000–00372–0. Available from: GPO.

   The first such book in support of the national alcohol fuels policy, this guide provides invaluable information on examining the potential of small-scale ethanol production. Useful decision and planning worksheets and a business plan case study are included.
6. U.S. Department of Agriculture. 1979. *Agricultural Statistics 1979*. Washington, D.C.: USDA. Stock No. SN–001–000–05775–7. Available from: GPO.

   This book presents official U.S. agricultural statistics for 197–9, primarily in the form of tables and charts.
7. U.S. Department of Agriculture. 1980. *Small-Scale Fuel Alcohol Production*. Washington, D.C.: USDA. Stock No. 001–000–04124–0. Available from: GPO.

   This book plays a role in implementation of national alcohol-fuels policy by providing information on small-scale, on-farm production. The emphasis is on utilization of alcohol fuel in vehicles and use of the stillage by-product. Additional information is given on feedstocks, production processes, and costs.
8. Winston, Steven. 1979. "Stillage Treatment Technologies." Idaho Falls, ID: Energy Incorporated. Available from: Energy Incorporated, Box 736, Idaho Falls, ID 83401.

   This paper describes the location of ethanol distilleries, the composition of stillage produced, a summary of annual tonnage produced, and a discussion on the use of stillage as an animal feed.
9. Winston, Steven. 1979. "Current State-of-the-Art Stillage Use and Disposal." Idaho Falls, ID: Energy Incorporated. Available from: Energy Incorporated, Box 736, Idaho Falls, ID 83401.

   This paper provides a comprehensive overview of stillage treatment for use as animal feed, human food, and for environmentally safe disposal by means of submerged combustion, evaporation, incineration, anaerobic digestion, aerobic digestion, fungal digestion, and sludge-plow injection as a soil amendment.

Fermentation-Ethanol Production

1. Casida, F. 1968. *Industrial Microbiology*. New York: John Wiley and Sons.
2. Paul, J.K. et al. 1979. *Ethyl Alcohol Production and Use as a Motor Fuel*. Chemical Technology Review (No. 44). Park Ridge, NJ: Noyes Data Corporation. Available from: Noyes Data Corp., Mill Rd. at Grant Ave., Park Ridge, NJ 07656.
3. Paturau, J.M. 1969. *By-Products of the Cane Sugar Industry*. Amsterdam: Elsevier Publishing Company.

   As well as a complete discussion on production, this book provides a comprehensive examination of those coproducts of ethanol fermentation when molasses is used as the feedstock.
4. Righelato, R.G.; Elsworth, R. 1970. *Industrial Applications of Continuous Culture: Pharmaceutical Products and Other Products and*

Available from GPO: Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402
Available from NTIS: National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161
Contact these agencies for current price and ordering information.

Processes. Advances in Applied Microbiology. Vol. 13. New York: Academic Press.

5. Roman, W. ed. 1952. *Yeasts*. The Hague: Dr. W. Junk, Publisher.
6. Solar Energy Research Institute. 1980. *Fuel From Farms: A Guide to Small-Scale Ethanol Production*. Golden, CO: SERI. Stock No. 061–000–00372–0. Available from: GPO.

   The first such book in support of the national alcohol-fuels policy, this guide provides invaluable information on examining the potential of small-scale ethanol production. Useful decision and planning worksheets and a business plan case study are included.
7. Tassios, D. P. 1972. "Rapid Screening of Extractive Distillation Solvents." *Extractive and Azeotropic Distillation*. Advances in Chemistry Series. No. 115. Washington, D.C.: American Chemical Society; pp. 46–63.
8. Underkofler, L.D.; Hickey, R.J., eds. 1954. *Industrial Fermentations*. Vol. 1. New York: Chemical Publishing Company.

   This book serves as a basic chemical text on fermentation processes.
9. U.S. Department of Agriculture. 1950. *Industrial Alcohol*. Washington, D.C.: USDA. Publication No. 695.
10. U.S. Department of Agriculture. 1980. *Small-Scale Fuel Alcohol Production*. Washington, D.C.: USDA. Stock No. 001–000–04124–0. Available from: GPO.

    This book plays a role in implementation of national alcohol-fuels policy by providing information on small-scale, on-farm production. The emphasis is on utilization of alcohol fuel in vehicles and use of the stillage by-product. Additional information is given on feedstocks, production processes, and costs.

General

1. Bernton, Hal. 1978 (23 Sept.). "Paving the Way for Alcohol Fuels." *Environmental Action*. Vol. 10 (No. 10): pp. 4–7.

   This article describes the revival of interest in alcohol fuels in the U.S. and states that the U.S. lags behind Sweden, Brazil, and West Germany in many areas of alcohol-fuel research and development. The author believes a strong push from environmentalists could provide the impetus needed for alcohol fuels to become a major contributor to energy alternatives and waste recycling.
2. Office of Technology Assessment. 1979. *Gasohol—A Technical Memorandum*. Washington, D.C.: Office of Technology Assessment, U.S. Congress. Stock No. 052–003–00706. Available from: GPO.

   This document discusses ethanol production and gasohol use as well as economics, environmental effects, social impacts, and federal programs and policies.
3. Pleeth, S.J.W. 1949. *Alcohol, A Fuel in Internal Combustion Engines*. London: Chapman and Hall.

   Written in 1949, this book represents a classic text on alcohol fuels. Today it still contains valuable information on production and use of alcohol fuels.
4. Solar Energy Research Institute. 1979 (Oct.). *Proceedings of the Third Annual Biomass Energy Systems Conference*. 5–7 June 1979, Golden, CO: SERI. Report No. SERI/TP–33–285. Available from: NTIS.

   This document contains over 70 individual papers on a wide range of subjects concerned with biomass energy systems.
5. U.S. Department of Energy. 1978. *Fuels From Biomass Program*. Washington, D.C.: USDOE. Stock No. 061–000–00063–1. Available from: GPO.

   This document is an overview of the ongoing research, development, and demonstration projects for FY 1977 for the Fuels From Biomass Program of the U.S. Department of Energy.
6. U.S. Department of Energy. 1979 (Sept.). *The Report of the Alcohol Fuels Policy Review*. Washington, D.C.: USDOE. Report No. DOE/PE–0012. Available from: NTIS.

   This series of documents presents studies on the availability of a variety of feedstocks for alcohol-fuels production. Feedstocks examined include agricultural and municipal wastes and residues, grain, sugar crops, and wood, as well as the availability of cropland for fuel production.
7. U.S. House of Representatives. Ninety-fifth Congress, Second Session. *Alcohol Fuels: Hearings Before the Subcommittee on Advanced Energy Technologies and Energy Conservation, Research, Development and Demonstration of*

the *Committee on Science and Technology.* Washington, D.C.: U.S. House of Representatives; 11–12 July 1978. Publication No. 101. Available from: House Committee on Science and Technology, Room 3154, House Annex #2, Washington, D.C. 20515.

Testimony at these hearings presents a variety of views on the potential of alcohol fuels by representatives of private industry and government. Detailed reports with bibliographies are included, as well as submitted testimony statements.

8. U.S. House of Representatives. Ninety-sixth Congress. *National Fuel Alcohol and Farm Commodity Production Act of 1979: Hearings Before the Subcommittees on Conservation and Credit Department Investigations, Oversight and Research, and Livestock and Grains, Committee on Agriculture.* Washington, D.C.: U.S. House of Representatives; 15–16 May 1979. Stock No. 052–070–05071–3. Available from: GPO.
9. U.S. Senate. Ninety-fifth Congress. *The Gasohol Motor Fuel Act of 1978: Hearings Before the Subcommittee on Energy Research and Development of the Committee on Energy and Natural Resources.* Washington, D.C.: U.S. Senate; 7–8 August 1978. Publication No. 95–165.
10. *Proceedings of the International Symposium on Alcohol Fuel Technology—Methanol and Ethanol.* 1978. Wolfsburg, Federal Republic of Germany; 21–23 Nov. 1977. Washington, D.C.: U.S. Department of Energy. Report No. CONF–77–117–5. Available from: NTIS.

    Over 40 papers are included concerning alcohol-fuel technology. Included are economic and political implications, use as a vehicle fuel, production from different feedstocks, environmental issues, and optimization of alcohol-fuel use.

International

1. Bernton, Hal. 1979 (16 Apr.). "Brazilian Ethanol Experience: New Automobile Fuel Comes of Age." *Solar Energy Intelligence Report.* Vol. 5 (No. 2): p. 417

    This particular issue contains an article on Brazil's alcohol-fuels program.
2. Brazil Ministry of Industry and Commerce. n.d. *Alcohol.* Rio de Janeiro, Brazil: Ministry of Industry and Commerce. Available from: Fundacao de Tecnologia Industrial, Av. Venezuela, 82 70 andar, 20081 Rio de Janeiro, RJ, Brazil.

    In the style of a public relations brochure, this booklet gives a good overview of Brazil's alcohol program.
3. "Elsewhere in the News: Australia." 1979 (Oct. 15). *Solar Energy Intelligence Report.* Vol. 5 (No. 2): p. 417.

    This issue contains an article on Australia's plans for developing alcohol fuels.
4. Madi, A.G. 1979. "Fermentation Alcohol Industry in Egypt in the Last Three Decades." *Workshop on Fermentation Alcohol for Use as a Fuel and Chemical Feedstock in Developing Countries.* Vienna, Austria: United Nations Industrial Development Organization; 26–30 Mar. 1979. Paper No. ID/WG. 293/16. Available from: UN Publications, Room A3315, New York, NY 10017.

    This paper thoroughly describes Egypt's production and use of fermentation alcohol.
5. Sharma, K.D. 1979. "Present Status of Alcohol and Alcohol Based Chemicals Industry in India." *Workshop on Fermentation Alcohol for Use as a Fuel and Chemical Feedstock in Developing Countries.* Vienna, Austria: United National Industrial Development Organization; 26–30 Mar. 1979. Paper No. ID/WG. 293/14. Available from: UN Publications, Room A3315, New York, NY 10017.

    This paper describes the production, use, and problems of India's alcohol-fuels industry.

Methanol

1. Paul, J.K. 1978. *Methanol Technology and Application in Motor Fuels.* Chemical Technology Review No. 114. Park Ridge, NJ: Noyes Data Corporation. Available from: Noyes Data Corp., Mill Rd. at Grand Ave., Park Ridge, NJ 07656.

    This book includes thoroughly referenced information on methanol production technology, methanol use as a vehicle fuel, economics of methanol production and distribution, and a review of the gasoline-from-methanol patent technology.
2. Reed, T.B. et al. 1974. "Improved Performance of Internal Combustion Engines Using 5–30% Methanol in Gasoline." *Ninth Intersociety Energy Conversion Conference,* Paper No. 749104; San Francisco, CA: 26–30 Aug. 1974.

Available from GPO: Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402
Available from NTIS: National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161
Contact these agencies for current price and ordering information.

American Society of Mechanical Engineers; pp. 952–955.

This paper reports on experiments conducted using M5 to M30 gasoline blends in internal combustion engines.

3. Reed, T.B.; Lerner, R.M. 1973 (28 Dec.). "Methanol: A Versatile Fuel for Immediate Use." Science. Vol. 182 (No. 4119): pp. 1299–1304.

   This was the first technical article on methanol after the 1973 OPEC oil cartel embargo which served to spark interest in the potential of methanol.

4. Reed, T. B. 1976 (Apr.). "Efficiencies of Methanol Production from Gas, Coal Waste or Wood." *Symposium on Net Energetics of Integrated Synfuel Systems.* American Chemical Society, Division of Fuel Chemistry. Preprints. Vol. 21 (No. 2): pp. 37–55.

   Dr. Reed's paper discusses and compares the net production energy efficiencies for methanol produced from gas, coal, waste, and wood.

5. U.S. Department of Energy. 1978. *Fuels From Biomass Program.* Washington, D.C.: USDOE. Stock No. 061–000–00063–1. Available from: GPO.

6. Wan, E.I. et al. 1979 (Oct.). "Biomass Based Methanol Processes." *Proceedings of the Third Annual Biomass Energy Systems Conference.* 5–7 June 1979. Golden, CO: Solar Energy Research Institute. SERI/TP-33-285; pp. 477–487. Available from: NTIS.

   This paper evaluates biomass to methanol processes including examination of the availability of biomass feedstocks, the thermochemical conversion of biomass to methanol fuels, and the distribution and potential market for methanol fuels.

Regulations and Legislation

1. Abeles, T.P.; King, Janna R. 1978. "Parameters for Legislature Consideration of Bioconversion Technologies." St. Paul, MN: Minnesota Legislature Science and Technology Project. Report No. PB–284742/45T. Available from: NTIS.

2. Bureau of Alcohol, Tobacco and Firearms. *Alcohol Fuels Information Directory.* Washington, D.C.: BATF; 1980. Brochure No. ATF P 5000.3 (7/80). Available from: BATF Distribution Center, 3800 S. 4 Mile Run Drive, Arlington, VA 22226.

3. Bureau of Alcohol, Tobacco and Firearms. *Alcohol Fuel Plants.* Washington, D.C.: BATF; 1980. Brochure No. ATF P 5000.4 (7/80). Available from: BATF Distribution Center, 3800 S. 4 Mile Run Drive, Arlington, VA 22226.

4. U.S. National Alcohol Fuels Commission. 1980 (Apr.). *Alcohol Fuels Tax Incentives—A Summary: Alcohol Fuels Provisions of the Crude Oil Windfall Profit Tax Act.* Washington, D.C.: USNAFC. Available from: U.S. National Alcohol Fuels Commission, 412 First St. SE, Washington, D.C. 20003.

   This booklet reviews those provisions in the Crude Oil Windfall Profit Tax Act relevant to alcohol fuels including: four-cent-per-gallon excise tax exemption, income tax credits, energy-investment tax credit for biomass, alcohol-fuel-plant operating permits, tax-exempt bonds for alcohol fuel from solid waste, state financing of renewable energy property, imported alcohol study, and the annual reports on alcohol fuels.

Safety

1. National Fire Protection Association. 1977 *Standard for Storage of Flammable and Combustible Liquids on Farms and Isolated Construction Projects.* Boston, MA: NFPA. Available from: NFPA, 470 Atlantic Ave., Boston, MA 02210.

2. Solar Energy Research Institute. 1980. *Fuel From Farms: A Guide to Small-Scale Ethanol Production.* Golden, CO: SERI Stock No. 061–000–00372–0. Available from: GPO.

   The first such book in support of the national alcohol-fuels policy, this guide provides invaluable information on examining the potential of small-scale ethanol production. Useful decision and planning worksheets and a business plan case study are included as well as information on operations and maintenance of a small-scale plant.

3. U.S. Department of Agriculture. 1980. *Small-Scale Fuel Alcohol Production.* Washington, D.C.: USDA. Stock No. 001–000–04124–0. Available from: GPO.

   This book plays a role in implementation of national alcohol fuels policy by providing information on small-scale, on-farm production. The emphasis is on utilization of alcohol fuel in vehicles and use of the stillage by-product. Additional information is given on feedstocks, production processes, and costs.

Available from GPO: Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402
Available from NTIS: National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161
Contact these agencies for current price and ordering information.

4. U.S. Department of Labor. 1977 (Nov.). *OSHA Safety and Health Standards: General Industry Standards*. Revised. Washington, D.C.: USDOL. Stock No. 029–01–81001–7. Available from: GPO.

Vehicle Fuel Use

1. Allsup, J.R.; Eccleston, D.B. 1979 (May). *Ethanol/Gasoline Blends as Automotive Fuel*. Bartlesville, OK: Bartlesville Energy Technology Center. Report No. BETC/RI–79/2. Available from: NTIS.

2. Anderson, C.J. 1978. "Environmental Aspects of Alternative Fuels Utilization for Highway Vehicles." *Environmental Control Symposium*. Washington, D.C.: 28 November 1978. Washington, D.C.: U.S. Department of Energy. Report No. CONF–781109–22. Available from: NTIS.

This paper reviews environmental considerations of nonpetroleum-derived fuels including alcohol fuels. Projects examining these issues and their resulting data are described and research gaps are identified.

3. Brinkman, N.D.; Gallopoulos, N.E.; Jackson, M.W. 1975 (Feb.). "Exhaust Emissions, Fuel Economy, and Driveability of Vehicles Fueled with Alcohol Gasoline Blends." Warrendale, PA: Society of Automotive Engineers. SAE Paper No. 750120. Available from: Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA 15096.

This paper provides an overview of emissions, economy, and driveability with alcohol/gasoline blends. Their findings included an increase of three numbers in research octane (RON) and two numbers in motor octane (MON) with an E10 or gasohol blend.

4. California Energy Commission. 1980 (Mar.). "Methanol/Ethanol/Gasoline Blend Fuels Demonstration with Stratified Change Engine Vehicles." Sacramento, CA: California Energy Commission. Report No. 500–80–014. Available from: California Energy Commission, Publications Unit, 1111 Howe Avenue, Sacramento, CA 95824.

5. Kaufman, K.R.; Klosterman, H.J. 1978 (July-Aug.). "A Highway Test of Gasohol." *Farm Research*. Vol. 37 (No. 1): pp. 18–27.

6. Pleeth, S.J.W. 1949. *Alcohol, A Fuel in Internal Combustion Engines*. London: Chapman and Hall.

Written in 1949, this book represents a classic text on alcohol fuels. Today it still contains valuable information on production and use of alcohol fuels.

7. Scheller, William A.; Mohr, B.J. 1977 (Oct.). "Gasoline Does Too Mix With Alcohol." *Chemtech*. Vol. 7 (No. 10): pp. 616–623.

Dr. Scheller, who was connected with the Nebraska two-million-mile gasohol test, describes ethanol production and gasohol performance.

8. Society of Automotive Engineers. 1979. "Alternate Portable Fuels for Internal Combustion Engines." Warrendale, PA: Society of Automotive Engineers. SAE Preprint 790426. Available from: Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA 15096.

9. U.S. Department of Agriculture. 1980. *Small-Scale Fuel Alcohol Production*. Washington, D.C.: USDA. Stock No. 001–000–04124–0. Available from: GPO.

This book plays a role in implementation of national alcohol-fuels policy by providing information on small-scale, on-farm production. The emphasis is on utilization of alcohol fuel in vehicles and use of the stillage by-product. Additional information is given on feedstocks, production processes, and costs.

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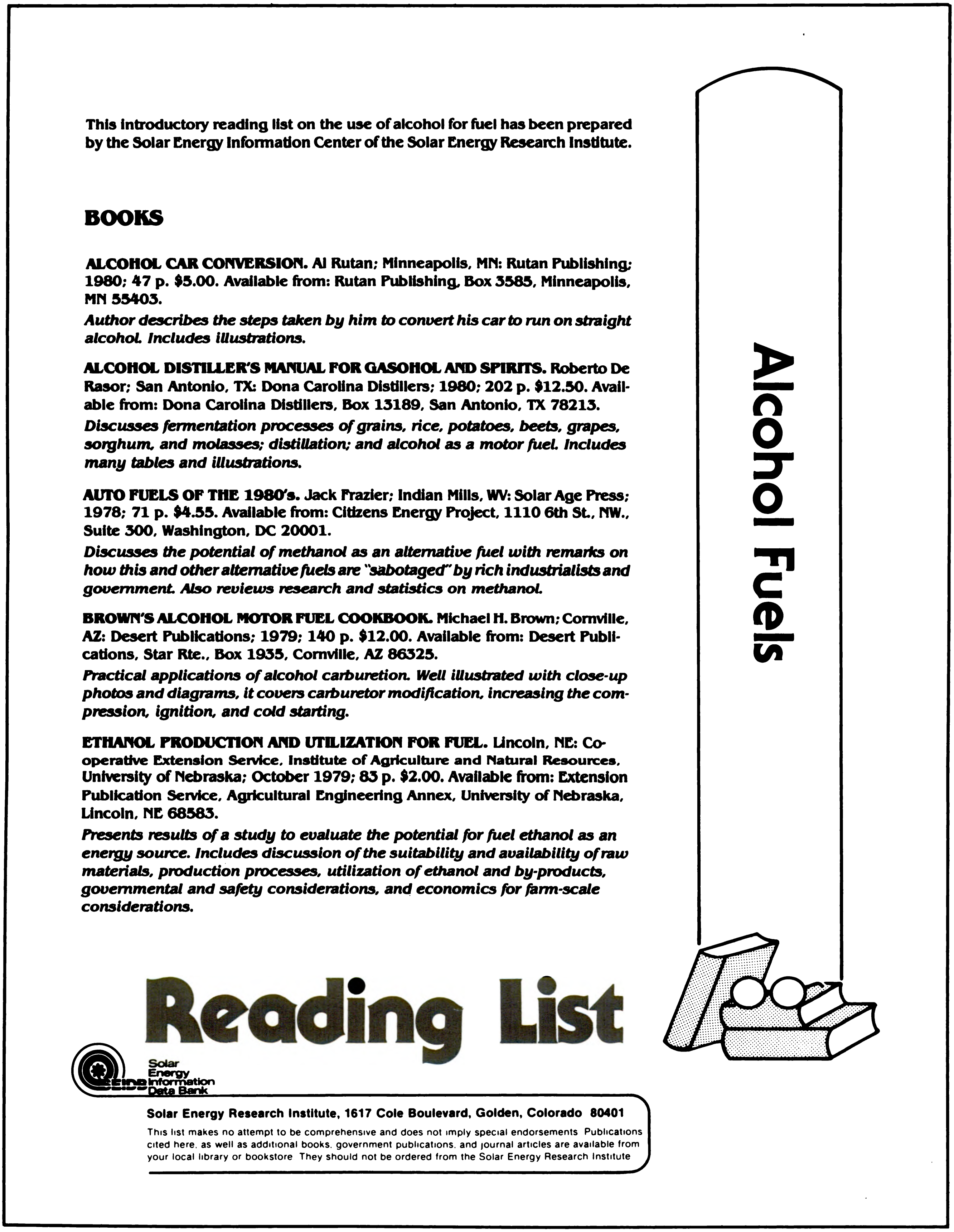

This introductory reading list on the use of alcohol for fuel has been prepared by the Solar Energy Information Center of the Solar Energy Research Institute.

BOOKS

ALCOHOL CAR CONVERSION. Al Rutan; Minneapolis, MN: Rutan Publishing; 1980; 47 p. $5.00. Available from: Rutan Publishing, Box 3585, Minneapolis, MN 55403.

Author describes the steps taken by him to convert his car to run on straight alcohol. Includes illustrations.

ALCOHOL DISTILLER'S MANUAL FOR GASOHOL AND SPIRITS. Roberto De Rasor; San Antonio, TX: Dona Carolina Distillers; 1980; 202 p. $12.50. Available from: Dona Carolina Distillers, Box 13189, San Antonio, TX 78213.

Discusses fermentation processes of grains, rice, potatoes, beets, grapes, sorghum, and molasses; distillation; and alcohol as a motor fuel. Includes many tables and illustrations.

AUTO FUELS OF THE 1980's. Jack Frazier; Indian Mills, WV: Solar Age Press; 1978; 71 p. $4.55. Available from: Citizens Energy Project, 1110 6th St., NW., Suite 300, Washington, DC 20001.

Discusses the potential of methanol as an alternative fuel with remarks on how this and other alternative fuels are "sabotaged" by rich industrialists and government. Also reviews research and statistics on methanol.

BROWN'S ALCOHOL MOTOR FUEL COOKBOOK. Michael H. Brown; Cornville, AZ: Desert Publications; 1979; 140 p. $12.00. Available from: Desert Publications, Star Rte., Box 1935, Cornville, AZ 86325.

Practical applications of alcohol carburetion. Well illustrated with close-up photos and diagrams, it covers carburetor modification, increasing the compression, ignition, and cold starting.

ETHANOL PRODUCTION AND UTILIZATION FOR FUEL. Lincoln, NE: Cooperative Extension Service, Institute of Agriculture and Natural Resources, University of Nebraska; October 1979; 83 p. $2.00. Available from: Extension Publication Service, Agricultural Engineering Annex, University of Nebraska, Lincoln, NE 68583.

Presents results of a study to evaluate the potential for fuel ethanol as an energy source. Includes discussion of the suitability and availability of raw materials, production processes, utilization of ethanol and by-products, governmental and safety considerations, and economics for farm-scale considerations.

Alcohol Fuels

Reading List

Solar
Energy
Information
Data Bank

Solar Energy Research Institute, 1617 Cole Boulevard, Golden, Colorado 80401

This list makes no attempt to be comprehensive and does not imply special endorsements. Publications cited here, as well as additional books, government publications, and journal articles are available from your local library or bookstore. They should not be ordered from the Solar Energy Research Institute.

The *Alcohol Fuels Reading List* was produced for distribution by the National Alcohol Fuels Information Center. Since the termination of NAFIC, individual copies of the list are available from the Conservation and Renewable Energy Inquiry and Referral Service (CAREIRS), Box 8900, Silver Spring, MD 20907.

ETHYL ALCOHOL PRODUCTION AND USE AS A MOTOR FUEL. J. K. Paul; Park Ridge, NJ: Noyes Data Corp.; Chemical Technology Review, no. 144; 1979; 354 p. $48.00. Available from: Noyes Data Corp., Mill Rd. at Grand Ave., Park Ridge, NJ 07656.

Presents an economic assessment of possible modes of preparation of ethanol from various forms of biomass, natural resources, and their waste materials or by-products. Includes discussion of production technology, the Brazilian and Nebraska programs, and motor vehicle operation with ethanol and ethanol blends.

GASOHOL. Ken Bossong and Maureen Paskin; Washington, DC: Citizens Energy Project; Report Series, no. 24; Spring 1978; 7 p. $1.50. Available from: Citizens Energy Project, 1110 6th St., NW., Washington, DC 20001.

Overview of alcohol fuels and several gasohol programs. Statistics and forecasts are given for future developments.

GASOHOL FOR ENERGY PRODUCTION. Nicholas P. Cheremisinoff; Ann Arbor, MI: Ann Arbor Science; Energy Technology Series; 1979; 140 p. $14.95. Available from: Ann Arbor Science, Box 1425, Ann Arbor, MI 48106.

Gives an overview of the present state-of-the-art and the potentials and uses of biomass as a source of alcohol and chemical feedstocks. Extensive bibliography.

INDIVIDUAL AND GROUP GASOHOL-ALCOHOL FUEL PRODUCTION AND USAGE. B. W. Kirby; Columbia, SC: B. W. Kirby Co.; 1979; 70 p. $10.00. Available from: Energy Economy Digest, 3615 Verner St., Columbia, SC 29204.

Includes chapters on an overview of gasohol and alcohol fuels; alcohol fuel production; and legislative, technical, and marketing advancements needed for the national gasohol movement to win energy independence.

A LEARNING GUIDE FOR ALCOHOL FUEL PRODUCTION. Colby, KS: Colby Community College; July 1979; 348 p. $45.00. Available from: National Alcohol Fuel Producers Association, 1700 South 24th St., Lincoln, NE 68502.

Covers resources, principles of alcohol fuel production, and decisions for implementing alcohol fuel production and plant design.

MAKIN' IT ON THE FARM: ALCOHOL FUEL IS THE ROAD TO INDEPENDENCE. Micki Nellis; Iredell, TX: American Agriculture News; 1979; 88 p. $4.00. Available from: American Agriculture News, Box 100, Iredell, TX 76649.

Summary of the "Schroeder Plant" in Colorado, one of the first legally built, farm-sized operations put together in the 1970's. Includes discussion of ethanol production, solar stills, use of alcohol as a fuel, and regulations.

MAKING ALCOHOL FUEL—RECIPE AND PROCEDURE. Lance Crombie; Minneapolis, MN: Rutan Publishing; revised, 1979; 111 p. $8.00. Available from: Rutan Publishing, Box 3585, Minneapolis, MN 55403.

A handbook on alcohol production. Includes plant design, processes, raw materials, engine modifications, and alcohol use.

MAKING FUEL IN YOUR BACK YARD. Jack Bradley; Wenatchee, WA: Biomass Resources; 1979; 63 p. $10.95. Available from: Biomass Resources, Box 2912, Wenatchee, WA 98801.

Down-to-earth book by a person who built the small still he is writing about. Written in narrative form with easy instructions and useful drawings and pictures.

MANUAL FOR THE HOME AND FARM PRODUCTION OF ALCOHOL FUEL. Stephen W. Mathewson; Las Banos, CA: J. A. Diaz Publications; 2nd ed.; 1980; 208 p. $12.95. Available from: J. A. Diaz Publications, Box 709, Las Banos, CA 93635.

Primer for small-scale ethanol production. Deals with fuel theory, government regulations, water and alcohol injection, engine modifications, equipment design, and production processes.

METHANOL AND OTHER WAYS AROUND THE GAS PUMP. John W. Lincoln; Charlotte, VT: Garden Way Press; 1976; 134 p. $5.95. Available from: Garden Way Press, Ferry Rd., Charlotte, VT 05445. Revised edition to be published under title: DRIVING WITHOUT GAS; July 1980. $8.95.

Discusses the methanol alternative to gasoline, both in blended form and straight. Other exotic types of fuels are reviewed and future fuels are surveyed.

METHANOL TECHNOLOGY AND APPLICATION IN MOTOR FUELS: J. K. Paul; Park Ridge, NJ: Noyes Data Corp.; Chemical Technology Review, vol. 114; 1978; 85 p. $54.00. Available from: Noyes Data Corp., Mill Rd. at Grand Ave., Park Ridge, NJ 07656.

Discusses methanol production from coal, solid waste and natural gas; the utilization of methanol as an automotive fuel; and the conversion of methanol into gasoline.

NET ENERGY ANALYSIS OF ALCOHOL FUELS. D.M. Jenkins; T. A. McClure; T. S. Reddy; Washington, DC: American Petroleum Institute; API Publication no. 4312; November 1979; 39 p. $3.00. Available from: American Petroleum Institute, 2101 L St., NW., Washington, DC 20037.

Presents the results of a study undertaken by Battelle Columbus Laboratories to determine the *net energy required to make alcohol from sugar cane, corn, corn stover, and wood.*

SOLAR ALCOHOL: THE FUEL REVOLUTION. Michael Wells Mandeville; Seattle, WA: Ambix; 2nd ed.; 1980; 127 p. $10.00. Available from: Ambix, 1223 North Northgate Way, Seattle, WA 98133.

Presents a complete briefing on the alcohol biofuel potential.

GOVERNMENT REPORTS AND PUBLICATIONS

AGRICULTURAL SECTOR IMPACTS OF MAKING ETHANOL FROM GRAIN. Donald Hertzmark; Golden, CO: Solar Energy Research Institute; March 1980; Report no. SERI/TR-352-554; 64 p. $5.25. Available from: NTIS*.

The role of renewable alcohol fuels as extenders of gasoline supplies is considered. Questions discussed include the effects of grain diversions to ethanol on supplies and prices, the net energy output of the conversion process, the impacts of land for energy crop production, and the impacts of products from ethanol conversion on feed markets.

BIOMASS-BASED ALCOHOL FUELS: THE NEAR TERM POTENTIAL FOR USE WITH GASOLINE. W. Park; E. Price; D. Salo; McLean, VA: MITRE Corp. Prepared for the U.S. Department of Energy; August 1978; Report no. HCP/T4101-3; 74 p. $6.00. Available from: NTIS*.

Discusses requirements and prospects for a nationwide alcohol-gasohol fuels system based on biomass-based alcohol. Production technology and economic aspects are reviewed.

COMPARATIVE AUTOMOTIVE ENGINE OPERATION WHEN FUELED WITH ETHANOL AND METHANOL. E. E. Ecklund; Santa Clara, CA: Santa Clara Univ.; Coral Gables, FL: Miami Univ. Prepared for the U.S. Department of Energy; May 1978; Report no. HCP/W1737-01; 59 p. $7.00. Available from: NTIS*.

The use of pure ethanol in conventional automotive type engines is discussed in relation to performance and exhaust emission comparisons with gasoline and pure methanol tests in the same engine.

DENATURANTS FOR ETHANOL/GASOLINE BLENDS. Mueller Associates, Inc. Prepared for the U.S. Department of Energy; April 1978; Report no. HCP/M2098-01; 16 p. $5.00. Available from: NTIS*.

This study assesses: 1) if the ordinary methods of denaturing ethyl alcohol are satisfactory to prevent the recovery of potable ethanol from any future ethanol/gasoline fuel blends; and 2) if there is a need for the development of a more effective denaturant.

ETHANOL/GASOLINE BLENDS AS AUTOMOTIVE FUEL. J. R. Allsup; D. B. Eccleston; Bartlesville, OK: Bartlesville Energy Technology Center, U.S. Department of Energy; May 1979; Report no. BETC/RI-79/2; 13 p. $5.00. Available from: NTIS*.

Presents results for vehicle tests conducted to determine the influence of ethanol in a 10% ethanol/90% gasoline fuel mixture on: fuel economy, regulated and unregulated exhaust emission, exhaust hydrocarbon distribution, and road octane quality.

FUEL FROM FARMS—A GUIDE TO SMALL-SCALE ETHANOL PRODUCTION. Golden, CO: Solar Energy Research Institute; 1980; Report no. SERI/SP-451-519; 157 p. $4.50. Available from: NTIS*.

Covers basic ethanol production, feedstocks, plant design, a business plan, and worksheets to enable the reader to calculate factors affecting the decision to become a producer (such as markets, production potential, equipment selection, and financial requirements).

FUELS FROM SUGAR CROPS: SYSTEMS STUDY FOR SUGAR CANE, SWEET SORGHUM, AND SUGAR BEETS. Richard A. Nathan; Oak Ridge, TN: Technical Information Center, U.S. Department of Energy; 1978; Report no. TID-22781; 137 p. $6.50. Available from: NTIS*.

This review presents the outcome of a comprehensive evaluation of sugar cane, sweet sorghum, and sugar beets as renewable resources for the production of fuels and chemical feedstocks.

GASOHOL: A TECHNICAL MEMORANDUM. Washington, DC: Office of Technology Assessment; September 1979; Report no. PB80-105885; 89 p. $8.00. Available from: NTIS*.

Presents results from an extensive analysis of alcohol fuels from agricultural products. Includes discussion on ethanol production, gasohol as an automotive fuel, economics, environmental effects, social impacts and current Federal programs and policies.

METHANOL AS AN AUTOMOTIVE FUEL WITH SPECIAL EMPHASIS ON METHANOL-GASOLINE BLENDS. A. Landman; U.S. Department of Transportation; 1977; Report no. PB-270 401; 82 p. $8.00. Available from: NTIS*.

Results of various tests on methanol blends are presented. Production methods for methanol are discussed and several source materials are reviewed.

REPORT OF THE ALCOHOL FUELS POLICY REVIEW. Washington, DC: U.S. Department of Energy; June 1979; Report no. DOE/PE-0012; 129 p. $10.00. Available from: NTIS*.

An outline brief of the alcohol field. Sets forth a basic policy stance for the Department of Energy in administering its development program.

STATUS OF ALCOHOL FUELS UTILIZATION—TECHNOLOGY FOR HIGHWAY TRANSPORTATION. Mueller Associates, Inc. Prepared for the U.S. Department of Energy; June 1978; Report no. HCP/M2923-01; 144 p. $10.00. Available from: NTIS*.

Covers topics of exhaust emissions, performance and fuel economy, and environmental considerations. Results of fuels testing are given. Previous technology status in summarized in appendix.

ARTICLES

AN ALCOHOL FUEL ALTERNATIVE. R. K. Pefley. *Mechanical Engineering.* vol. 101 (no. 11): pp. 52-53; November 1979.

Research in the Department of Mechanical Engineering, University of Santa Clara, indicates that alcohol-blended fuels are not only feasible, but are a desirable step in the national effort to conserve and supplant petroleum.

ALCOHOL FUELS—CAN THEY REPLACE GASOLINE? *Popular Science.* vol. 216 (no. 3): pp. 25+; March 1980.

Discusses the technical and economic aspects of alcohol production and use as a gasoline extender.

BRAZIL GROWS ITS MOTOR FUELS. F. Garner. *Environment.* vol. 20 (no. 1); pp. 5, 40; January/February 1978.

As a national energy policy, Brazilian fuels must be supplemented or replaced with alcohol produced from fermentation of biomass. This alcohol fuel program has the potential to make Brazil energy independent.

DON'T BE FUELISH: PRODUCING GASOHOL WILL BE EXPENSIVE. Ernst R. Habicht, Jr. *Wall Street Journal.* vol. 102: p. 20; May 1, 1980.

Criticizes the Government's subsidy program for gasohol, citing net energy loss, vehicle operating problems, and high cost of production among problems facing the gasohol program in the future.

ETHANOL MOTOR FUELS AND "GASOHOL". T. A. Sladek. *Mineral Industries.* B. vol. 21 (no. 3): pp. 1-6; May 1978.

Fermentation of biomass to produce ethanol for motor fuels. Biomass sources are surveyed.

THE ETHANOL RACE: WAITING FOR THE GOVERNMENT PLAN. R. Remirez; R. Grover; L. Marlon. *Chemical Engineering.* vol. 87 (no. 5): pp. 80-81; March 10, 1980.

Discusses the Federal Government's proposed legislation concerning incentives for gasohol production.

FERMENT IN THE ALCOHOL MOVEMENT. David Holzman. *Solar Age.* vol. 4 (no. 12): pp. 42-46; December 1979.

Describes the National Academy Still-Building Workshop held at Colby Community College, Colby, KS, summer 1979.

GASOHOL: ENERGY MOUNTAIN OR MOLEHILL? Earl V. Anderson. *Chemical and Engineering News.* vol. 56 (no. 31): pp. 8-16; July 31, 1978.

Views of both proponents and opponents are given. Pro's say that ethanol blends can reduce exports while con's say that it takes more energy to produce ethanol which will increase imports.

NEW GASOHOL PLAN SETS HIGH PRODUCTION GOAL. L. R. Ember. *Chemical and Engineering News.* vol. 58 (no. 3): pp. 24-25; January 21, 1980.

Outlines the Federal Government's incentives and forecasts for the production of alcohol. Raises questions the author feels the Government has not answered regarding the alcohol program.

NEW PROCESS MAKES GASOLINE FROM ALCOHOL. V. Elaine Imay. *Popular Science.* vol. 212: pp. 90-91; June 1978.

Conversion of alcohol, which can be produced from coal, biomass, or wastes, directly into high-octane gas.

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SERI/SP-751-800

PAVING THE WAY FOR ALCOHOL FUELS. Hal Bernton. *Environmental Action.* vol. 10 (no. 10): pp. 4-8; September 23, 1978.

U.S. alcohol fuel program lags behind Sweden, Brazil and West Germany. Environmentalists could give a big push to make alcohol fuels a major contributor to energy alternatives and waste recycling.

PAY NOW? OR PAY LATER? *Forbes.* vol. 123: pp. 36-37; February 1979.

Overview of gasohol is given with discussion on what the Government and industry can do to get gasohol moving.

RESEARCH NEWS/ALCOHOL: A BRAZILIAN ANSWER TO THE ENERGY CRISIS: A. L. Hammond. *Science.* vol. 195 (no. 4278): pp. 564-566; February 1977.

Brazilian alcohol fuels program is discussed.

U.S. DETAILS GASOHOL PROGRAM: CARTER'S GOAL IS RATE OF 5 BILLION GALLONS IN 1981. *New York Times.* p. 27: January 12, 1980.

Details of Carter Administration Gasohol Program are reported.

PERIODICALS

ALTERNATIVE SOURCES OF ENERGY. Bimonthly; 1972+; $15.00/yr. Available from: Alternative Sources of Energy, Inc., 107 South Central Ave., Milaca, MN 56353.

Articles emphasize the development of alternative technologies for energy production, agriculture, architecture, transportation, and communication in a decentralized society. Several features on alcohol fuels appear.

BIOTIMES. Bimonthly; January 1979+; $10.00/yr. Available from: International Biomass Institute, 1522 K St., NW., Suite 600, Washington, DC 20005.

Newsletter devoted to research, education, and promotion of biomass applications in energy, farming and other fields. Includes reports on alcohol fuels activities.

GASOHOL U.S.A. Monthly; June 1979+; $12.00/yr. Available from: Box 9547, Kansas City, MO 64133.

Trade journal covering production, marketing, and research related to gasohol. Provides articles, news bulletins, and advertising (for alcohol equipment and supplies) aimed at the generalist involved with the alcohol fuels movement.

MOTHER EARTH NEWS. Bimonthly; 1970+; $15.00/yr. Available from: Mother Earth News, Inc., Box 70, Hendersonville, NC 28379.

Popular magazine which deals with alternative technologies and do-it-yourself projects. Has frequent articles on still plans and automobile modifications.

SMALL FARM ENERGY PROJECT NEWSLETTER. Bimonthly; September 1976+; $5.00/yr. Available from: Center for Rural Affairs, P.O. Box 736, Hartington, NE 68739.

Communicates information on energy-saving innovations implemented on small, low-income farms by the Small Farm Energy Project, Cedar County, Nebraska.

BIBLIOGRAPHIES

ALCOHOL FUELS (CITATIONS FROM THE NTIS DATA BASE), V. 1, 1964-1977; Springfield; VA: National Technical Information Service; July 1979; Report no. NTIS/PS-79/0712; 170 p. $30.00. Available from: NTIS*.

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Bibliography with abstracts on alcohol fuels. Includes synthesis, performance evaluation, safety, cost analysis, economic analysis, sources, agricultural wastes, process charting, pollution, plants, engines, and by-products.

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*These publications are available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161. All orders must be prepaid or charged to an existing account. Please include the report number to insure that your order is filled properly.

Appendix F

Site-Specific Audits: Schroder Plant, Campo, Colorado

The information presented in this appendix was first published as a Solar Energy Research Institute report, *Preliminary Energy Balance and Economics of a Farm-Scale Ethanol Plant,* SERI/RR–624–669R. It is reprinted here in its entirety.

Introduction

Motivated by the desire to have an alternative market for their grain, the Schroder family of Campo, CO, has designed, built, tested, and modified a small-scale ethanol plant over the past 18 months. The plant currently operating is the second design. A third, and probably final, design was to be installed and operating by mid–1980. The second plant produces approximately 30 gallons per hour of 190-proof alcohol on a continuous basis. The third plant will produce 50 gallons per hour of 200-proof alcohol.

The key feature of the Schroder plant is the relatively low process-heat requirement, which is achieved by extensive use of waste-heat recovery heat exchangers. This is manifested in the low temperatures of the process output streams.

Purpose

Representatives from the Solar Energy Research Institute, Dan Jantzen and Tom McKinnon, evaluated the energy balance on the Schroder plant to help clear up the controversy surrounding the net energy benefit of ethanol production. Although the study was site-specific to the Schroder plant and limited in scope, it should provide an indication of the performance of grain-to-ethanol plants in general.

Plant Description as of March 27, 1980

The plant has two 3,500-gallon cookers fitted with agitators; three 7,000-gallon fermenter tanks, also with agitators and soon to have cooling coils; three 16–foot sieve-tray distillation columns; and two steam generators with heat exchangers (see Figure F/1.1). All the heat exchangers are the field-fabricated double-pipe type. The plant is designed to operate continuously. Cookers and fermenters operate batchwise, going through a complete cycle every 36 hours. Two cook batches are required per fermentation batch.

To start the process, the cooker is half filled with 68°C water that is preheated in a counter-flow heat exchanger against the hot mash from the previous batch; 124 bushels of milled grain and an enzyme are added to the hot water. Steam is injected to raise the temperature to 88°C. The batch is held for one-and-one-half hours and is continuously agitated. The enzyme breaks the starch into dextrins (short hexose chains), liquefying the starch.

The batch is then pumped through counter-flow heat exchangers to preheat the water for the next batch. Currently, the makeup water is from a well at 16°C.

Two cooker batches are put in the fermenter tank along with the saccharifying enzyme and a concentrated yeast solution. The fermentation takes approximately 36 hours at 45°C. The fermenters are also continuously agitated.

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Upon completion of fermentation, the beer solution should be 12% ethanol. This beer solution with stillage suspended is pumped through a counter flow heat exchanger where the beer is heated against the hot stillage from the bottom of the beer column; the heated beer is then pumped to the top of the beer column. Two rectifying columns in series are then used to distill the ethanol to 192 proof. The alcohol is then condensed, with the condenser water entering at 16°C and leaving at 70°C. It is saved in a large insulated tank and used as boiler feedwater.

The cooled stillage is pumped to a tapered auger, which produces a solid product with a 65% moisture content and a thin stillage that contains approximately one-third of the solids. The solids, which are 28%–32% protein on a dry basis, are a valuable protein supplement product sold to livestock growers.

Plant Improvement

The Schroders are building a new plant which will incorporate a number of improvements to increase production, reduce operating labor, and further reduce process heat demands.

The new plant will have molecular-sieve drying columns to take the alcohol from 188 proof to 200 proof (anhydrous) so it may be used as a gasoline octane booster. The molecular-sieve columns are expected to have much lower energy demands relative to benzene distillation schemes. By reducing the proof from the distillation columns from 192 to 188 proof, considerable distillation energy will be saved by reducing the reflux rate on the rectifier.

The new plant will use hot water from the hot-water storage tank for makeup water to the cookers. Thus, the condenser will have the only process-water input to the system.

An improved recovery scheme will be developed for the stillage to reduce the loss of the solids in the thin stillage.

This plant design has significantly reduced process heat demands, but the electricity consumption remains high. The tank agitators are run more than necessary, and the heat exchangers may be causing large pumping losses.

Energy-Balance Measurements

The energy inputs to the system are diesel fuel and electricity. The other inputs are grain, water, and enzymes. The diesel fuel was measured by weighing the fuel into a tank specially set up for the test. The electricity was measured with a watt-hour meter on the plant. The process outputs are ethanol, stillage, and hot condenser outlet water. The ethanol was measured with a calibrated integrating flowmeter. The stillage was not measured. The diesel inputs occur in the cooking and distillation steps. The electricity is used for agitators, pumps, and lights. Two steam generators are used, one for the distillation and one for cooking, and thus the heat inputs to each step could be measured separately.

The test was conducted by measuring the diesel fuel used in one cook batch and that used to distill a different fermentation batch. The cooking energy was doubled since two cooks are used per fermentation batch.

The Schroders made a crude estimate of the quantity of diesel fuel required to load, mill, and unload the grain from the storage bins to the cooker. Thus, the system boundaries are the grain bins on the farm to the ethanol tanks and stillage pile on the farm.

Energy-balance calculations for the conversion process are shown below. A global energy balance would include, in addition, energy debits for production and delivery of fuel and enzymes, construction of the plant, distribution of alcohol and stillage, and farming energy. An energy credit would be given for stillage.

Energy-Balance Calculations

Input	*Factors*	*Energy MBtu*
Grain input	6,957 lb/cooker x 2 cookers = 13,914 lbs or 238.5 bu	
Cooking energy input	75 lb diesel x 2 cooks x 18,500 Btu/lb	= 2.775
Distillation energy	398 lbs diesel x 18,500 Btu/lb	= 7.363
Electrical input	270 kWh x 11,600 Btu/kWh (29% conversion efficiency)	= 3.132
Grinding, augering, site-transport energy	5 gal diesel x 138,700 Btu/gal	= 0.693
Total Energy Input:		= 13.963
Output		
190-proof ethanol	481 gal x 0.95 x 85,000 Btu/gal	= 38.840
Stillage	11 lb (dry)/bu x 248.5 bu = 2,733 lb	

Energy requirements/gallon 190-proof ethanol $\frac{13{,}963{,}000 \text{ Btu}}{481 \text{ gal}} = 29{,}029$ Btu/gal

Net energy ratio (processing only) $\frac{38{,}840{,}000}{13{,}963{,}000} = 2.78$

Note: This energy balance was run on a fermentation batch using a new supply of yeast, and the alcohol yield is said by Gene Schroder to not be representative of yields in previous batches.

Preliminary Economic Analysis

Basis: Farm-scale ethanol plant processing 160,000 bu/year of grain sorghum producing 400,000 gal of 190-proof ethanol; total capital cost of plant is $400,000 installed, per Gene Schroder.

Cost/Bushel Grain Processed		*Factors*
$1.90	Value of sorghum on the farm	$0.04/wet lb x $\frac{\text{11 lbdry/bu}}{\text{0.35 dry matter}}$
– 1.25	Credit for stillage sales	
0.65	Net feedstock cost for alcohol	
0.05	Electricity costs	$\frac{\text{\$0.05/kWh x 270 kWh}}{\text{248 bu}}$
0.44	Diesel costs	$1.10/gal x 0.40 gal
0.38	Enzymes	$0.15/gal x 2.5 gal
0.60	Capital	$400,000; 20% interest; 10 years Capital Recovery Factor = 0.238 $95,200/160,000 bu
0.50	Labor	4 men x $20,000/year ÷ 160,000
0.08	Bonding, insurance, taxes	$12,000/160,000 bu
0.06	Maintenance	2.5% of capital 0.25 x 400,000/160,000 bu
0.25	Depreciation	10-year straight line $40,000/160,000 bu
$3.01	Production cost/bushel or **$1.20/gal** at 2.5 gal/bu	

Assume alcohol sells for $1.90/gal:

Gross profit	$0.70/gal x 400,000 gal = $280,000
Net profit after 50% taxes	$140,000
ROI	$\frac{\text{\$140,000}}{\text{400,000}} = 35\%$

This Appendix is taken from *Fermentation Guide for Common Grains: A Step-by-Step Procedure for Small-Scale Ethanol Fuel Production*, SERI/SP-75-1007. The complete publication is available from the Superintendent of Documents, Government Printing Office, and from the National Technical Information Service.

Appendix G

Fermentation Guide for Common Grains

Introduction

The information contained in this booklet is designed to inform you of the steps necessary for successful **batch** starch conversion and fermentation of corn, barley, wheat, and milo for the production of fuel alcohol (ethanol). No matter what you may have heard before, the efficiency of your efforts to produce alcohol does not come solely from the still. The alcohol to be distilled comes from fermenting glucose converted from the starches in the grains. If the fermentation is successful every time and produces as much alcohol as possible for the capacity of the fermenting vessel, then an effective operation is possible. If, on the other hand, the fermentation process is ignored or left to itself as a "natural" process, then it is likely that **much** of the glucose will not be converted to alcohol, and poor ethanol yields will result. Often those producing ethanol are unaware of how inefficient their process is and of its true potential. By following the directions in this booklet carefully, you should be able to consistently produce a yield of ethanol that is 9% to 10% of the weight of the mash in the fermenting vessel.* For corn, this is about 2.5 gallons of 200-proof ethanol per 56-lb bushel. Such a yield is considered good by any professional distiller.

The first part of this booklet is an overview of ethanol production from feedstock to fermentation. The central part of the booklet is a recipe section that gives step-by-step procedures necessary for successful fermentation. Following that, there are refinements that can help improve ethanol production. Of all the sections, the procedural one is the most important. The other sections are designed to help you understand it.

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*These results are documented in **Fermentation Studies of Wheat, Barley, Corn, Milo and Potatoes** by Kent Lines of Energy Incorporated, P.O. Box 736, Idaho Falls, ID 83401 (1981).

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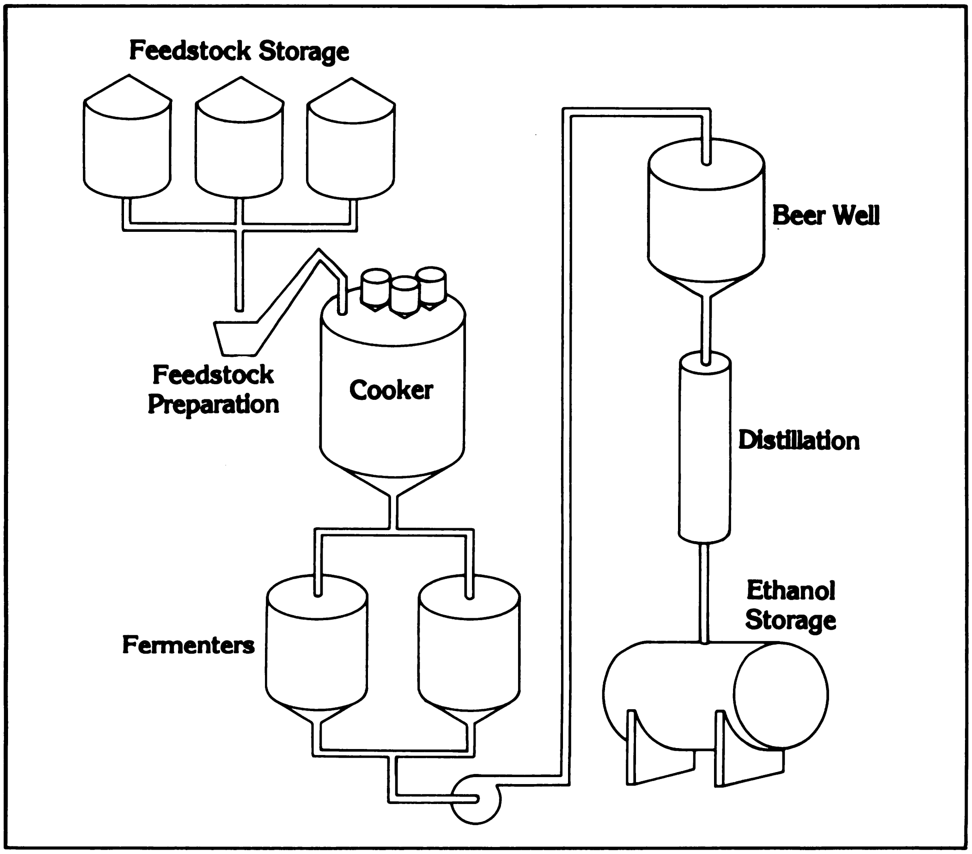
Major Steps in Ethanol Production

- **Choosing the Feedstock.** The feedstock should be the most inexpensive starch-bearing grain for which you have handling and storage equipment.
- **Water Testing.** Chemicals in water can harm the yeast used in fermentation. The water will need to be tested and perhaps adjusted.
- **Preparing the Feedstock.** The feedstock should be washed to free it from dirt, and any metal objects should be removed. It is then milled to a fine particle size to aid in the starch conversion and fermentation.



An idealized flow diagram of ethanol production. The *Fermentation Guide* covers *feedstock preparation, cooking,* and *fermentation.*

- **Blending the Feedstock with Process Water.** After the feedstock is prepared, it is blended in specific proportions with process water. This mixture is called a **mash.**
- **Mash Cooking.** The pH of the mash is adjusted; enzymes for conversion are added; and the mash is heated. This breaks down the starches to fermentable sugars.
- **Fermentation.** Conditions suitable for good yeast growth are established, and a specific amount of yeast is added to the mash. The yeast acts on the mash's sugars, fermenting them and producing ethanol.
- **Distillation and Storage.** The ethanol produced during fermentation is separated, or distilled, from the mixture of water and fermented feedstock. This booklet does not go into the details of distillation and storage.

Equipment and Chemicals

What equipment and chemicals are needed, and what do they typically cost?

Proper preparation for consistently high yields of ethanol includes getting the right equipment and chemicals. Despite the cost involved, deciding to "cut corners" by not purchasing proper items will produce inadequate results — lending further credibility to those who say that small-scale ethanol production cannot be performed in a serious, effective manner.

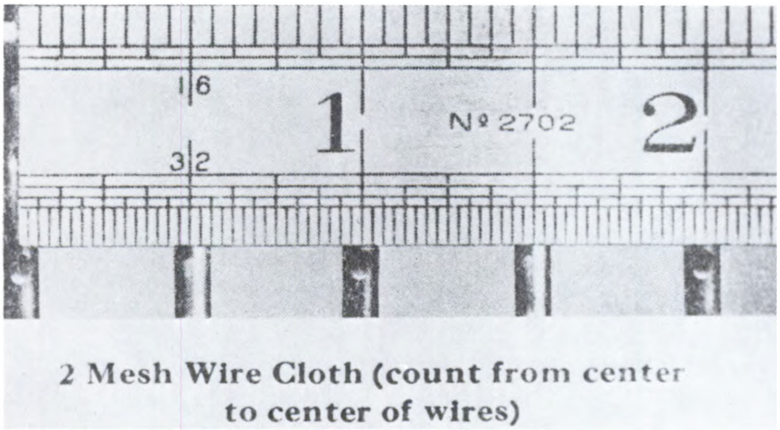
This booklet deals with the chemical and biological rather than the engineering aspects of ethanol production. Setting up the ethanol plant should be done with an expert. Production efficiencies (use of low-grade fuels like coal and farm wastes, recycling of heat and water) can determine a plant's overall profitability.

Typical Costs

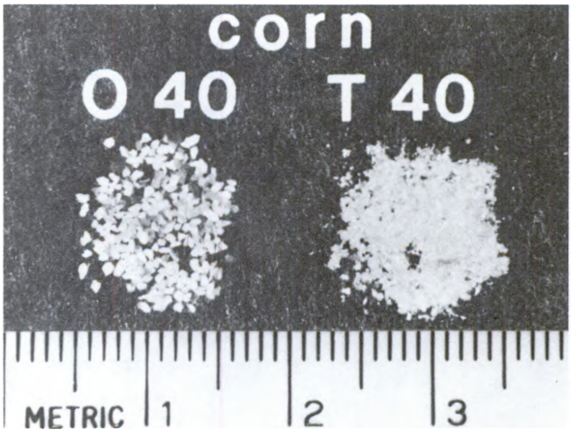
Major Equipment

$3000-$3500

A **hammermill** or other suitable milling device will be capable of reducing the feedstock to particles of which a majority are between 20 and 40 U.S. standard mesh screen size (0.036 to 0.017 inch). Milling is absolutely necessary to produce a proper mash. It may be possible, however, to get a local grain mill to produce a whole-wheat-flour grist consistency, which will work well. Just crushing the grain is not sufficient.



American Society for Testing and Materials (ASTM) has a commonly used standard for screens and their sizes. Mesh size is defined by the number of gaps between wires per inch. Thus a 2-mesh screen (shown magnified about 3 times) has two gaps per inch. A 40-mesh screen would have 40 gaps per inch. (Photo courtesy of W.S. Tyler, Inc.)



Corn that has gone *through* (T) an ASTM 40-mesh screen has a finer texture than that which is *over* (O) the same screen (the measure on the ruler is centimeters, magnified 2 times).

$6.00 to $10.50 per sq ft of surface area, depending upon thickness. Prices will vary in different areas.

Containers for cooking and fermenting may be of the same size, shape, and material. Carbon steel is satisfactory. The thickness of the steel depends upon the size of the tank and the amount of liquid it is expected to hold; 10-gauge steel to ¼" steel will probably be satisfactory. Methods to heat and cool the tanks are necessary, as are a drain and a vent for the fermenting tanks. Some provision for cleaning should be made. Tanks may be closed or open, though the former are much to be preferred.

Typical Costs	Major Equipment
10-hp motor — $3750, 3-hp motor — $1250. Prices will vary, as will needs.	**Electric motors** for agitating the cooker and fermenter are necessary. A ten-horsepower motor should be large enough for the cooker, and a three-horsepower motor should agitate fermenters sufficiently. Less powerful motors can be used if they are used with gear reducers. Do not go lower than 3 hp, geared down, in the cooker on medium-sized batches.
$25-$300, depending upon type	**Pumps** will be necessary to move mash, beer, and alcohol from tank to tank. They should be of a kind that can be cleaned and should stand up to the corrosion caused by grains and low pH.
	Minor Equipment and Chemicals
$325	A **pH meter** is a very accurate and relatively difficult device to use and maintain, but is highly recommended for best results.
$2.50 to $7.50 (100 sticks)	pH **papers** or **sticks** (rather than a pH meter) may be used if one does not desire precise readings. Also, they are less complicated to use and maintain than a meter. They can, however, deteriorate and give inaccurate readings **Do not confuse pH papers or sticks with litmus paper, which will not work.**
50-lb scale — up to $400 500-gram scale — $80 to $130.	**Scales** are necessary to weigh feedstock quantities in pounds and chemical and enzyme quantities in grams.
Rent or borrow one — it may only be needed a few times.	**A metering device for water** that measures gallons, or some other way (a bucket) to measure gallons of water to be added to the mash.
$25	A **thermometer** (metal is best) in either degrees Celsius (30°-100°C) or degrees Fahrenheit (80°-212°F).
Funnel $2-$5 Paper $10 Cheesecloth $5	A **filtering funnel** and either **coarse filter paper or fine cheesecloth** to separate solids from liquid in the mash or in the beer for testing.
$30 — Laboratory brown glass bottle	A **brown glass bottle** to store the iodine solution used to test for breakdown of the starch to dextrins during cooking. A brown wine bottle or beer bottle will work if it can be sealed.
Hydrometer $10 Cylinder $10	**°Plato or °Brix hydrometers**, calibrated from 0° to 35°, measure percentage by weight of sugar solutions filtered from the mash or the beer. A measuring cylinder is needed with each hydrometer.
$2.50-$5.00	Clinitest™ tablets or Testape™, available in drugstores as part of kits to test for glucose in the urine of diabetics, can be used to test the fermenter for unconverted sugar concentrations down to 1%-2%.

Typical Costs	Minor Equipment and Chemicals
Hydrometer \$10 Cylinder \$10	An **ethanol hydrometer**, calibrated from 0 to 200 proof, will measure the proof of the ethanol as it comes from the still. Buy only those labeled "U.S. Custom House"; the Alcohol, Tobacco, and Firearms inspectors require them, and they are more accurate. Hydrometers with built-in thermometers save using temperature conversion charts. Do not buy "potential" alcohol hydrometers, which really measure sugar. The hydrometer needs a measuring cylinder.
\$10 — unbreakable, 250 milliliters	A **volumetric cylinder** calibrated in milliliters can be used to measure acid for addition to water to make pH-adjusting solutions.
$ZnSO_4$ — 6.6 lb for \$40; $CaSO_4$ — 22 lb for \$20. Quotes are from laboratory suppliers, not large chemical companies	**Zinc sulfate** ($ZnSO_4$) and **calcium sulfate** ($CaSO_4$) may be added to the mash prior to cooking and fermentation. Very small amounts will be used.
H_2SO_4 — 15-gal drum for \$30; NaOH — 50-lb bag for \$15; 500-lb drum for \$50; KOH — 400-lb drum for \$240	**Sulfuric acid** (H_2SO_4) in concentrated solution and **sodium hydroxide** (NaOH) or **potassium hydroxide** (KOH) in pellet form will be necessary to change the pH of the mash.
\$20 for 5½ gallon size	**Large glass or corrosion-resistant plastic carboys** can be used to mix 2N solutions of the pH-changing chemicals.
Glasses — \$3 Gloves — \$7 to \$19 Apron — \$8 to \$17	**Safety glasses, goggles, or face shield, rubber gloves, and a rubber apron** for acid/base mixing safety should be used.

Water Testing and Treatment

Are there any special precautions to be taken with respect to the water?

For the most part, water in the United States is fairly pure — it does not kill the yeast necessary for fermentation. However, minor variations in water quality can have major repercussions in the fermentation because the yeast's growth rate (and thus its conversion efficiency) **is** affected. To avoid this, it is necessary to test and adjust the water used in the fermentation. The tests usually can be done at a local commercial laboratory or at the farm support organization. The local county agent should be able to direct you properly. It should not be necessary to test your water more than once.

Tests and corrective measures needed are for:

- **pH** — A measure of how many hydrogen ions are present in water, more commonly referred to as the degree of acidity or basicity. A pH of 7 is considered neutral; values below 7 are acid and above 7 are basic. Yeasts of all types flourish when the pH is between 4 and 6; commercial yeasts — such as the ones used in fermentation — thrive at pH 5.

  The addition of milled grain to process water will usually yield a pH in the range of 4.5 to 6.5. Local water that has abnormal pH would probably produce a pH out of the range needed for healthy yeast.

  It is important to have a pH meter or pH papers to check the pH value at various points in the fermentation process. Meters, pH papers, and pH sticks give much more accurate readings than do litmus papers, and accuracy is very important in many production steps. Also, litmus paper is prone to degradation, which could result in misreadings. We recommend against using litmus.

- **Nitrates and Nitrites** — A level of these salts above 50 ppm* is usually indicative of water pollution by sewage or animal waste, and pollution should be avoided in fermentation process water. Nitrites, besides indicating pollution, can prove directly harmful to the yeast.

- **Trace Elements** — As with other living organisms, yeast require small amounts of certain metals (called trace elements) to live. However, both life-giving and destructive metal ions may be found in the water supply. Levels of 1.0 ppm copper, 160 ppm fluoride, 360 ppm tin, 350 ppm tellurium and beryllium, and 185 ppm nickel can each **inhibit** the yeast population.

  On the other hand, magnesium to 300 ppm and zinc to 3.0 ppm are **necessary** to good yeast activity and are sometimes added as sulfate salts (magnesium sulfate, zinc sulfate) if they are not in sufficient quantity in the mix of feedstock and process water. Usually, however, magnesium is in sufficient quantity in the feedstock and does not need to be added.

  Iron, aluminum, iodine, and chlorine are considered nondetrimental at levels up to 500 ppm.

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*Most laboratories will use parts per million (ppm) as a measure of the weight of impurity present. For instance, if there are 50 grams of sodium present in a million grams of water, the level of sodium present is 50 ppm.

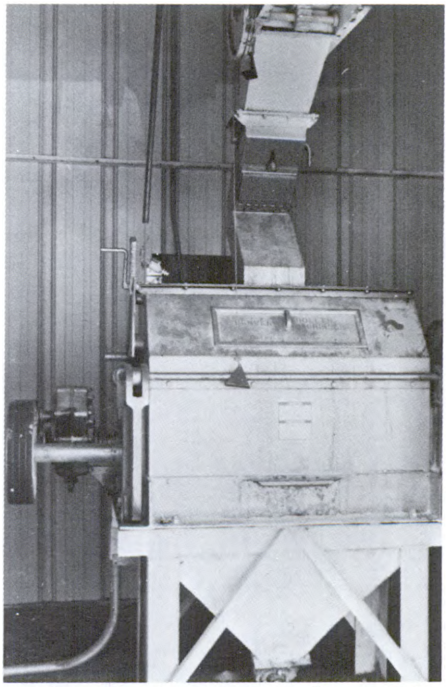
Feedstock Cleaning and Milling

How should the feedstock be prepared for fermentation?

Prior to processing the crop for fermentation, it should be screened to remove stones, metal, and other debris. Cereal grains can be cleaned by blowing air over the grains or washing them as they travel along a screen conveyor or auger. Commercially available equipment is often installed in large operations to clean the crops, but it can prove too expensive on a small scale, where homemade equipment may suffice.

After cleaning, the crop must be prepared so that the starch in it is exposed for conversion. This is done by milling. Starch is present in the feedstock in small granules called micelles. Milling frees the starch micelles, exposing them for the next steps of hydration, dextrinization, and conversion to glucose.

A grain cleaner prepares the milo at the Shroder Farms Alcohol Plant in Campo, Colorado. Forced air and rotary motion remove loose hulls, weeds, rocks, and dirt.



A roller mill reduces grains to fine particles with a sliding motion of its rollers. Particles are then sifted through proper screens to ensure that they are of the correct size.

How should cereal grains be milled?

Milling reduces grain to small particle sizes. No prior treatment other than cleaning is necessary. Roller mills, flour mills, and hammermills are commonly used. These machines are capable of reducing whole grains to particles of between 20 to 40 U.S. standard mesh screen size (0.036 to 0.017 inch); such particle sizes are necessary for proper cooking and conversion. Small mills are available commercially but are slow and may use quite a bit of electricity. Local grain mills will often grind small amounts of grain for individuals at nominal cost; if the mill is capable of reducing the grain to the proper size — a whole-wheat-flour consistency — it may be advantageous to use it. Some commercial feed mills simply **crush** the grains **without milling** them; a grain feedstock treated this way **will not ferment** because the micelles are not sufficiently exposed to enzymes during conversion. Ethanol yield will be small. Beware of airborne grain dust during milling: it can be explosive.

Mash Blending

What are the characteristics of a good mash?

Once the crop has been prepared, it must be mixed with water (the amount is calculated in the recipe section). The primary aim of this step is to prepare a mash with a consistent amount of starch in it. This will yield a consistent amount of fermentable sugars after conversion, which in turn will lead to a consistent amount of ethanol in the fermenter at the end of fermentation. Consistency simplifies the procedures. Also, the efficiency of the overall process depends to a considerable extent on the production of the maximum possible amount of ethanol in each fermentation vessel; high alcohol concentration also has the virtue of minimizing the amount of water that passes through the still during distillation to 200-proof ethanol. Thus, less energy is used during the entire process.

The amount of fermentable sugars found to be most efficient for the ethanol production process is 20% to 22% by weight of the mash. (Percent by weight means that all amounts are measured in weight rather than volume.) This will yield ethanol concentrations (by weight) of 9.4% to 10.3% after successful fermentation.

It can be as bad to have too **much** sugar or carbohydrate as it is to have too little. Concentrations of sugars above 40% by weight will kill yeast cells. Also, there is a limit to the amount of ethanol the yeast can survive; if too much ethanol is produced before all the sugars are fermented, no more fermentation will occur, and sugars (i.e., feedstock) will be wasted. The rate of yeast cell reproduction can begin to lessen when the alcohol concentration reaches 8%; reproduction is near zero at 15% concentration, and it ceases totally at 20%. Fermentable sugar concentrations of 20% to 22%, as suggested above, produce near-10% ethanol yields and do not damage the yeast population.

How should the water and feedstock be blended?

Blending of the feedstock and water may be done in the same vessel that will be used for cooking. Water that is at room temperature is satisfactory. In sophisticated systems, it would be better to use high-temperature (up to 140°F; 60°C) water recycled from another part of the process; but this may not be available to you.

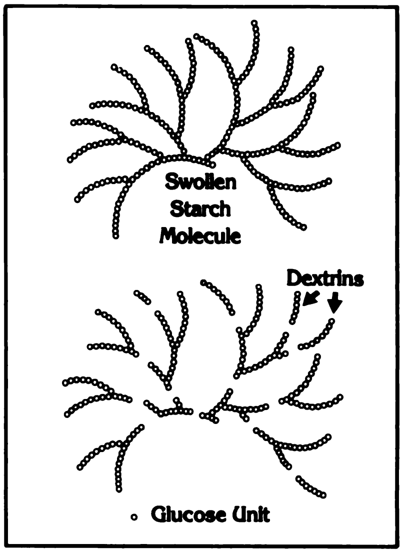
Hydration and Dextrinization

What is hydration?

Hydration is a process whereby water molecules are introduced between the starch molecules in the micelles, causing the micelles to swell. The starch molecules in the micelles are exposed by the swelling so that they are available for enzymes to break them down into fermentable sugars.

What is dextrinization?

Dextrinization is the process of turning starches, which are large, complex molecules, into smaller molecules called dextrins. Dextrinization is done by introducing alpha-amylase enzyme during the hydration. The alpha-amylase randomly attacks the starch molecule strands, breaking them into the smaller dextrins.

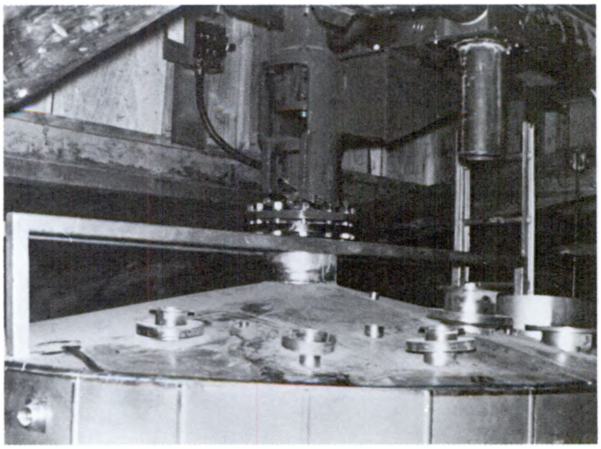


Dextrinization: Alpha-amylase enzymes attack the swollen starch molecule strands, breaking them into simpler starches called dextrins. Dextrinization prevents the mash from hardening during the cook and prepares it for final reduction to fermentable sugars.

How are hydration and dextrinization done?

The actual method of hydration and dextrinization varies somewhat depending upon the specific source of the enzymes used. In general, the alpha-amylase is added directly to the mash, which is being continually mixed and heated in the cooking vessel. The pH may have to be adjusted. Heating aids hydration as well as dextrinization; alpha-amylase requires a fairly high temperature for maximum activity. Heating without the addition of alpha-amylase would lead to a hardening of the starch. Dextrins, however, will not harden. Thus, the alpha-amylase performs two functions — prevention of hardening during hydration and the production of dextrins, which is a necessary step toward obtaining fermentable sugars.

When the correct temperature for the maximum alpha-amylase activity is reached, it is maintained for a certain length of time (at least an hour), completing the dextrinization. The high temperatures also help to reduce contamination of the mash by microorganisms.



Keeping the mash mixed during cooking is essential to prevent uneven heating (and perhaps burning) and to ensure complete starch conversion. Failure to properly mix the mash during cooking is one of the leading causes of poor ethanol yields. This two-speed mixer, atop a 2100-gallon cook tank, has a 7 horsepower capacity with 28,000 pounds of torque pressure (from the farm co-op plant, Monte Vista, Colorado).

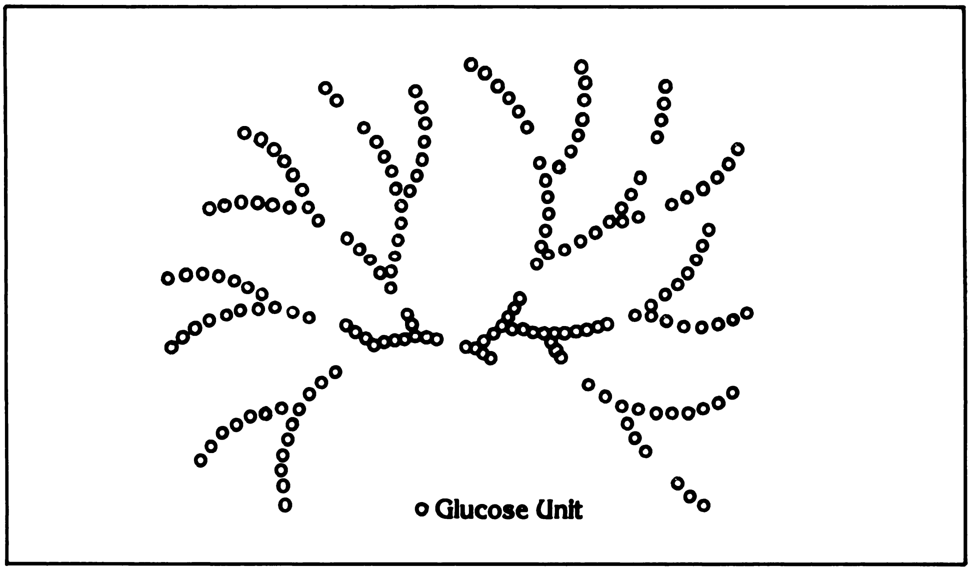
Cooking

What is cooking?

Cooking is a term often applied to the entire process whereby starch in the already swollen (hydrated) micelles is heated, agitated, and broken down to dextrins and from there to fermentable sugars. The dextrinization produced by the alpha-amylase (as explained in the previous paragraphs), precedes the final cooking step, which is the use of a glucoamylase enzyme to break the dextrins into even smaller molecules that are simple, fermentable sugars. The process of obtaining fermentable sugars from dextrins is called **saccharification.**

How is the conversion to fermentable sugars accomplished?

To perform the saccharification, the hot, dextrinized mash is cooled to a temperature tolerated by the glucoamylase. Frequently, the pH of the mixture must be adjusted. The glucoamylase is added, and with the proper temperature, pH, and agitation, the glucoamylase breaks the dextrins into smaller, fermentable sugars. The glucoamylase acts by clipping glucose molecules off the dextrins like removing single beads from a string. Sometimes the conversion to fermentable sugars is completed not in the cooking process but rather in the fermenter; yeast is added to the dextrinized mash, beginning the fermentation, and the dextrins-to-sugars conversion by the glucoamylase enzyme goes on concurrently with the fermentation.



Saccharification: Glucoamylase enzymes remove the glucose molecules one at a time from the end of the dextrins. Saccharification completes the conversion of the original mash material to fermentable sugars.

Choosing the Best Enzymes

What are enzymes?

The previous sections describe the use of enzymes in starch conversion. However, there are several choices of type and manufacturer of enzymes, and these enzymes vary significantly in their use. The choice of enzyme you make will determine your actual procedure throughout the hydration and starch conversion.

Enzymes are large, complex protein molecules that act as catalysts, facilitating the starch-to-fermentable sugars conversion. They are very sensitive to temperature, pH, and water contaminants. In addition, they often require very small amounts of substances called cofactors; calcium is usually a needed cofactor. The cofactor is sometimes identified (or supplied) by the manufacturer, who also gives the conditions needed by the specific enzyme. The instructions for enzyme use given here and in the step-by-step procedures that follow are only a guide: you should always follow the manufacturer's actual instructions.

What kinds of enzymes are effective, and how can you choose between them?

Starch conversion uses the two types of enzyme mentioned previously: alpha-amylase and glucoamylase. However, these enzymes can be derived from different sources, which are bacteria or fungi. The enzymes are called (after their sources) **bacterial** or **fungal** alpha-amylase and **fungal** glucoamylase. Each behaves differently. There are two choices of these enzymes most frequently used in actual operations. One choice is a **bacterial** alpha-amylase used in the dextrinization and a **fungal** glucoamylase that completes the conversion to fermentable sugars (saccharification). The second choice is to use a **fungal** alpha-amylase in the dextrinization, completing the saccharification (as before) with a **fungal** glucoamylase. The basic difference between these methods is that the first is faster but more complicated (in terms of temperature and pH adjustments) and requires a higher temperature; whereas the second choice is simpler and slower.

Properties of Fungal and Bacterial Alpha-Amylase and Fungal Glucoamylase

Enzyme	Use	Temperature	pH	Approximate Conversion Time
bacterial alpha-amylase	dextrinization	185°-203°F (85°-95°C)	6.0-6.5	1-2 hours
fungal alpha-amylase	dextrinization	133°-140°F (56°-60°C)	4.0-5.0	4-6 hours
fungal glucoamylase	completion of saccharification (2 procedures)	86°F (30°C) in fermenter or	4.0-5.0	24-65 hours
		140°F(60°C) in cooker	4.0-5.0	3 hours plus time for completion in fermenter

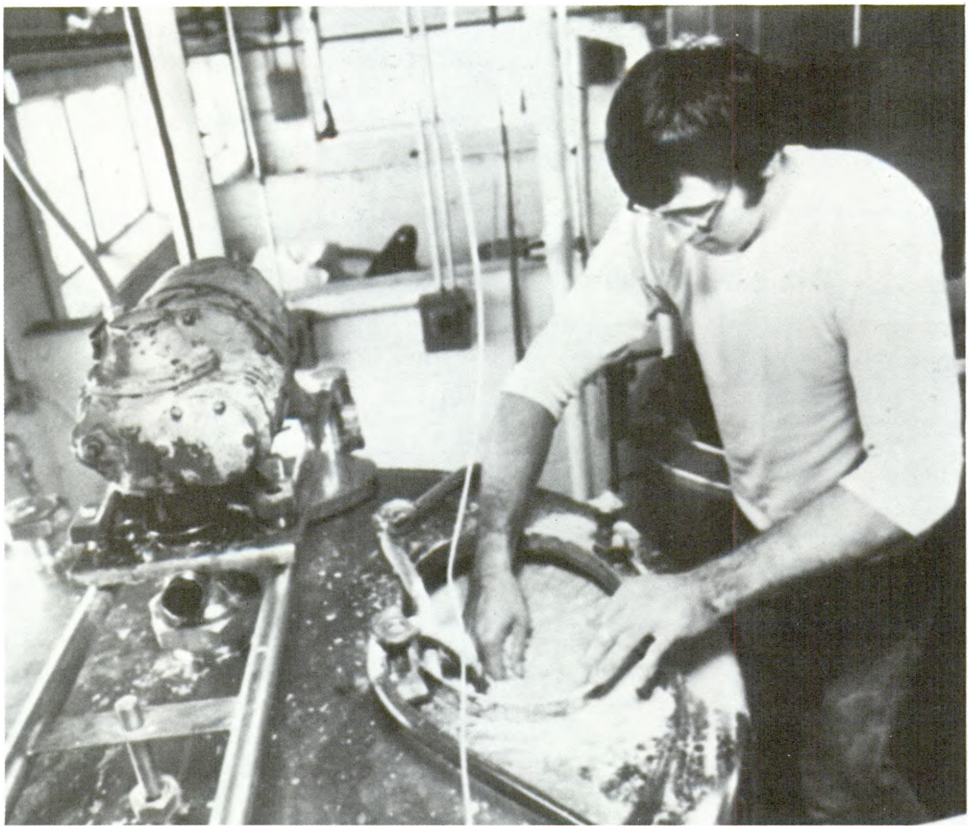
What enzyme should be used to complete the conversion?

Although the glucoamylase we suggest for completing the conversion is always fungal, there are different procedures for using the fungal glucoamylase available from different manufacturers. One procedure is to add the glucoamylase to the cooker for about 2 hours, converting 70%-80% of the dextrins to glucose. The glucoamylase completes its work in the fermenter. The other procedure is to add the glucoamylase to the fermenter (at about 86°F); **all** the necessary starch conversion occurs during the fermentation. Usually, the first, and fastest, of these procedures is the most efficient.

Fermentation

What is fermentation?

Fermentation is the process of using yeast to convert sugars to ethanol. Basically, yeast — a living organism — consumes sugar to live and reproduce and gives off ethanol (under oxygenless conditions) as a waste product. When the yeast has consumed and transformed all the sugar, the fermentation is over. The goal of the fermentation is to produce the greatest amount of ethanol in the shortest time. Vigorous ethanol production is a result of healthy yeast, the propagation and maintenance of which are dependent upon several factors.



Fermentation is a process that is sensitive to many parameters: proper temperature, pH, mash sugar, and contaminants. Vessels are closed, with vents for CO_2 and agitators to keep the mash mixed.

What are the factors necessary for good fermentation?

The pH of the mash is important. Yeasts thrive between pH 4 and pH 6. They will multiply at a pH as low as 3 and as high as 10, but very slowly and with little or no alcohol production. The best pH for ethanol production has been found to be 4.5 to 5. If a pH higher than 6.0 is used, glycerol may be formed at the expense of ethanol. If a pH of less than 4.0 is used, the routine fall of pH during fermentation will drop the pH to 3.5. This pH slows the fermentation and — although inhibiting certain contaminants — may allow others to grow and outpace the yeast.

What kind of yeast is used?

The rate of fermentation increases with temperature to an optimum between 86° and 104°F (30° and 40°C). The optimal temperature for fermentation is actually about 97°F (36°C), but at this temperature too much ethanol is evaporated and lost unless there is a scrubber to remove the ethanol vapor entrained in exhaust CO_2 gas. Temperatures of 86° to 90°F (30° to 32°C) will allow successful fermentation without excess ethanol evaporation. Because fermentation produces heat, this heat must be dissipated or the vessel cooled to maintain a steady, appropriate temperature.

The yeast also requires sufficient nutrients, as mentioned previously. Fortunately, most feedstocks made from whole grains contain these nutrients, and more need not be added to the fermentation. Zinc is sometimes added to the process water if not in sufficient quantity (see the procedural section).

The yeast most commonly used to produce fuel alcohol is called **Saccharomyces cerevisiae**; it is the yeast used industrially to produce beverage alcohol. This type of yeast is available from several suppliers in bulk quantities and is specifically a distiller's yeast. Baker's yeast, the kind of yeast available from the grocery store, will not produce a successful fermentation. It is less tolerant than distiller's yeast to alcohol, and may, in either moist cake or dried form, be up to 90% and 50% dead cells, respectively.

How should yeast be added to the fermenter?

About 0.5 to 1.0 oz of the correct dried distiller's yeast per 100 pounds of mash will provide enough cells to start a good fermentation. The dried cells can be rehydrated for 5 to 10 minutes in tepid water (not over 100°F; 38°C) before being added to the mash, or they can be added directly to the mash as it is being pumped into the fermenter. Yeast reuse is also a possibility (see the refinements section).

What kind of fermentation vessel is needed?

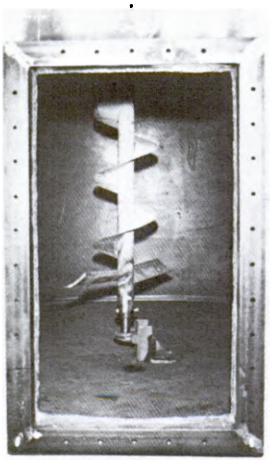
The material out of which the fermentation vessel is made is also important to the fermentation. The best material for the interior is polished stainless steel, which can be quite expensive. Less-expensive materials include food-processing-grade epoxy or fiberglass over mild or carbon steel, or simply plain carbon steel. However, some epoxy paints and fiberglass resins dissolve easily in ethanol; check with the manufacturer or test a sample. No matter what is used, the interior vessel lining should be chemically inert, smooth, easily cleaned, and repairable. It should resist corroding and pitting due to the low pH of the fermentation and not leach undesirable metal ions into the mash. Infections and reduced yeast performance can be prevented if an adequate vessel lining is employed. (Some materials to avoid include concrete, rough fiberglass, and painted surfaces.)

How much should the fermenting mash be mixed?

Yeast cells can live either in the presence of oxygen (aerobic growth) or in the absence of oxygen (anaerobic growth). Each situation causes the cell to use the fermentable sugar in a different manner: aerobic growth encourages yeast reproduction, and anaerobic growth encourages ethanol production.

This does not mean that absolutely no oxygen is necessary. Some oxygen is required at the very beginning of the fermentation to help the newly added yeast reproduce. Enough oxygen has probably been introduced into the mash during feedstock blending and cooking, so adding more to the mash just prior to addition of the yeast is not necessary, but is sometimes done. This can be accomplished by rapidly agitating the mash in the fermenter prior to addition of the yeast. The oxygen is quickly used up and disappears from the fermentation about two to four hours after the start of the process. **Once the yeast has been added, no oxygen should be introduced.**

Two types of fermentation vessels can be used: a covered, vented vessel, which is preferable, or an open vessel, which is apt to become infected. Fermentation can be facilitated by keeping the broth mixed at all times to allow the yeast to come into contact with its nutrients, reducing the fermentation time. For a covered container, there is no danger that mixing will introduce oxygen — even though there is a space above the mash in a closed vessel, carbon dioxide fills the space, and its pressure keeps oxygen from being mixed into the broth. If an open fermentation vessel is used, the mixing of the broth must be gentler to prevent oxygen from being introduced. However, even with an open vessel, the layer of CO_2 above the mash is usually enough to prevent much oxygen from penetrating if the mixing is gentle enough.



Mixing the mash during fermentation allows the yeast to get to all the sugars. Besides the screw-type mixer shown here, propeller-type and multibladed designs are also effective. Care must be taken that oxygen is not introduced during mixing.

Is there any danger associated with the generation of carbon dioxide?

A word of caution about carbon dioxide: Familiar from beer foam or champagne bubbles, carbon dioxide is produced in large quantities during fermentation and can be harmful. The gas is not poisonous of itself but tends to push out the breathable air in a closed space. A room filled with carbon dioxide will have little oxygen in it, and a person could become unconscious or even die if he were breathing mostly carbon dioxide rather than air. It is important, especially if fermenters are in closed rooms, to vent the carbon dioxide outside to the atmosphere. Also, if the fermenting vessel is closed and relatively airtight, it is important to vent the gas from the vessel as a means of relieving the pressure buildup caused by the generation of carbon dioxide during the fermentation. If this is not done, the tank may rupture.

Care and Cleaning

The equipment and chemicals needed for ethanol production require special care. The following are several areas of major concern.

Two means of measuring pH are suggested for you to choose from: a pH meter and pH papers.

How should a pH meter be cared for?

A **pH meter** is a delicate instrument and should be treated with care. The glass electrode that is inserted in the sample to get a reading should not be bumped or treated roughly and, when not in use, should be immersed in a water solution of pH 7 or so to prevent breakdown. Unbreakable electrodes are also available. A standard buffer solution of pH 7 should be purchased with the meter and used to calibrate the unit. Calibration has to be done quite frequently to maintain accuracy. A calibration control on the unit should allow the adjustment of the reading to pH 7 when the standard solution is being used.

The electrode should be rinsed between uses with clean water and immersed in clean solution. The meter should be turned to the "standby" mode when readings are not being taken and to the "pH" mode when a reading is being taken. The meter does not have to be turned off when not in use; putting it on standby lessens the need for recalibration.

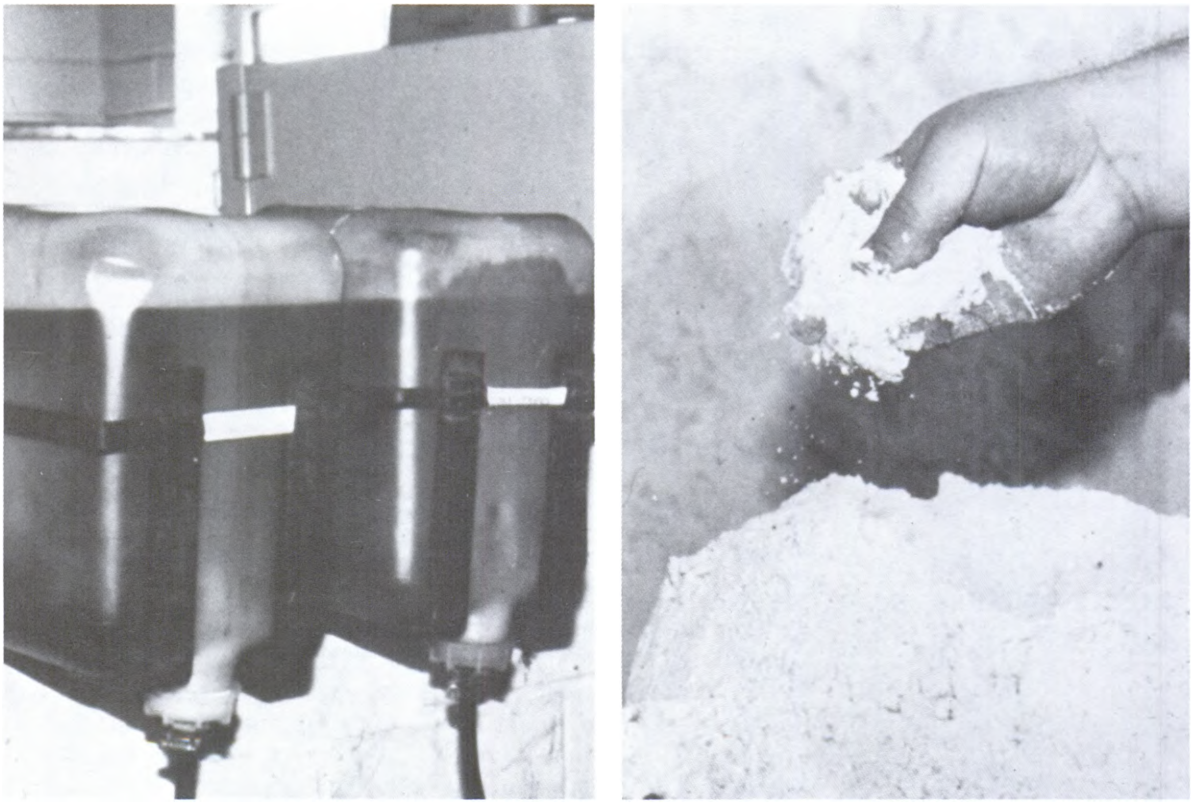
How should pH papers or sticks be handled?

pH papers or **pH color squares** or **plastic sticks** are accurate to within 0.3 of a pH unit if used correctly. They indicate a certain pH by means of a color change of the indicator material; accurately matching the color of the stick to the color standards supplied with them is the **major obstacle** in reading the pH correctly. It is often necessary to immerse the papers for longer periods of time (minutes) in mashes; gauging the immersion time can thus be a matter of judgment, increasing the inaccuracy. The indicator should also be matched to the standard while still moist, preferably within several minutes after development. The indicators should be kept dry and protected between uses, since moist air or water will cause the color to change. They also have a tendency to deteriorate after prolonged storage. Indicator sticks or papers are more accurate than the better known litmus paper, which should not be used. But even indicators are hard to read, and we recommend a pH meter.

How should enzymes be stored?

The **enzymes** to be used in the cooking come in liquid and dried forms, depending upon the manufacturer. Both forms should be kept in a cool, dry place (refrigerated enzymes will last 6 months). Coolness is especially important, since heated storage will cause some portions of the enzyme to lose activity, and consequently more enzymes will have to be added to achieve a desired result. If cool storage is not possible, only enough enzyme for a specific number of batches should be on hand at any one time — so that the enzyme can be used up before it can start to deteriorate. Enzymes generally can stay at room temperature (70°F) for two months without problems. Dry storage is more important for granular enzymes because if they get damp they may begin to lose some of their activity and will also become a good place for bacteria to start growing. Liquid enzymes will already be in tightly closed containers and generally will not be affected by dampness.

Liquid enzymes contain preservatives that prevent microorganisms from growing. These preservatives will not harm yeast because they are greatly diluted when mixed in the mash. Eventually, after long storage, the liquid enzymes may support growth of mold on the surface of the liquid.



Liquid enzymes (*left*) for dextrinization and saccharification should be stored in a cool place in closed containers. Yeast (*right*) can be adversely affected by many organic and chemical contaminants.

What are the difficulties associated with impure fermentations?

The fermentation can never be totally free of contaminating microorganisms, but care should be taken to reduce the incidence of infections that reduce ethanol yields. Infectious microorganisms use sugar as an energy source very easily but usually fail to produce ethanol; contamination can lead to reduced ethanol yields and weaken yeast performance. If the yeast from one fermenter is used to start another batch, infections are easily spread and rapidly get out of hand unless care is taken.

What are some likely contaminants and their characteristics?

Certain contaminating organisms are most likely to be encountered by fuel alcohol producers. Coliform bacteria inhabit soil and cling to grains and tubers and can also gain access to the fermenters through well water and operators. They develop quite rapidly in mashes of pH above 4, especially if the yeast does not establish itself quickly. Once a vigorous fermentation takes hold, these bacteria will generally be out-competed, especially if the pH falls during fermentation.

Acetobacter species of bacteria produce acetic acid (vinegar) from ethanol. They are quite acid tolerant but need oxygen for rapid growth, so they generally become a problem only if a fermentation stops early for some reason. If a fermentation stops and this goes undetected, these organisms could consume some of the ethanol present in the beer, especially if aerobic conditions accidentally become established due to cessation of fermentation.

Lactobacillus species of bacteria, a very potent contaminant, can grow under anaerobic conditions and in the presence of carbon dioxide. They may be introduced with infected cereal grains. These organisms will generally consume some of the sugar that the yeast could use to produce ethanol. Unlike other organisms, some **Lactobacilli** can drive a fermentation pH down all the way to 3.5; a fermentation pH less than 3.5 usually indicates their presence.

Pediococcus species are anaerobic and can grow over a wide pH range, utilizing sugars in the mash. They produce alcohol, and are not as destructive in a fuel-producing, as opposed to a beverage-producing, facility.

So-called "wild yeasts" are those of many species that can contaminate mashes by being introduced through the feedstock, dirt, water supply, or with operators. Since they often prefer the same conditions as the cultured yeast, they can grow rapidly and reduce the population of the wanted yeast. Many of them do not produce ethanol from the sugar they consume.

How should proper cleaning be done?

Often the best indications of contamination are a rapid drop of pH, a reduced output of ethanol from the fermenter, or less-than-vigorous fermentations. Microscopic examination of the mash will reveal some of the contaminants but will most often disclose deviations in the size and shape of the culture yeast cells, an indication that the cells are having trouble competing with the contaminants. Sometimes odors will reveal contamination. Coliforms will often produce celery-like or phenolic odors. **Acetobacter** will produce a characteristic vinegar smell, and **Zymomonas** will produce an offensive rotten fruit odor quite unlike the pleasant apple-like odor of a successful fermentation.

One idea for facilitating cleaning is to make tanks that have sloped bottoms for easy draining (Colorado Agro-Energy Inc. plant under construction, Monte Vista).

Thorough and constant cleaning is the only reliable means to prevent recurring infections. Breweries and distilleries often use CIP (clean-in-place) systems that wash all tanks and piping with 2% caustic (sodium hydroxide) solutions, followed by water or water-acid rinses. Washing takes place at least once a day and every time a tank is emptied. Small operations can use a high-pressure gun to spray the caustic inside tanks, and the solution can be pumped through piping with the same pumps used to transfer product. Spraying high-pressure steam into tanks and lines can also be of use. A caustic solution can be used more than once, provided remaining mash and beer have been rinsed from tank and pipe surfaces prior to application of the solution. The final rinse should be very thorough to remove any residual caustic.

Often small operators will make the mistake of leaving traps in piping that collect residual mash and beer. The traps serve to breed contaminants, which get washed into fermenters during mash pumping. Rinse-access ports in piping can make it easier to clear the pipes of residual organic material; sloping the pipes so that they can drain is also a good idea. **Simply cleaning tanks without cleaning piping and pumps is inadequate to prevent infection.**

This completes the steps of conversion and fermentation. This booklet does not cover the distillation and storage necessary to produce high-proof ethanol.

Step-by-Step Fermentation Procedures for Corn, Wheat, Barley, and Milo

What is the purpose of this procedure?

The purpose of this procedure is to give detailed, inclusive, step-by-step instructions that will result in consistently high yields of ethanol.

Instruction	Comments and Warnings
1 **Water Testing.** Test the water you will use in the production process for pH, nitrates and nitrites, and trace elements. This can be done through commercial laboratories or local farm support organizations. Your county agent can supply addresses of those who can perform these tests.	Usually, water in the United States conforms to the standards listed here. If it does not, it is usually easy to adjust it. See the refinements section (p. 29).
pH should be between 4 and 6.	
Nitrates and nitrites should be less than 50 ppm.	More than 50 ppm indicates polluted water.
Trace elements: Copper less than 1.0 ppm Fluoride less than 160 ppm Tin less than 360 ppm Tellurium and beryllium less than 350 ppm Nickel less than 185 ppm	These concentrations can inhibit the yeast population. Most drinkable water will have less than these amounts.
Needed trace elements (these can be added as sulfate salts): Magnesium needed, 300 ppm Zinc needed, 3.0 ppm	Magnesium is usually in great enough concentration in the feedstock.
2 **Choosing the Enzyme.** Choose the enzymes you will use for the conversion of starch to fermentable sugar. There are four basic choices of enzymes covered in this booklet; all are designed to be straightforward and effective. Choices **A** and **C** are the most common. The choices are A. Bacterial alpha-amylase at high temperature and fungal glucoamylase at moderate temperature added to the cooker. This is the fastest and most complex choice. B. Fungal alpha-amylase at moderate temperature in the cooker and fungal glucoamylase added to the fermenter. This is the simplest, slowest choice. C. Bacterial alpha-amylase at high temperature added to the cooker and fungal glucoamylase added to the fermenter.	In addition to the enzymes covered here, other equally effective enzymes are available that may vary in use and instructions. FOLLOW THE MANUFACTURER'S INSTRUCTIONS. If you cannot get enzymes exactly like those suggested here, you can still use this manual. Correct enzyme storage is important: improperly stored enzymes will not work.

D. Fungal alpha-amylase at moderate temperature and fungal glucoamylase at moderate temperature in the cooker.

These choices differ chiefly in how much time and energy is used during the mash cooking and fermenting. (A few other procedures also change during the cooking and fermenting and are covered below.)

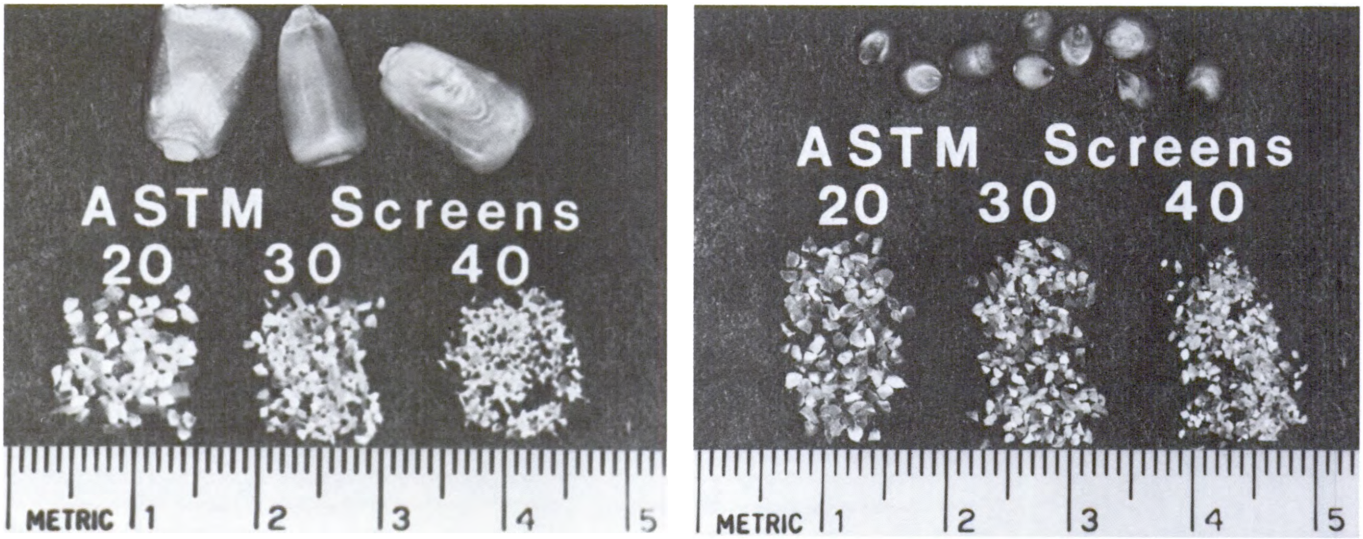
3 **Cleaning.** Clean the feedstock, removing excess dirt and any metal.

Microorganisms in dirt will be harmful to yeast, and dirt and metal can be very harmful to machinery. In no case should you use treated seedgrain: its fungicide may be harmful to the yeast and enzymes, as well as making the stillage inedible.

4 **Milling.** Mill the grain to particles of 20 to 40 U.S. standard mesh size (0.036 to 0.017 inch). This is about the consistency of whole wheat flour.

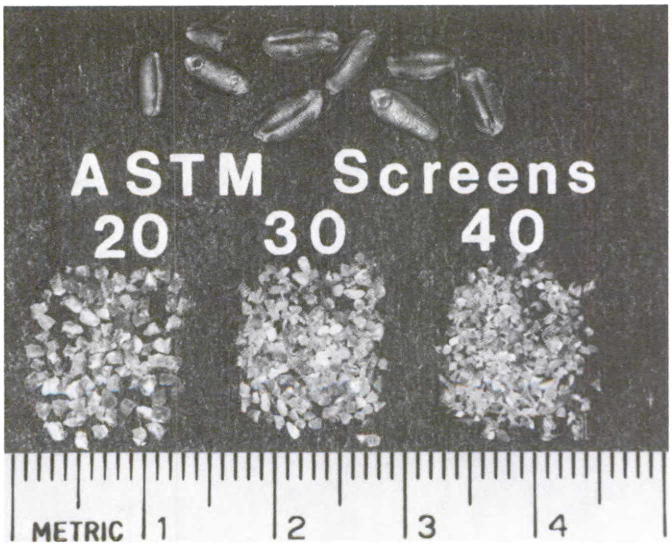
Do not just **crush** the grains; fermentation of crushed grains will not work! Erring on the side of **too small** is not as serious a problem. However, sizes smaller than 100 U.S. standard mesh may form lumps called "dough balls," especially if improperly mixed with water. **Note: Dust from milled grain is explosive.**

Various milled feedstocks over 20-, 30-, and 40-mesh screens, having passed through 18-, 24-, and 30-mesh screens, respectively. The ruler is scaled in centimeters, and the magnification is about 2.5 times.

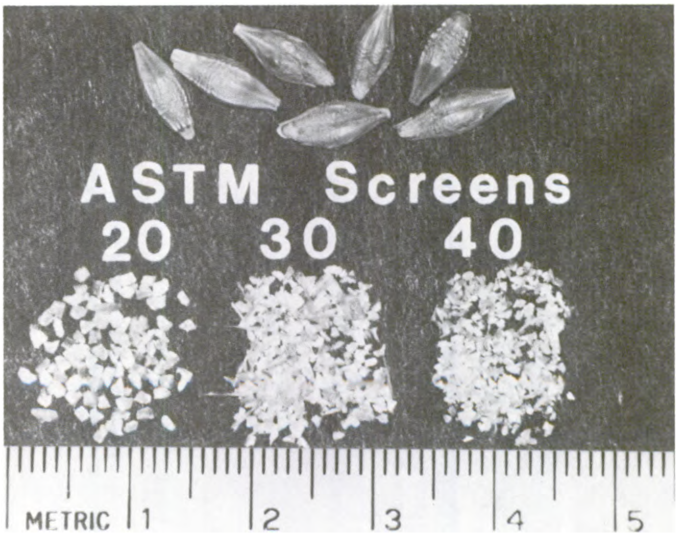


Corn

Milo



Wheat



Barley

Instruction

5 Blending. Mashes should be made in multiples of 100 pounds to make it easy to figure large or small batches and the weights of enzymes and of yeast to add. Proportions of grains and water to add to make **100 pounds of mash** are

	Pounds of Grain	**Volume of Tap Water**
Wheat	32	8 gal 1 quart
Barley	35	7 gal 3 quarts
Corn	30	8 gal 2 quarts
Milo	32	8 gal 1 quart

The volume of a hundred pounds of mash is about 11 gallons, or 1.5 cubic feet.

It is possible to make enough mash to fit any size vessel. Leave about 30 inches of headspace between the top of the cooking and fermenting vessels and the liquid level of the mash to accommodate the foam (generated by heat or CO_2) that will be produced during cooking and fermentation. Find the volume in gallons or cubic feet of the mash that your equipment can handle. Calculate and add the specified amount of water and then the feedstock, constantly mixing in the grains.

Comments and Warnings

It will be necessary to do some calculations to decide how much water and feedstock to mix in your specific case. By finding the volume of your tank, you can find the number of 100-pound units of mash the tank will hold by dividing the volume (in cubic feet or gallons) of the tank by 1.5 (for cubic feet) or 11 (for gallons). For instance, if you can process 1100 gallons of mash, divide 1100 by 11 to find that you need one hundred 100-lb units of mash. For corn, using the proportions given in the blending table, that would be 300 pounds of corn and 85 gallons of water.

Since the amount of acid or base solution needed to adjust the pH cannot be specified here (see Step 6!), it will be necessary to add pH-adjusting liquid **after** Step 5 the **first** time **only.** This will result in an incorrect, overly diluted mash (slightly). This is not a significant problem, especially the first time. However, in dilutions (Step 5) and pH adjustments (Step 6) for subsequent mashes, the amount of acid or base

6

pH Adjustment. The pH of the mash must be adjusted before hydration. You will be using either bacterial or fungal alpha-amylase for dextrinization **so follow the manufacturer's instructions, especially if they differ from our recommendations.**

Check the pH of the mash with pH papers or a pH meter.

Adjust the pH as follows (see below for specific instructions):

- **for bacterial** alpha-amylase, to pH 6.0-6.5 with 2N NaOH or KOH;
- **for fungal** alpha-amylase, to pH 4.0-4.5 with 2N H_2SO_4 if necessary.

The 2N solutions of the pH-changing chemicals can be made as follows:

- 2N H_2SO_4 (sulfuric acid)—210 milliliters (7 fluid ounces, or about one cup, of concentrated H_2SO_4) per gallon of water yields 2N H_2SO_4.
- 2N NaOH (sodium hydroxide, or caustic)—11 ounces (308 grams) of NaOH pellets per gallon of water.
- 2N KOH (potassium hydroxide)—15 ounces (420 grams) of KOH pellets per gallon of water.

The chemicals can be purchased in various forms. If they are already liquid, look for the "N," or "normality," designation. The normality designation will be preceded by a number; the greater the number, the stronger the solution. If solutions stronger than 2N are used, smaller volumes will be needed to change the pH of the mash; but stronger solutions are also **much more dangerous.**

solution for pH adjustment will be known. Therefore you can leave this amount **out** of Step 5 when the mixture of tap water and feedstock is being made and add it in Step 6 in the form of the correct acid or base solution.

The 30-inch headspace of the tank is a rule-of-thumb: your case may be substantially different.

The chemicals called for in this step are extremely dangerous. Wear rubber gloves, rubber apron, and a face shield and work in a well-ventilated area. Even breathing the vapor can cause damage. The chemicals must be stored and handled with caution or not at all. Those who think otherwise will soon find themselves in the hospital.

BE CAREFUL WITH THESE CHEMICALS

Store chemicals in glass or plastic bottles, properly labeled and out of reach of children (the chemicals are deadly). When mixing acid with water, **add the acid to the water**, not the water to the acid. Heat is generated when these chemicals are mixed with water. If they get on clothes or skin, wash immediately in cold water. Either an emergency shower stall or a powerful hose should be handy for emergency washing.

We do not recommend the use of high-concentration chemicals for pH adjustments.

Instruction	Comments and Warnings
Rather than give a hard-and-fast rule about the amount of 2N solution of base or acid to be added to bring about a specific pH change, we suggest a simple trial-and-error method. It will be necessary to add small amounts of the chemicals **(1 pint of 2N solution per 100 pounds of mash in any one addition)** and to check the pH with the pH meter or papers after every addition until the proper pH is reached. **The amount of the chemical used should be recorded so that the same amount can be used in future batches.** This known amount of liquid should be subtracted from the total water necessary to make 100 pounds of mash in Step 5. For instance, if 8 gallons and 1 quart of water are to be added to 32 pounds of wheat to make 100 pounds of mash, and 2 gallons of chemical are necessary to achieve the pH change, then only 6 gallons and 1 quart of process water should be added during the **blend** of feedstock and water (Step 5); the other 2 gallons of water will be provided by the chemical solution added during the pH change. Measure the mash's pH at the end of this procedure, and adjust it with small amounts of 2N solution.	The trial-and-error method is just that: it means pouring in small amounts until finally the pH meter (or papers) reads as the enzyme manufacturer says it should. **Do not overshoot if you can help it!** If you do, it can be fixed by adding a solution of the opposite type (acid or base). However, this also adds to the amount of water in the mash, which should be avoided if possible.
There may be some evaporation during the cooking, so after mixing the feedstock and water and adjusting the pH, mark the liquid level in the tank. After cooking (Step 10), more water may be added to bring the level back to the mark.	
7 **Adding Trace Elements.** This is a good time to add any trace elements that may be necessary, such as calcium and zinc. The process water testing will have shown what trace elements are present. About 50 to 400 parts per million (ppm) of calcium will help protect the enzymes and keep them working, and about 3 ppm of zinc will help the yeasts perform well. If the process water has more than these amounts of calcium and zinc (up to 500 ppm), it will not be harmful. If the process water has less than these amounts, 330 milligrams, or 0.33 grams, of zinc sulfate and 8 to 64 grams of calcium sulfate may be added per 100 pounds of mash to bring the levels up.	To weigh the trace elements, use the gram scale called for in the list of equipment.

Instruction	Comments and Warnings
8 Hydration and Dextrinization. The mash is ready to be dextrinized, the first step in converting starch to fermentable sugars. If you have followed the instructions of Step 5, you have about 21 pounds of starch per hundred pounds of mash. Use this number, or convert it to the unit the manufacturer requires, to determine how much alpha-amylase to add. For instance, one manufacturer asks for 0.15% alpha-amylase by weight of starch. Multiply 21 pounds of starch by 0.0015 to get 0.0315 pound (14 grams) of enzyme for each 100 pounds of mash. Multiply this number by the actual number of 100-pound units in your mash to get the proper amount of alpha-amylase.	Actually, the amount of starch per 100 pounds of mash varies somewhat, depending on conditions and feedstock: 21 lb — or slightly more — is a good estimate for this calculation. The amount of grain used for mash blending (Step 5) was designed to give about this optimal concentration of starch.
Begin to stir the mash; **continue this throughout.** There are two possible procedures, depending on whether you have bacterial (A) or fungal (B) alpha-amylase. Always check our recommendations against those of the manufacturer: A. **For bacterial alpha-amylase —** **A1. Heat the mash slowly** to about 130°F (54.5°C) while adding 25% of the amount of bacterial alpha-amylase specified by the manufacturer. A1. Continue to heat **slowly** to 160°F (7.1°C), add the rest of the alpha-amylase to equal the manufacturer's recommended amount, raise the temperature slowly to 194°F (90°C), and hold while mixing continuously for the time specified by the manufacturer, usually one to two hours.	Do not burn the mash. Always heat the mash **slowly:** about 2°F (1°C) per minute. The alpha-amylase is added partially to keep the mash fluid enough to mix it. Mixing at all times is necessary for proper heating, hydration, and enzyme activity. Using the wrong pH range or overheating will inactivate or destroy the enzymes. The faster (more efficiently) you can perform your process — following **all** the instructions carefully — the less the chance of contamination and the less overall costs and energy use.
B. **For fungal alpha-amylase —** **B1. Heat the mash slowly** to about 130°F (54.5°C) while adding 25% of the amount of the fungal alpha-amylase specified by the manufacturer. B2. Heat the mash **slowly** to 190°-212°F (88°-100°C). Hold for about one-half hour. B3. Cool the mash **slowly** to 131°-140°F (55°-60°C), add the rest of the fungal alpha-amylase, and hold for two to three hours.	Some bacterial alpha-amylase is destroyed at this temperature, and others can actually work better at higher temperature; check your manufacturer's instructions.
9 Check Reduction to Dextrins. To see if this part of the process is complete, check for liquefaction (reduction of starch to dextrins) with an iodine solution. To do this, place a drop or two of the mash on a white surface and apply a drop of iodine solution to it. The mixture will be blue if starch is present, purplish if some dextrins are present, and red or yellow if all the starch has become dextrin. If starch is still present, hold the mash for a longer period or, if necessary, add	Keep mixing the mash continuously. Many mashes (whole grain wheat or barley) give very nice, clear yellow tests after conversion. Corn mash will give a "false" positive (purple) after even a good conversion unless it is filtered. Even when filtered, it may give a reddish-purplish

more enzyme. **Corn mashes will need to be filtered before being tested with iodine** since some starch is always present in a corn mash, even with a good conversion; the mash sample can be diluted with water before filtration. Test the filtered liquid, not the residue. Tincture of iodine, obtainable from a drugstore, can be used. One part tincture of iodine should be diluted with nine parts of water before it is used to test for the presence of starch. Prepare a new solution every month and store it in a dark place in a brown bottle.

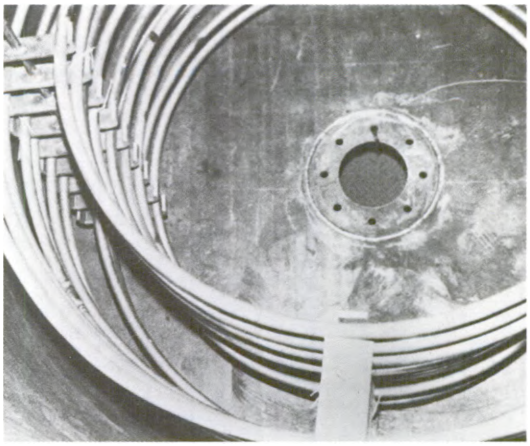
10

Completing the Starch Conversion. At this point, the dextrinization is complete. There are now usually two ways to proceed, depending on your choice of fungal glucoamylase. Either you have fungal glucoamylase that is added to the **cooker** (A) or you have fungal glucoamylase that is added directly with the yeast to the **fermenter** (B). The first is faster because most of the starch becomes fermentable sugars before fermentation begins, accelerating the fermentation; the second is easier because the process is done entirely in the fermenter. Start by calculating the amount of glucoamylase you will add, using the amount of starch per 100 pounds of mash and the manufacturer's instructions. Remember, there are about 21 pounds of starch per 100 pounds of mash. Then proceed with A or B:

A. **For fungal glucoamylase working in the cooker —**
   A1. Begin cooling to 140°F (60°C) the now liquefied mash and adjust the pH to 4.0 to 4.5 with 2N H_2SO_4, mixing continuously. The same trial-and-error procedure for adjusting pH as outlined before (but not the same amount) should be used.
   A2. When the temperature reaches 140°F (60°C), add the glucoamylase as the manufacturer recommends, based on the 21 pounds of starch per hundredweight present in the original mash.
   A3. Continue agitating the mash at 140°F (60°C) for two hours while the dextrins are broken down into fermentable glucose molecules.
   A4. Cool the mash to 86° ± 5°F (30° ± 2°C), which is the fermentation temperature.

result, and the operator will have to exercise some judgment gained from experience.

Mix the mash continuously. Always check and follow the manufacturer's instructions if they differ from those given here.

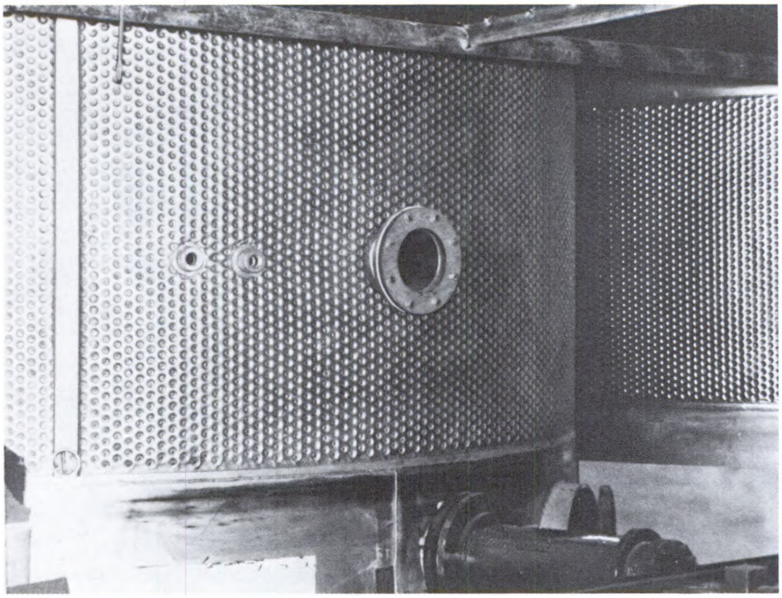


Rapid cooling of the mash can be done by heat exchange piping inside the cooker. Cold water running through the pipes carries away the heat. Mash contamination can result if cooling is not done quickly. The hole at the bottom of the tank is for the agitator.

Cooling should be done in less than two hours to minimize the possibility of **Lactobacillus** infection. **Lactobacillus** is especially dangerous if the mash stays at about 100°F (38°C) for several hours. Clean tanks will help avoid contamination if circumstances prevent cooling from being completed quickly.

Instruction	Comments and Warnings
A5. Check the mark in the tank indicating the original amount of mash. If the mash has fallen below the mark due to loss of water during the cooking, add enough to reach the mark. This concludes Step 10 for this enzyme; go to Step 11, fermentation.	If there is slightly too much liquid because of pH adjustments, no harm is done.
B. **For fungal glucoamylase working only in the fermenter —** B1. Begin cooling the mash. Check the pH, and adjust it to 4.5 to 4.7 if necessary (it will be, if you have used bacterial alpha-amylase), using 2N H_2SO_4. Mix continuously.	
B2. Cool to 86° ± 5°F (30° ± 2°C). Add the proper amount of fungal glucoamylase, as calculated on the basis of starch weight per 100 pounds of mash as the manufacturer recommends.	Cooling should be done in less than two hours to minimize the possibility of **Lactobacillus** infection. **Lactobacillus** is especially dangerous if the mash stays at about 100°F (38°C) for several hours. Clean tanks will help avoid contamination if circumstances prevent cooling from being completed quickly.
B3. Check the marker in the tank that indicates the amount of original mash. If the mash has been depleted, add enough water to return to the mark.	If there is slightly too much liquid because of pH adjustments, no harm is done.
11 **Fermentation.** The mash is now ready to be fermented. The pH of the mash should be 4.5 to 5.0, and its temperature should be 86° to 90°F (30° to 32°C). Distiller's yeast can be purchased in the dry form from several suppliers; it is generally called distiller's active dried yeast (DADY). About 0.5 to 1.0 ounce (14 to 28 grams) of the dried yeast per 100 pounds of mash will provide enough cells to start the fermentation. It is a good idea to wet the cells in a volume of tepid (less than 100°F) water equal to about five times the weight of the cells before they are added to the mash; a 5- to 10-minute soak is enough.	Baker's yeast will not work. Fermentation should be begun **as quickly as possible** to minimize the growth of contaminating organisms.

Yeast is rather delicate and must be handled correctly. The dried yeast should be stored in a cool, dry area. Excessive humidity could wet the yeast, causing it to become active and die if it is not used almost immediately. When wetting the yeast, just the amount needed for one batch should be used, and it should be added to the mash within 10 minutes of wetting. Liquid yeast cannot be stored well, even if refrigerated, unless it has nutrients to live on. Yeast in water will begin to consume itself if it is not supplied with food. Healthy, vigorous yeast cells are very important to successful, fast fermentation.

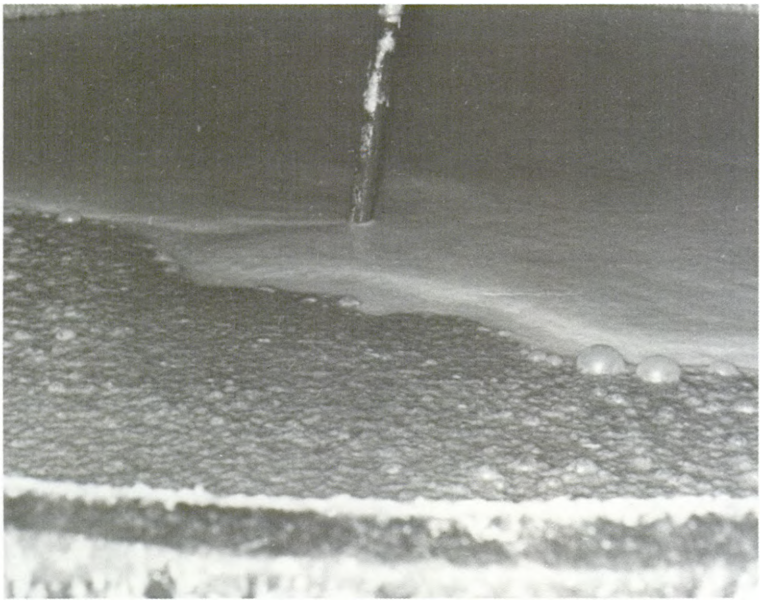


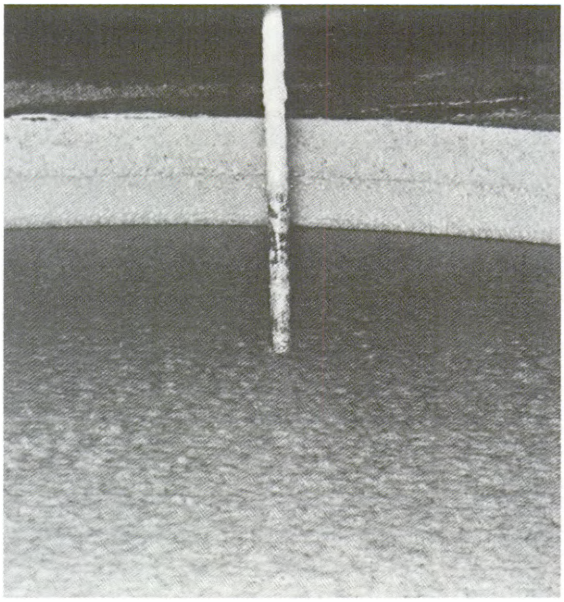
Fermentation is very sensitive to temperature variation, especially after the yeast has been acclimated to the mash. Temperature variations of even 4° F can be enough to disturb the yeast. To control temperature in the fermenter, it is necessary to have a cooling system such as the water jacket shown here because fermentation produces heat that must be dissipated.

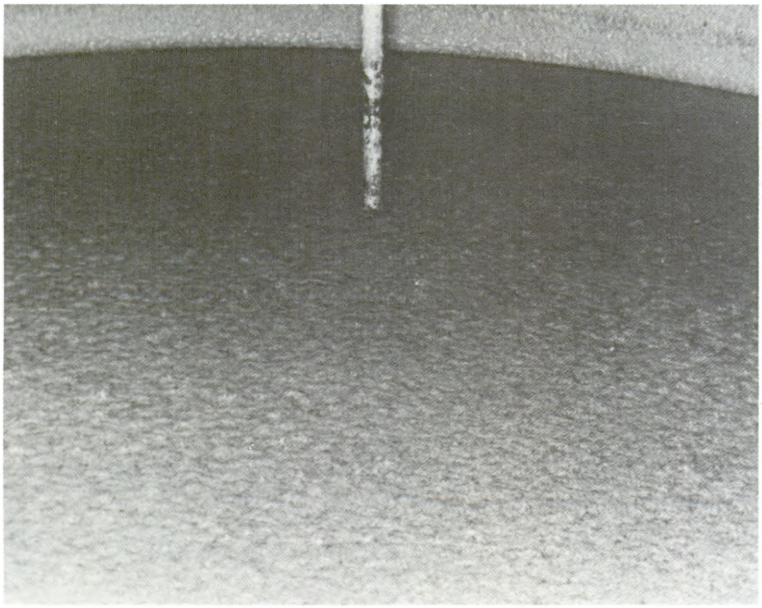
Once the yeast cells have been added, the cell population will increase and fermentation will begin. Fermentation generates about 500 Btu of heat per pound of ethanol produced. This heat must not be allowed to raise the temperature of the mash beyond 90°F (32°C). Carbon dioxide will also be generated, and it should be vented to the outside air, not inside a closed building. If the fermentation vessel is closed, the mash can be continually mixed as it ferments. If the vessel is open, mixing should be very gentle to avoid mixing oxygen into the mash.

Dissipating heat from fermentation almost always requires mechanical cooling such as the circulation of cold water in cooling pipes.

Fermentations should be completed within 48 to 96 hours, depending upon the type of glucoamylase used. Use of glucoamylase exclusively in the fermenter tends to lengthen fermentation time. Check for completed fermentation using a hydrometer, as explained in the refinements section, p. 30. Another way to check for unconverted glucose is with a urine enzymatic glucose test tape or kit (as indicated in the list of equipment).







Fermentation takes about 48 hours. After about 24 hours (*top left*), the fermentation is extremely active: CO_2 is rising to the surface along with natural oils. The rear portion of the tank shows as yet unconverted mash. After 39 hours (*above*), most of the mash sugars have been converted to ethanol. The yeast have entered their "death phase" due to a lack of food and because of the presence of their waste product, ethanol. After 44 hours (*left*) the fermentation is nearly over. The surface is homogeneous, with very little CO_2 surfacing and natural oils dispersed evenly. The ethanol concentration is nearly 10%.

Refinements

In what follows, further refinements are given that could be applied by those who are accomplished in fermentation and want to enhance their ethanol yield.

Instruction	Comments and Warnings
1 **Water Treatment.** It may be necessary to treat water for hardness or excess trace elements. Excess hardness can be treated in a relatively simple manner. The well-known water softeners found in private homes will work if your process uses only small amounts of process water. The same principles apply to large softeners that deal with greater water amounts. **All that is necessary is to purchase an industrial-sized water softener (as per your own needs).** Basically, the material in the softener, called zeolite, traps the metal ions of the salts that are making the water hard. When all the zeolite has been reacted, a strong salt (sodium chloride) solution is automatically forced through the softener, causing the zeolite to become regenerated and ready to soften more water.	Use judgment about water treatment. If the water to be used in the fermentation process is fit for human consumption, it probably will not need to be treated, except perhaps to soften it to prevent added zinc, calcium, or magnesium from forming salts, which would make these needed nutrients unusable by the yeast or enzymes.
Methods for treating alkalinity involve precipitating the dissolved salts causing the alkalinity; they are brought out of solution by physical or chemical means and settle. Boiling the water will convert bicarbonates to carbonates, which will precipitate. Hot lime solutions [CaO or $Ca(OH)_2$] also precipitate carbonates. Hot soda ash (Na_2CO_3) solutions precipitate sulfates. Calcium chloride ($CaCl_2$) and sodium phosphate (Na_3PO_4) can also be used to precipitate these materials. After the precipitates settle, the water is decanted, that is, poured off, leaving the solids on the bottom of the tank. In some cases, it is necessary to further filter the decanted water to clarify it again.	Excess alkalinity may cause scaling on equipment.
If it is necessary to eliminate specific metals from the water, for instance excess copper, ion exchange resins may be used. These are available from commercial suppliers, who will set up the system and detail its use.	
5 **Backset of Stillage.** To conserve water and energy, it is possible to recycle hot, acidic (pH 4 to 5, usually) stillage from the still by feeding it into the cooking vat where the feedstock is being blended. This replaces an equal amount of process water, which would otherwise have to be heated. If fungal alpha-amylase is to be used, backset has the advantage of adjusting the mesh pH to about 4 to 5. Thus less acid would be needed for the cooking steps.	It may not be possible to set this up in your situation — you may not have enough vessels, and stillage directly from the still may not be available when you need it. Do not use old stillage because of probable bacterial contamination.

11 **Yeast for Fermentation.** It may not be necessary to use a new portion of dried yeast for every new fermenter batch. A portion of an ongoing fermentation may be pumped into a fresh fermenter along with fresh mash to "seed" the new batch, thereby adding the yeast necessary to carry out fermentation. More than one fermenting vessel is necessary when using this method, and all vessels, pipes, and pumps must be kept **very** clean.

Yeast cells often reach a high population level in grain mashes after about 12 to 15 hours of fermentation. This is the time to transfer about one-third of the volume of the ongoing fermentation into a clean, empty fermenter and to fill the remaining two-thirds of the volume of the new fermenter with fresh mash. Be certain the temperature of the incoming fresh mash is at fermentation temperature (86° to 90°F; 30° to 32°C); temperatures over 100°F (38°C) will harm the yeast. The first vessel from which the one-third-volume working mash came is then refilled with fresh mash. Both vessels are then working, and the process can be repeated 12 to 15 hours later, using the second vessel as the source of the "seed" yeast for a third vessel. If this method is used, it is vital to maintain good cleanliness, as any infection will be spread rapidly.

Spontaneous mutations and general weakening of the yeast can also be a problem when using this method over a long period of time, so it is a good idea to add fresh, commercially dried yest cells to a fermenter once every week to initiate a new population.

Checking for Unfermented Sugars. Finished fermentation mashes (beers) should be checked to see if there is any unfermented sugar. This can be done with glucose test strips (as mentioned in the text) or with a hydrometer, which is discussed here. Sugar solutions have specific gravities (weight per milliliter of solution), which can be measured using hydrometers. There are three types of hydrometers that can be used — °Plato, °Brix, and regular specific gravity. °Plato and °Brix hydrometers are calibrated to directly read percent by weight of sugar in solution, or grams of sugar per 100 grams of mash; a 0% to 10% calibration is adequate for this work. Specific gravity hydrometers are calibrated to read direct weights of milliliters of solution; for example, a specific gravity of 1.07 to 1.08 reveals a sugar concentration of 17% to 20%. Measurement of the solutions must take place in a cylinder specific to the type of hydrometer; the cylinders can be purchased with the

The cylinder must be large enough for the hydrometer to float freely.

hydrometer. Hydrometers are effective on filtered (clear) solutions and will not work with beers that still contain the grains. Beer samples for testing should be filtered using coarse filter paper or fine cheesecloth in a funnel, and then the filtered liquid should be tested.

When a beer has been considered to be finished — that is, 48 to 96 hours have passed since the onset of fermentation — it can be tested for the amount of sugar remaining, if any. A good fermentation should leave little or no residual sugar. The sample is filtered, the liquid placed in the measuring cylinder, and the hydrometer dropped into the liquid and allowed to stabilize. A °Plato or °Brix hydrometer should show 1.0% or less of sugar remaining. The specific gravity hydrometer should show a reading of 1.004 **or less**. If readings are higher than this, the fermentation can be left for 8 to 12 more hours and checked again. If readings are very much higher (2.0° Brix or 1.008 specific gravity), more yeast can be added (which sometimes helps) and/or the fermentation can be left for another 12 hours and retested. If no change occurs after this treatment, further fermentation may not be achievable, and the mash should be sent to distilling.

12 **Checking Proof after Distillation.** It is possible to measure the ethanol content (proof) of the liquid from the finished distillation; it should be mostly ethanol. The proof of the distillate can be checked rapidly using a hydrometer. The hydrometer is calibrated to directly read proof from 0 to 200 (0% to 100% ethanol). The distillate must be placed for measurement in a special cylinder purchased with the hydrometer. The still should be delivering at least 150-proof ethanol.

13 **Calculating Your Yield.** To judge the efficiency of your process by comparing it with a maximally efficient process, it is necessary to

A. Assay the feedstock at a local agricultural lab for:
  a. starch
  b. protein
  c. fiber
  d. ash
  e. moisture

a and **e** are the most important.

These amounts will often be reported as percent by weight of whole grain. One problem — many methods for starch measuring actually measure glucose. The lab should specify what is actually being reported so that step D below (multiplying by 1.11) does not give a higher value than actual.

B. Multiply the weight of feedstock you used as specified in Step 5 for 100 lb of mash times the starch percentage found above. This is the amount, by weight, of starch you have in 100 lb of mash. (We have been using 21 lb in the procedural section.)

C. Multiply the amount of starch found in **B** by the conversion efficiency of starch to sugar. This will vary, depending on how well your process performs. A good conversion efficiency, and one you can use for an estimate, is 90%.

D. Fermentable sugars weigh slightly more than starches (they incorporate a water molecule for each molecule of glucose produced during conversion). Multiply the number found in **C** by 1.11 to account for this effect. This is the weight of fermentable sugars in 100 lb of mash.

E. Multiply the weight of fermentable sugars found in **D** by 0.47. This is the efficiency (47%) of the conversion from sugar to ethanol via fermentation, including some loss in efficiency due to yeast cell maintenance and production of some by-products other than ethanol.

F. Multiply the figure calculated in **E** by the recovery efficiency of your still. This is 50%-97%; use the latter for an estimate.

G. Divide the number found in F by 6.6 lb/gal to get the number of gallons of 200-proof ethanol produced from your feedstock per 100 lb of mash.

H. Different grains have different weights per bushel.

Corn	56 lb/bu
Wheat	60 lb/bu
Barley	48 lb/bu
Milo	57 lb/bu

To find the fraction of a bushel you have per hundred pounds of mash, divide the amount of the grain used per hundred pounds of mash by the weight per bushel of that grain.

I. To find ethanol yield in gallons of 200 proof per bushel, divide the figure found in **G** by the figure found in **H**.

When combined into a formula, the above is

(B)		(C)
wt. of feedstock in 100-lb mash multiplied by the percentage of starch in the whole grain	×	starch-to-sugar conversion efficiency: 0.90%

	(D)		(E)		(F)
×	(1.11)	×	sugar-to-ethanol conversion efficiency: 47%	×	0.97

(G)

÷ 6.6 lb of ethanol/gal = gal of 200-proof ethanol/100 lb of mash

(H)

$$\frac{\text{grain used per 100-lb mash}}{\text{weight per bushel of that grain}} = \text{fraction of bushel used per 100-lb mash}$$

(I)

$$\frac{\text{gallons of ethanol per 100-lb mash}}{\text{fraction of bushel used per 100-lb mash}} = \text{200-proof ethanol yield per bushel}$$

These formulas can be simplified somewhat. Since the **C** to **G** terms are constant, they can be combined by multiplying them together. The formula from **A** through **G** for the number of gallons of 200-proof ethanol produced by each 100-lb unit of mash then becomes

$$\text{wt. of feedstock in your 100-lb mash} \times \text{\% of starch in the whole grain} \times 0.069$$

= gallons of 200-proof ethanol/100 lb of mash.

This result can then be used in **H** and **I** to provide the ethanol yield per bushel you **should** be getting. If you are not getting this yield, your process can be improved.

Equipment, Chemical, Enzyme, and Yeast Suppliers*

General Products

Fisher Scientific
Corporate Headquarters
711 Forbes Ave.
Pittsburgh, PA 15219

Scientific Products
General Office
1430 Waukegan Rd.
McGaw Park, IL 60085

Sargent-Welch
Sales Service Center
8709 Grovemont Circle
Gaithersburg, MD 20760

Enzyme Manufacturers

Miles Laboratories, Inc.
Enzyme Products Division
P.O. Box 932
Elkhart, IN 46515
(219) 264-8111

Novo Laboratories, Inc.
59 Danbury Road
Wilton, CT 06897
(203) 762-2401

Premier Malt Products, Inc.
1037 W. McKinley
Milwaukee, WI 53201
(414) 347-7300

Biocon (U.S.), Inc.
261 Midland Ave.
Lexington, KY 40507
(606) 254-0517

Scientific Products Co.
North Kansas City, MO 64116
(816) 221-2533

ColorpHast Plastic Indicator Sticks

EM Laboratories, Inc.
500 Executive Blvd.
Elmsford, NY 10523

MC/B Manufacturing Chemists, Inc.
2909 Highland Ave.
Cincinnati, OH 45212

Yeast Suppliers

Red Star Yeast
Fermentation Products Division
Universal Foods Corporation
433 East Michigan St.
Milwaukee, WI 53201
(414) 271-6755

Biocon (U.S.) Inc.
261 Midland Ave.
Lexington, KY 40507
(606) 254-0517

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*This list is necessarily not all inclusive and is meant neither to recommend nor to eliminate by its incompleteness.

This Appendix is taken from *Fermentation Guide for Potatoes: A Step-by-Step Procedure for Small-Scale Ethanol Fuel Production*, SERI/SP-751-1006. The complete publication is available from the superintendent of Documents, Government Printing Office, and from the National Technical Information Service.

Appendix H

Fermentation Guide for Potatoes

Introduction

The information contained in this booklet is designed to inform you of the steps necessary for successful **batch** starch conversion and fermentation of potatoes for the production of fuel alcohol (ethanol). The advantage of the batch process for small-scale producers is that it minimizes potentially harmful interactions between steps.

No matter what you may have heard before, the efficiency of your efforts to produce alcohol does not come solely from the still. The alcohol to be distilled comes from fermenting glucose converted from the starches in the potatoes. If the fermentation is successful every time and produces as much alcohol as possible for the capacity of the fermenting vessel, then an effective operation is possible. If, on the other hand, the fermentation process is ignored or left to itself as a "natural" process, then it is likely that **much** of the glucose will not be converted to alcohol, and poor ethanol yields will result. Often, those producing ethanol are unaware of how inefficient their process is and of its true potential. By following the directions in this booklet carefully, you should be able to consistently produce a yield of ethanol that can be 6.5% to 8.5% of the weight of the mash in the fermenting vessel depending upon the initial starch concentration of the potato.* For potatoes, this is about 1.1 gallons of 200-proof ethanol per 100 lb of potatoes.

The first part of this booklet is an overview of ethanol production from feedstock to fermentation. The central part of the booklet is a recipe section that gives step-by-step procedures necessary for successful fermentation. Following that, there are refinements that can help improve ethanol production. Of all the sections, the procedural one is the most important. The other sections are designed to help you understand it.

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*These results are documented in **Fermentation Studies of Wheat, Barley, Corn, Milo and Potatoes** by Kent Lines of Energy Incorporated, P.O. Box 736, Idaho Falls, ID 83401 (1981).

Available from GPO: Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402
Available from NTIS: National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161
Contact these agencies for current price and ordering information.

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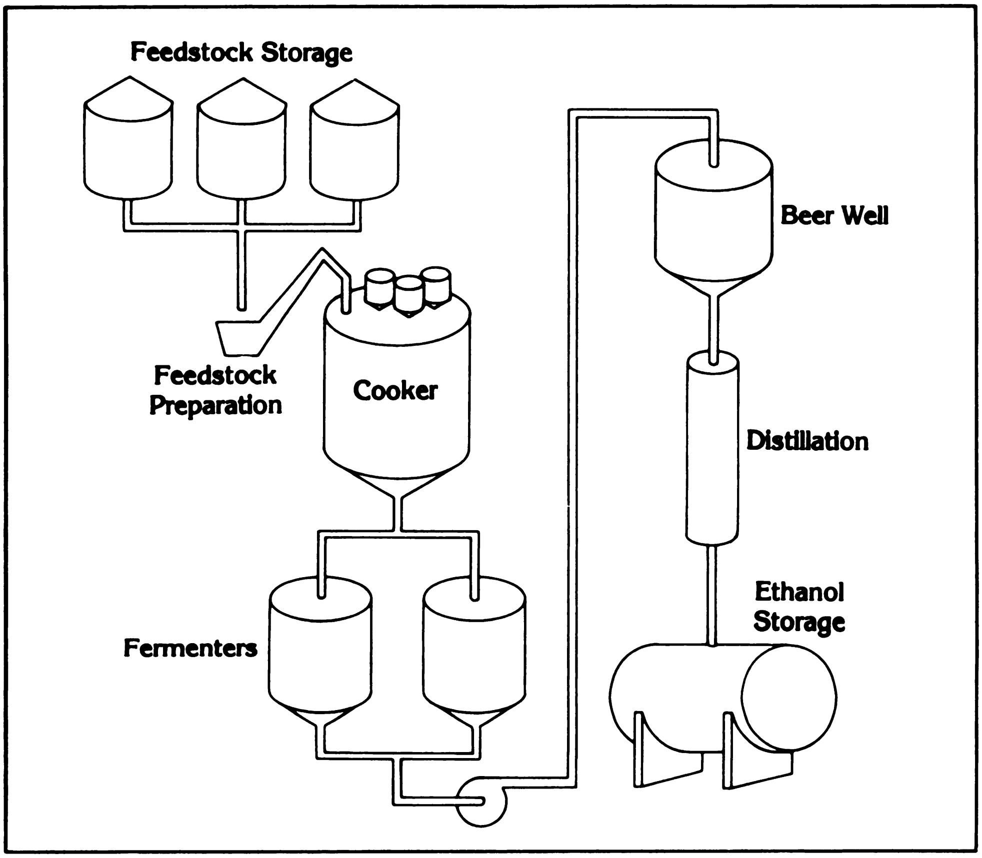
Solar Energy Research Institute
1617 Cole Boulevard
Golden, Colorado 80401

Major Steps in Ethanol Production

- **Water Testing.** Chemicals in water can harm the yeast used in fermentation. The water will need to be tested and perhaps adjusted.
- **Preparing the Feedstock.** The feedstock should be washed to free it from dirt, and any metal objects should be removed. It is then crushed to a "mash" that has the consistency of a milkshake.



An idealized flow diagram of ethanol production. The **Fermentation Guide** covers *feedstock preparation, cooking,* and *fermentation.*

- **Mash Cooking.** The pH of the mash is adjusted; enzymes for conversion are added; and the mash is heated. This breaks down the starches to fermentable sugars.
- **Fermentation.** Conditions suitable for good yeast growth are established, and a specific amount of yeast is added to the mash. The yeast acts on the sugars in the mash, fermenting them and producing ethanol.
- **Distillation and Storage.** The ethanol produced during fermentation is separated, or distilled, from the mixture of water and fermented feedstock. This booklet does not go into the details of distillation and storage.

Equipment and Chemicals

What equipment and chemicals are needed, and what do they typically cost?

Proper preparation for consistently high yields of ethanol includes getting the right equipment and chemicals. Despite the cost involved, deciding to "cut corners" by not purchasing proper items will produce inadequate results.

This booklet deals with the chemical and biological rather than the engineering aspects of ethanol production. Setting up the ethanol plant should be done with an expert. Production efficiencies (use of low-grade fuels like coal and farm wastes, recycling of heat and water) can determine a plant's overall profitability.

The following lists of equipment and chemicals can only be a guide. Actual prices and types of equipment vary widely.

Typical Costs (1981)	Major Equipment
\$3000–\$3500	A **hammermill** (with 1/4- or 1/8-inch screen) or similar milling device will be capable of reducing the feedstock to a milkshake-like consistency. Slicing and crushing or using a grinder may suffice (and will be much cheaper). No particle should be larger than 1/8 inch when milling is complete (no lumps or chunks should be visible).
\$6.00 to \$10.50 per sq ft of surface area, depending upon thickness. Prices will vary in different areas.	**Containers for cooking and fermenting** may be of the same size, shape, and material. Carbon steel is satisfactory. The thickness of the steel depends upon the size of the tank and the amount of liquid it is expected to hold; 10-gauge steel to 1/4-inch steel will probably be satisfactory. Methods to heat and cool the tanks are necessary, as are a drain and a vent for the fermenting tanks. Some provision for cleaning should be made. Tanks may be closed or open, though the former are much to be preferred.
15-hp motor — \$4800, 3-hp motor — \$1250. Prices will vary, as will needs.	**Electric motors** and agitators for mixing the cooker and fermenter are necessary. The success of potatoes processing, especially in the starch-to-sugar conversion step, depends greatly on the agitation system involved. If the agitator is ineffective or the motor too weak to do the job, the potatoes will become so thick that conversion will fail. On the other hand, good mixing will soon result in a successfully converted mash. One system may use a 15-hp motor for an 11,000 gallon cooker, but a similar tank with a less-well-engineered agitator blade might need a 40-hp motor. A 3-hp motor should be sufficient for the fermenter. A good type of agitator blade to use would be similar to a boat propeller, the blades rounded and pitched. Other designs are possible, even superior, but should be tested for efficiency.
\$25–\$300, depending upon type	**Pumps** will be necessary to move mash, beer, and alcohol from tank to tank. They should be of a kind that can be cleaned and should stand up to the corrosion caused by grains and low pH.

Typical Costs (1981)	Minor Equipment and Chemicals
$325	A **pH meter** is a very accurate and relatively difficult device to use and maintain, but is highly recommended for best results.
$2.50 to $7.50 (100 sticks)	Narrow-range pH **papers** or **sticks** (rather than a pH meter) may be used if one does not desire precise readings. Also, they are less complicated to use and maintain than a meter. They can, however, deteriorate and give inaccurate readings. **Do not confuse pH papers or sticks with litmus paper, which will not work.**
50-lb scale—up to $400; 500-gram scale—$80 to $130; Parow—$600	**Scales** are necessary to weigh feedstock quantities in pounds and chemical and enzyme quantities in grams. A "Parow" balance can be used for starch determination.
Rent or borrow one—it may only be needed a few times.	**A metering device for water** that measures gallons, or some other way (a bucket) to measure gallons of water.
$25	A **thermometer** (metal is best) in either degrees Celsuis (30°–100°C) or degrees Fahrenheit (80°–212°F).
Funnel $2–$5 Paper $10 Cheesecloth $5	A **filtering funnel** and either **coarse filter paper or fine cheesecloth** to separate solids from liquid in the mash or in the beer for testing.
$30—Laboratory brown glass bottle	A **brown glass bottle** to store the iodine solution used to test for breakdown of the starch to dextrins during cooking. A brown wine bottle or beer bottle will work if it can be sealed.
Hydrometer $10 Cylinder $10	**°Plato or °Brix hydrometers,** calibrated from 0° to 35°, measure percentage by weight of sugar solutions filtered from the mash or the beer. A measuring cylinder is needed with each hydrometer.
$2.50–$5.00	Clinitest^{tm} tablets or Testape^{tm}, available in drugstores as part of kits to test for glucose in the urine of diabetics, can be used to test the fermenter for unconverted sugar concentrations down to 1%–2%.
Hydrometer $10 Cylinder $10	An **ethanol hydrometer,** calibrated from 0 to 200 proof, will measure the proof of the ethanol as it comes from the still. Buy only those labeled "U.S. Custom House"; the Alcohol, Tobacco, and Firearms inspectors require them, and they are more accurate. Hydrometers with built-in thermometers save using temperature conversion charts. Do not buy "potential" alcohol hydrometers, which really measure sugar. The hydrometer needs a measuring cylinder.
$10-unbreakable, 250 milliliters	A **volumetric** cylinder calibrated in milliliters can be used to measure acid for addition to water to make pH-adjusting solutions.

Typical Costs (1981)	Minor Equipment and Chemicals
$ZnSO_4$—6.6 lb for \$40; $CaSO_4$—22 lb for \$20. Quotes are from laboratory suppliers, not large chemical companies.	**Zinc sulfate** ($ZnSO_4$) and **calcium sulfate** ($CaSO_4$) may be added to the mash prior to cooking and fermentation. Very small amounts will be used.
H_2SO_4— 15-gal drum for \$30; NaOH—50-lb bag for \$15; 500-lb drum for \$50; KOH—400-lb drum for \$240	**Sulfuric acid (H_2SO_4)** in concentrated solution and **sodium hydroxide** (NaOH) or **potassium hydroxide** (KOH) in pellet form will be necessary to change the pH of the mash.
\$20 for 5-1/2 gallon size	**Large glass or corrosion-resistant plastic carboys** can be used to mix 2N solutions of the pH-changing chemicals.
Glasses—\$3 Gloves—\$7 to \$19 Apron—\$8 to \$17	**Safety glasses, goggles, or face shield, rubber gloves, and a rubber apron** for acid/base mixing safety should be used.

Water Testing and Treatment

Are there any special precautions to be taken with respect to the water?

A great deal of water is not needed for processing potatoes. However, since some will necessarily be used, it is usual to test it. For the most part, water in the United States is fairly pure—it does not kill the yeast necessary for fermentation. However, minor variations in water quality can have major repercussions in the fermentation because the yeast's growth rate (and thus its conversion efficiency) **is** affected. Water testing usually can be done at a local commercial laboratory or at a farm support organization. The local county agent should be able to direct you properly. It should not be necessary to test your water more than once.

Tests and corrective measures needed are for

- **pH**—A measure of how many hydrogen ions are present in water, more commonly referred to as the degree of acidity or basicity. A pH of 7 is considered neutral; values below 7 are acid and above 7 are basic. Yeasts of all types flourish when the pH is between 4 and 6; commercial yeasts—such as the ones used in fermentation — thrive at pH 5. A mash made of crushed potatoes will usually yield a pH in the range of 4.5 to 6.5

  It is important to have a pH meter or pH papers to check the pH value at various points in the fermentation process. Meters, pH papers, and pH sticks give much more accurate readings than do litmus papers, and accuracy is very important in many production steps. Also, litmus paper is prone to degradation, which could result in misreadings. We recommend against using litmus.

- **Nitrates and Nitrites**—A level of these salts above 50 ppm* is usually indicative of water pollution by sewage or animal waste, and pollution should be avoided in fermentation process water. Nitrites, besides indicating pollution, can prove directly harmful to the yeast.

- **Trace Elements**—As with other living organisms, yeast require small amounts of certain metals (called trace elements) to live. However, both life-giving and destructive metal ions may be found in the water supply. Levels of 1.0 ppm copper, 160 ppm fluoride, 360 ppm tin, 350 ppm tellurium and beryllium, and 185 ppm nickel can each **inhibit** the yeast population.

  On the other hand, magnesium to 300 ppm and zinc to 3.0 ppm are **necessary** to good yeast activity and are sometimes added as sulfate salts (magnesium sulfate, zinc sulfate) if they are not in sufficient quantity in the mix of feedstock and process water.

  Most alpha-amylase enzymes require 100–150 ppm of calcium. Potatoes contain about half this amount. If the water added during pH adjustments does not have enough, further calcium additions may be necessary.

  Iron, aluminum iodine, and chlorine are considered nondetrimental at all levels up to 500 ppm.

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*Most laboratories will use parts per million (ppm) as a measure of the weight of impurity present. For instance, if there are 50 grams of sodium present in a million grams of water, the level of sodium present is 50 ppm.

Feedstock Cleaning and Crushing

How should the potatoes be prepared for fermentation?

Prior to processing the potatoes, they should be screened to remove stones, metal, and other debris. Commercially available equipment is often installed in large operations to clean the potatoes, but it can prove too expensive on a small scale, where homemade equipment may suffice. Washing the potatoes with water sprays as they move along a conveyor is a common cleaning method.

After cleaning, the potatoes must be prepared so that their starch is exposed for conversion. Several processes are used, including slicing, mashing, crushing, or combinations thereof. Starch is present in the feedstock in small granules called micelles. Crushing frees the starch micelles, exposing them for the next steps of hydration, dextrinization, and conversion to glucose.

Potatoes are washed on the way to the pulper at a 9-million-gallon per year ethanol plant.

What are the characteristics of a good mash?

To extract the starch, the entire potato, including skin, must be reduced to the consistency of a milkshake. This can be accomplished in a hammermill or by putting the potatoes through a large meat grinder and then blending this mass using rapidly moving blades. Large lumps of unblended potato should be avoided, as the starch may prove inaccessible during cooking. The water found naturally in the potato **should not be discarded** during blending; it contains nutrients for the yeast and helps to suspend the starch and other particulates during the cooking step. Once the potatoes are processed, they should be transferred to the cooking vessel as soon as possible.

Precooking

High starch concentration has the virtue of minimizing the amount of water that passes through every step, especially distillation, to produce 200-proof ethanol. Thus, less energy is used during the entire process.

The amount of fermentable sugars found to be most efficient for the ethanol production process is 20% to 22% by weight of the mash. (Percent by weight means that all amounts are measured in weight rather than volume.) Such a concentration of sugars will yield ethanol concentrations (by weight) of 9.4% to 10.3% after successful fermentation. However, the starch content of potatoes varies widely, from 13% to 20%. Average is considered 17%. Thus, a potato mash will **not** contain the optimal 20%–22% concentration of sugars.*

It can be as bad to have too **much** sugar or carbohydrate as it is to have too little (i.e., the mash should **not** be concentrated by drying). Concentrations of sugars above 40% by weight will kill yeast cells (and must be diluted for successful fermentation). Also, there is a limit to the amount of ethanol the yeast can survive; if too much ethanol is produced before all the sugars are fermented, no more fermentation will occur, and sugars (i.e., feedstock) will be wasted. The rate of yeast cell reproduction can begin to lessen when the alcohol concentration reaches 6%; reproduction is near zero at 10% concentration, and it ceases totally at 12%. Fermentable sugar concentrations of as high as 20% to 22% produce near-10% ethanol yields and do not damage the yeast population.

Should you add water to potatoes?

Whole, raw potatoes can contain about 15% to 18% starch and are 70% to 75% water by weight. Ethanol concentrations resulting from fermentation of a potato mash are about 7.0% to 8.5%. There is little point to adding **extra** water to potato mash: it would just reduce the sugar concentration further, which only increases the water volume that has to be eliminated during distillation at the cost of extra time and energy. The only reason water is ever added is to dissolve calcium salts for calcium-ion-requiring enzymes and to lessen the amount of viscosity of the potatoes during cooking; however, the small amount of water added has little effect on viscosity, and it meanwhile lowers the sugar concentration. In sum, water should **not** be added to potatoes, but the water already in the mash should be retained because of its nutrients.

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*Sugar concentration is 1.11 times starch concentration after a perfect conversion.

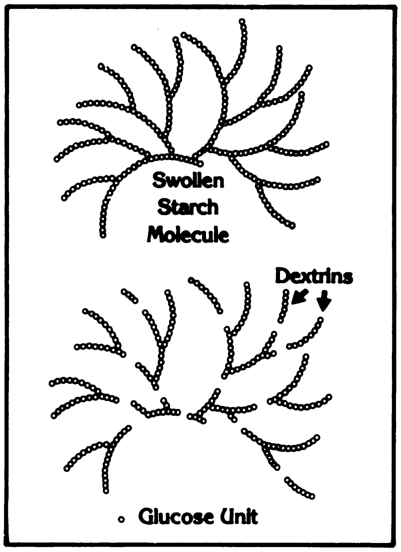
Hydration and Dextrinization

What is hydration?

Hydration is a process whereby water molecules are introduced between the starch molecules in the micelles, causing the micelles to swell. The starch molecules in the micelles are exposed by the swelling so that they are available for enzymes to break them down into dextrins and eventually into fermentable sugars.

What is dextrinization?

Dextrinization is the process of turning starches, which are large, complex molecules, into smaller molecules called dextrins. Dextrinization is done by introducing alpha-amylase enzyme during the hydration. The alpha-amylase randomly attacks the starch molecule strands, breaking them into the smaller dextrins.



Dextrinization: Alpha-amylase enzymes attack the swollen starch molecule strands, breaking them into simpler starches called dextrins. Dextrinization prevents the mash from hardening during the cook and prepares it for final reduction to fermentable sugars.

How are hydration and dextrinization done?

The actual method of hydration and dextrinization varies somewhat depending upon the specific source of the enzymes used. In general, the alpha-amylase is added directly to the mash, which is being continually mixed and heated in the cooking vessel. The pH may have to be adjusted. Heating aids hydration as well as dextrinization; alpha-amylase requires a fairly high temperature for maximum activity. Heating without the addition of alpha-amylase would lead to hardening of the starch. Dextrins, however, will not harden. Thus, the alpha-amylase performs two functions—prevention of hardening during hydration and production of dextrins, which is a necessary step toward obtaining fermentable sugars.

When the correct temperature for the maximum alpha-amylase activity is reached, it is maintained for a certain length of time (at least an hour), completing the dextrinization. The high temperature also helps to reduce contamination of the mash by microorganisms.

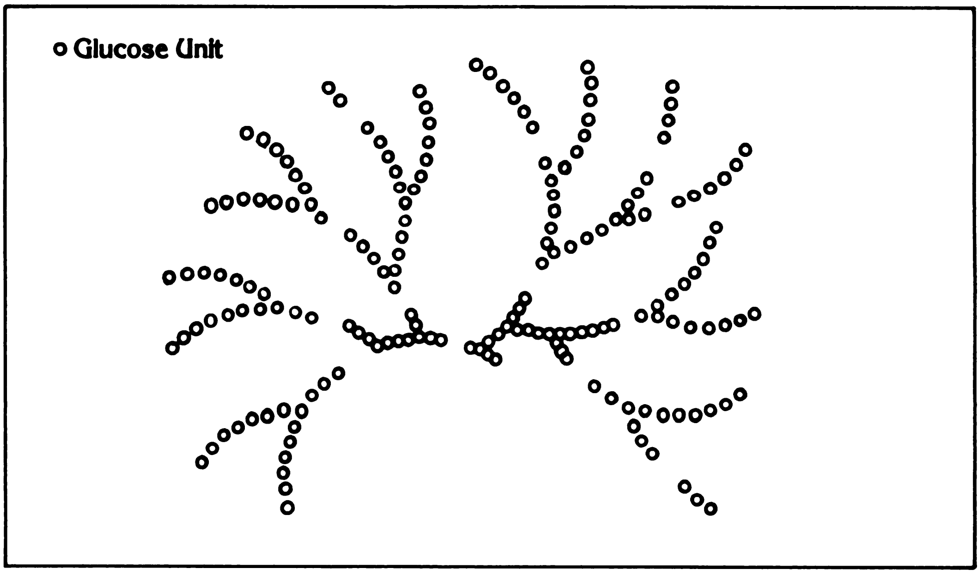
Cooking

What is cooking?

Cooking is a term often applied to the entire process whereby starch in the already swollen (hydrated) micelles is heated, agitated, and broken down to dextrins and from there to fermentable sugars. The dextrinization produced by the alpha-amylase (as explained in the previous paragraphs), precedes the final cooking step, which is the use of a glucoamylase enzyme to break the dextrins into even smaller molecules that are simple, fermentable sugars. The process of obtaining fermentable sugars from dextrins is called **saccharification.**

How is the conversion to fermentable sugars accomplished?

To perform the saccharification, the hot, dextrinized mash is cooled to a temperature tolerated by the glucoamlyase. The pH of the mixture must also be adjusted. The glucoamlyase is added, and with the proper temperature, pH, and agitation, the glucoamylase breaks the dextrins into smaller, fermentable sugars. The glucoamlyase acts by clipping glucose molecules off the dextrins like removing single beads from a string. Sometimes the conversion to fermentable sugars is completed not in the cooking process but rather in the fermenter; yeast is added to the dextrinized mash, beginning the fermentation, and the dextrins-to-sugars conversion by the glucoamylase enzyme goes on concurrently with the fermentation.



Saccharification: Glucoamylase enzymes remove the glucose molecules one at a time from the end of the dextrins. Saccharification completes the conversion of the original mash material to fermentable sugars.

Choosing the Best Enzymes

The previous sections describe the use of enzymes in starch conversion. However, there are several choices of type and manufacturer of enzymes, and these enzymes vary significantly in their use. The choice of enzyme you make will determine your actual procedure throughout the hydration and starch conversion.

What are enzymes?

Enzymes are large, complex protein molecules that act as catalysts, facilitating the starch–to–fermentable sugars conversion. They are very sensitive to temperature, pH, and water contaminants. In addition, some of them require very small amounts of substances called cofactors; calcium is usually a needed cofactor. The cofactor is sometimes identified (or supplied) by the manufacturer, who also gives the conditions needed by the specific enzyme. The instructions for enzyme use given here and in the step-by-step precedures that follow are only a guide: you should always follow the manufacturer's actual instructions.

What kinds of enzymes are effective, and how can you choose between them?

Starch conversion uses the two types of enzyme mentioned previously: alpha-amylase and glucoamylase. However, these enzymes can be derived from different sources: bacteria or fungi. These enzymes are called (after their sources) **bacterial** or **fungal** alpha-amylase and **fungal** glucoamylase. Each behaves differently. There are two choices of these enzymes most frequently used in actual operations. One choice is a **bacterial** alpha-amylase used in the dextrinization and a **fungal** glucoamylase that completes the conversion to fermentable sugars (saccharification). The second choice is to use a **fungal** alpha-amylase in the dextrinization, completing the saccharification (as before) with a **fungal** glucoamylase. The basic difference between these methods is that the first is faster but more complicated (in terms of temperature and pH adjustments) and requires a higher temperature; the second choice is simpler, slower, and may have a lower yield.

Properties of Fungal and Bacterial Alpha-Amylase and Fungal Glucoamylase

Enzyme	Use	Temperature	pH	Approximate Conversion Time
bacterial alpha-amylase	dextrinization	185°–203°F (85°–95°C)	6.0–6.5	1–2 hours
fungal alpha-amylase	dextrinization	133°–140°F (56°–60°C)	4.0–5.0	4–6 hours
fungal glucoamylase	completion of saccharification (2 procedures)	86°F(30°C) in fermenter	4.0–5.0	24–65 hours
		or		
		140°F(60°C) in cooker	4.0–5.0	2 hours plus residual activity in fermenter

Although the glucoamylase we suggest for completing the conversion is always fungal, there are different procedures for using the fungal glucoamylase available from different manufacturers. One procedure is to add the glucoamylase to the cooker for about 2 hours, converting 70%–80% of the dextrins to glucose. The glucoamylase completes its work in the fermenter. The other procedure is to add the glucoamylase to the fermenter (at about 86 °F); all the necessary dextrin conversion to sugar occurs during the fermentation. Usually, the first and fastest of these procedures is the most efficient.

Fermentation

What is fermentation?

Fermentation is the process of using yeast to convert sugars to ethanol. Basically, yeast—a living organism—consumes sugar to live and reproduce and gives off ethanol (under oxygenless conditions) as a waste product. When the yeast has consumed and transformed all the sugar, the fermentation is over. The goal of the fermentation is to produce the greatest amount of ethanol in the shortest time. Vigorous ethanol production is a result of healthy yeast, the propagation and maintenance of which are dependent upon several factors.

What are the factors necessary for good fermentation?

The pH of the mash is important. Yeasts thrive between pH 4 and pH 6. They will multiply at a pH as low as 3 and as high as 10, but very slowly and with little or no alcohol production. The best pH for ethanol production has been found to be 4.5 to 5. If a pH higher than 6.0 is used, glycerol may be formed at the expense of ethanol. If a pH of less than 4.0 is used, the routine fall of pH during fermentation will drop the pH to 3.5. This pH slows the fermentation and—although inhibiting certain contaminants—may allow others to grow and outpace the yeast.

The rate of fermentation increases with temperature to an optimum between 86° and 104°F (30° and 40°C). The optimal temperature for fermentation is about 97°F (36°C). Since it produces heat, a fermentation should be started at about 86°F (30°C). Cooling should be begun near 90°F (32°C), and the fermentation temperature can be stabilized near the optimum of 97°F (36°C). Once stable, the temperature must be maintained, as higher temperatures or even fluctuations will damage the yeast. Evaporating ethanol can become entrained in escaping CO_2 gas, and it may be appropriate to install a scrubber. Another means of lessening vapor loss is to lower the fermentation temperature, but this is not recommended because it entails losses from a slower rate of fermentation and a greater cooling-water volume.

The yeast also require sufficient nutrients, as mentioned previously. Fortunately, most feedstocks made from potatoes contain these nutrients, and more need not be added to the fermentation. Zinc and magnesium are sometimes added if not in sufficient quantity (see the procedural section).

What kind of yeast is used?

The yeast most commonly used to produce fuel alcohol is called **Saccharomyces cerevisiae;** it is the yeast used industrially to produce beverage alcohol. This type of yeast is available from several suppliers in bulk quantities and is specifically a distiller's yeast. Baker's yeast, the kind of yeast available from the grocery store, will not produce a successful fermentation. It is less tolerant than distiller's yeast to alcohol, and may, in either moist cake or dried form, be up to 90% and 50% dead cells, respectively.

How should yeast be added to the fermenter?

About 0.5 to 1.0 oz of the correct dried distiller's yeast per 100 pounds of mash will provide enough cells to start a good fermentation. The dried cells can be rehydrated for 5 to 10 minutes in tepid water (not over 100 °F; 38 °C) before being added to the mash, or they can be added directly to the mash as it is being pumped into the fermenter. Yeast reuse is also a possibility (see the refinements section).

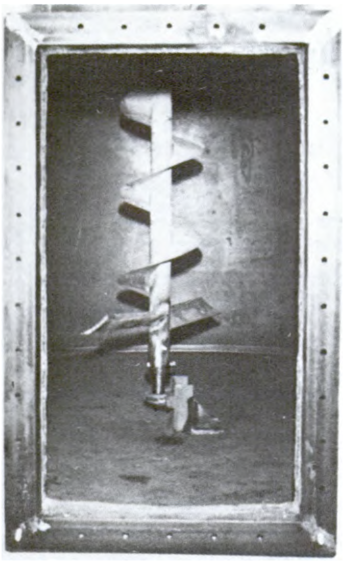
What kind of fermentation vessel is needed?

The material out of which the fermentation vessel is made is also important to the fermentation. The best material for the interior is polished stainless steel, which can be quite expensive. Less-expensive materials include food-processing-grade epoxy or fiberglass over mild or carbon steel, or simply plain carbon steel. However, some epoxy paints and fiberglass resins dissolve easily in ethanol: check with the manufacturer or test a sample. No matter what is used, the interior vessel lining should be chemically inert, smooth, easily cleaned, and repairable. It should resist corroding and pitting due to the low pH of the fermentation and not leach undesirable metal ions into the mash. Infections and reduced yeast performance can be prevented if an adequate vessel lining is employed. (Some materials to avoid include concrete, rough fiberglass, and painted surfaces.)

How much should the fermenting mash be mixed?

Yeast cells can live either in the presence of oxygen (aerobic growth) or in the absence of oxygen (anaerobic growth). Each situation causes the cell to use the fermentable sugar in a different manner: aerobic growth encourages yeast reproduction, and anaerobic growth encourages ethanol production.

This does not mean that absolutely no oxygen is necessary. Some oxygen is required at the very beginning of the fermentation to help the newly added yeast reproduce. Enough oxygen has probably been introduced into the mash during feedstock preparation and cooking, so adding more to the mash just prior to addition of the yeast is not necessary, but is sometimes done. This can be accomplished by rapidly agitating the mash in the fermenter prior to addition of the yeast. The oxygen is quickly used up and disappears from the fermentation about two to four hours after the start of the process. **Once the yeast has been added, no oxygen should be introduced.**



Mixing the mash during fermentation allows the yeast to get to all the sugars. Besides the screw-type mixer shown here, propeller-type and multibladed designs are also effective. Care must be taken that oxygen is not introduced during mixing.

Two types of fermentation vessels can be used: a covered, vented vessel, which is preferable, or an open vessel, which is apt to become infected and loses ethanol via evaporation. Fermentation can be facilitated by keeping the broth mixed at all times to allow the yeast to come into contact with its nutrients, reducing the fermentation time. For a covered container, there is no danger that mixing will introduce oxygen—even though there is a space above the mash in a closed vessel, carbon dioxide fills the space, and its pressure keeps oxygen from being mixed into the broth. If an open fermentation vessel is used, the mixing of the broth must be gentler to prevent oxygen from being introduced. However, even with an open vessel, the layer of CO_2 above the mash is usually enough to prevent much oxygen from penetrating if the mixing is gentle enough.

Is there any danger associated with the generation of carbon dioxide?

A word of caution about carbon dioxide. Familiar from beer foam or champagne bubbles, carbon dioxide is produced in large quantities during fermentation and can be harmful. The gas is not poisonous of itself but tends to push out the breathable air in a closed space. A room filled with carbon dioxide will have little oxygen in it, and a person could become unconscious or even die if he were breathing mostly carbon dioxide rather than air. It is important, especially if fermenters are in closed rooms, to vent the carbon dioxide outside to the atmosphere. Also, if the fermenting vessel is closed and relatively airtight, it is important to vent the gas from the vessel as a means of relieving the pressure buildup caused by the generation of carbon dioxide during the fermentation. If this is not done, the tank may rupture.

Care and Cleaning

The equipment and chemicals needed for ethanol production require special care. The following are several areas of major concern.

Two means of measuring pH are suggested for you to choose from: a pH meter and pH papers.

How should a pH meter be cared for?

A **pH meter** is a delicate instrument and should be treated with care. The glass electrode that is inserted in the sample to get a reading should not be bumped or treated roughly and, when not in use, should be immersed in a water solution of pH 7 or so to prevent breakdown. Unbreakable electrodes are also available. A standard buffer solution of pH 7 should be purchased with the meter and used to calibrate the unit. Calibration has to be done quite frequently to maintain accuracy. A calibration control on the unit should allow the adjustment of the reading to pH 7 when the standard solution is being used.

The electrode should be rinsed between uses with clean water and immersed in clean solution. The meter should be turned to the "standby" mode when readings are not being taken and to the "pH" mode when a reading is being taken. The meter does not have to be turned off when not in use; putting it on standby lessens the need for recalibration.

How should pH papers or sticks be handled?

pH papers or pH color squares on plastic sticks are accurate to within 0.3–0.5 of a pH unit if used correctly. They indicate a certain pH by means of a color change of the indicator material; accurately matching the color of the stick to the color standards supplied with them is the **major obstacle** in reading the pH correctly. It is often necessary to immerse the papers for longer periods of time (minutes) in mashes; gauging the immersion time can thus be a matter of judgment, increasing the inaccuracy. The indicator should also be matched to the standard while still moist, preferably within several minutes after development. The indicators should be kept dry and protected between uses, since moist air or water will cause the color to change. They also have a tendency to deteriorate after prolonged storage.

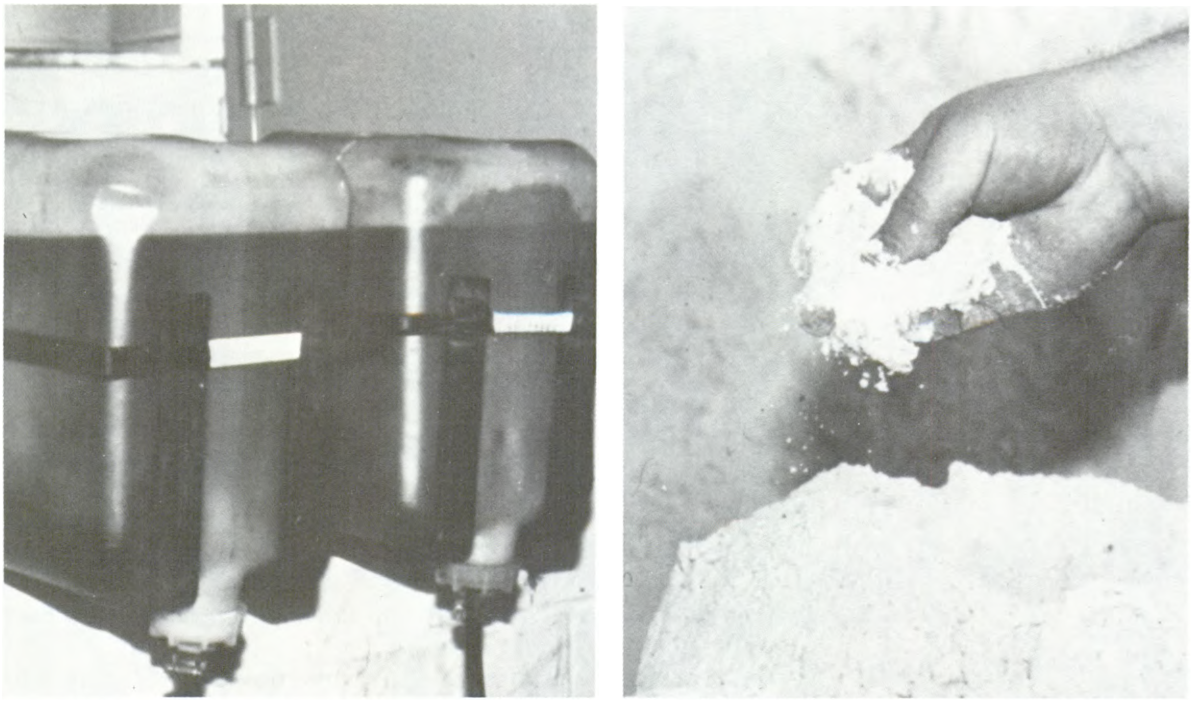
Narrow-range pH indicator sticks or papers are more accurate than the better known litmus paper, which should not be used. But even indicators are hard to read, and we recommend a pH meter.

How should enzymes be stored?

The **enzymes** to be used in the cooking come in liquid and dried forms, depending upon the manufacturer. Both forms should be kept in a cool, dry place (refrigerated enzymes will last 6 months). Coolness is especially important, since heated storage will cause some portions of the enzyme to lose activity, and consequently more enzymes will have to be added to achieve a desired result. If cool storage is not possible, only enough enzyme for a specific number of batches should be on hand at any one time—so that the enzyme can be used up before it can start to deteriorate. Enzymes generally can stay at room temperature (70 °F) for two months without problems.

Dry storage is more important for granular enzymes because if they get damp they may begin to lose some of their activity and will also become a good place for bacteria to start growing. Liquid enzymes will already be in tightly closed containers and generally will not be affected by dampness.

Liquid enzymes contain preservatives that prevent microorganisms from growing. These preservatives will not harm yeast because they are greatly diluted when mixed in the mash. Eventually, after long storage, the liquid enzymes may support growth of mold on the surface of the liquid.



Liquid enzymes (*left*) for dextrinization and saccharification should be stored in a cool place in closed containers. Yeast (*right*) can be adversely affected by many organic and chemical contaminants.

What are the difficulties associated with impure fermentations?

The fermentation can never be totally free of contaminating microorganisms, but care should be taken to reduce the incidence of infections that reduce ethanol yields. Infectious microorganisms use sugar as an energy source very easily but usually fail to produce ethanol; contamination can lead to reduced ethanol yields and weakened yeast performance. If the yeast from one fermenter is used to start another batch, infections are easily spread and rapidly get out of hand unless care is taken.

What are some likely contaminants and their characteristics?

Certain contaminating organisms are most likely to be encountered by fuel alcohol producers. Coliform bacteria inhabit soil and cling to tubers and can also gain access to the fermenters through well water and operators. They develop quite rapidly in mashes of pH above 4, especially if the yeast does not establish itself quickly. Once a vigorous fermentation takes hold, these bacteria will generally be out-competed, especially if the pH falls during fermentation.

Acetobacter species of bacteria produce acetic acid (vinegar) from ethanol. They are quite acid tolerant but need oxygen for rapid growth, so they generally only become a problem if a fermentation stops early for some reason. If a fermentation stops and this goes undetected, these organisms could consume some of the ethanol present in the beer, only if aerobic conditions accidentally become established due to cessation of fermentation.

Lactobacillus species of bacteria, a very potent contaminant, can grow under anaerobic conditions and in the presence of carbon dioxide. They may be introduced with soil particles. These organisms will generally consume some of the sugar that the yeast could use to produce ethanol. Unlike other organisms, some **Lactobacilli** can drive a fermentation pH down all the way to 3.5; a fermentation pH less than 3.5 usually indicates their presence.

Pediococcus species are anaerobic and have been found in connection with yeast that is being stored for reuse. They also consume, and waste, sugar.

Zymomonas species are anaerobic and can grow over a wide pH range, utilizing sugars in the mash. They produce alcohol and are not as destructive in a fuel-producing, as opposed to a beverage-producing, facility.

So-called "wild yeasts" are those of many species that can contaminate mashes by being introduced through the feedstock, dirt, water supply, or with operators. Since they often prefer the same conditions as the cultured yeast, they can grow rapidly and reduce the population of the wanted yeast. Many of them do not produce ethanol from the sugar they consume.

Often the best indications of contamination are a rapid drop of pH, a reduced output of ethanol from the fermenter, or less-than-vigorous fermentations. Microscopic examination of the mash will reveal some of the contaminants but will most often disclose deviations in the size and shape of the culture yeast cells, an indication that the cells are having trouble competing with the contaminants. Sometimes odors will reveal contamination. Coliforms will often produce celery-like or phenolic odors, **Acetobacter** will produce the characteristic vinegar smell, and **Zymomonas** will produce an offensive rotten fruit odor quite unlike the pleasant apple-like odor of a successful fermentation.

How should proper cleaning be done?

Thorough and constant cleaning is the only reliable means to prevent recurring infections. Breweries and distilleries often use CIP (clean-in-place) systems that wash all tanks and piping with 2% caustic (sodium hydroxide) solutions, followed by water or water-acid rinses. Washing takes place at least once a day and every time a tank is emptied. Small operations can use a high-pressure gun to spray the caustic inside tanks, and the solutions can be pumped through piping with the same pumps used to transfer product.

Spraying high-pressure steam into tanks and lines can also be of use. A caustic solution can be used more than once, provided remaining mash or beer have been rinsed from tank and pipe surfaces prior to application of the solution. The final rinse with water should be very thorough to remove any residual caustic.

Often small operators will make the mistake of leaving traps in piping that collect residual mash and beer. The traps serve to breed contaminants, which get washed into fermenters during mash pumping. Rinse-access ports in piping can make it easier to clear the pipes of residual organic material; sloping the pipes so that they drain is also a good idea. Putting valves at the piping's lowest points can be helpful. Open the valves and allow mash to drain when the system is being cleaned. **Simply cleaning tanks without cleaning piping and pumps is inadequate to prevent infection.**

One idea for facilitating cleaning is to make tanks that have sloped bottoms for easy draining (Colorado Agro-Energy Inc. plant under construction, Monte Vista).

Step-by-Step Fermentation Procedure for Potatoes

What is the purpose of this procedure?

The purpose of this procedure is to give detailed, inclusive, step-by-step instructions that will result in consistently high yields of ethanol.

Instruction	Comments and Warnings
1 **Water Testing.** Potatoes are 75% water, and it is not usually desirable to add water to them for the cooking step. If for some reason you do add water, do not add any more than 14% (by weight) because further dilution of the sugar content would result in an extremely low concentration of ethanol after fermentation.	Usually, water in the United States conforms to the standards listed here. If it does not, it is usually easy to adjust it. See the refinements section (p. 28).
Of necessity, some water is used during the processes. Test the water you will use for pH, nitrates and nitrites, and trace elements. This can be done through commercial laboratories or local farm support organizations. Your county agent can supply addresses of those who can perform these tests.	
pH should be between 4 and 6.	
Nitrates and nitrites should be less than 50 ppm.	More than 50 ppm of nitrates and nitrites indicates polluted water. However, yeast do need **some** of these compounds.
Trace elements present in the mash: Copper less than 1.0 ppm Fluoride less than 160 ppm Tin less than 360 ppm Tellurium and beryllium less than 350 ppm Nickel less than 185 ppm	These concentrations can inhibit the yeast population. Most drinkable water will have less than these amounts.
Needed trace elements in the mash (these can be added as sulfate salts): Magnesium needed, 300 ppm Zinc needed, 3.0 ppm	
2 **Choosing the Enzyme.** Choose the enzymes you will use for the conversion of starch to fermentable sugar. There are four basic choices of enzymes covered in this booklet; all are designed to be straightforward and effective. Choices **A** and **C** are the most common. The choices are	In addition to the enzymes covered here, other equally effective enzymes are available that may vary in use and instructions. FOLLOW THE MANUFACTURER'S INSTRUCTIONS. If you cannot get enzymes exactly like those suggested here, you can still use this manual.

Instruction	Comments and Warnings
A. Bacterial alpha-amylase at high temperature and fungal glucoamylase at moderate temperature added to the cooker. This is the fastest, most complex, and most efficient choice.	Correct enzyme storage is important: improperly stored enzymes will not work.
B. Fungal alpha-amylase at moderate temperature in the cooker and fungal glucoamylase added to the fermenter. This is the simplest, slowest choice.	
C. Bacterial alpha-amylase at high temperature added to the cooker and fungal glucoamylase added to the fermenter.	
D. Fungal alpha-amylase at moderate temperature and fungal glucoamylase at moderate temperature in the cooker.	
These choices differ chiefly in how much time and energy is used during the mash cooking and fermenting. (A few other procedures also change during the cooking and fermenting and are covered below.)	
3 **Cleaning.** Clean the feedstock, thoroughly removing dirt and any metal.	Microorganisms in dirt will be harmful to yeast, and dirt and metal can be very harmful to machinery (and people) as well as ruinous to the by-product stillage. In no case should you use treated seed potatoes: their fungicide may be harmful to the yeast and enzymes, as well as making the stillage inedible.
4 **Processing the Potatoes.** Reduce the potatoes to particles no larger than 0.125 inch or to about the consistency of a milkshake.	Chunks in the cooking mash will not be sucessfully converted to fermentable sugars.

Instruction	Comments and Warnings
5 **Making the Mash.** Add the hammer-milled potatoes to the cooker as quickly as possible. The cooker must be mixed continuously from the very beginning, even before heat is applied. Failure to do so will result in a hardened mash. Keep mixing the mash **throughout** the cooking process. It is not appropriate to mix water with potatoes, because potatoes are already 75% liquid. The volume of a hundred pounds of mash (pure potatoes or 86 lb of potatoes and 14 lb of water) is about 11 gallons, or 1.5 cubic feet.	Do not remove water from the potato mash; it has nutrients important to the yeast. The only perceptible reasons to add water are to dissolve calcium salts and to thin the mash for easier mixing. However, there are pH adjustments later in the process that will add water to the mash. Thus, it is best to resist the temptation to add water at this step. If you do add water to reduce viscosity, it should have been tested (Step 1), and you should certainly not add more than 14% by weight.
Since 100 pounds of potatoes make about 11 gallons of mash, it is possible to grind enough potatoes to fit any size vessel. Leave about 30 inches of headspace between the top of the cooking and fermenting vessels and the liquid level of the mash to accommodate the foam (generated by CO_2) in rapid fermentations at higher than optimal temperatures.	The 30-inch headspace of the tank is a rule-of-thumb: your case may be substantially different.
6 **pH Adjustment.** The pH of the mash must be adjusted before hydration. You will be using either bacterial or fungal alpha-amylase for dextrinization **so follow the manufacturer's instructions, especially if they differ from our recommendations.** Check the pH of the mash with pH papers or a pH meter. Adjust the pH as follows (see below for specific instructions): • for **bacterial** alpha-amylase, to pH 6.0–6.5 with 2N NaOH, $Ca(OH)_2$, or KOH (bases); • for **fungal** alpha-amylase, to pH 4.0–4.5 with 2N H_2SO_4 (acid) if necessary.	Keep mixing the mash. The chemicals called for in this step are extremely dangerous. Wear rubber gloves, rubber apron, and a face shield and work in a well-ventilated area. Even breathing the vapor can cause damage. The chemicals must be stored and handled with caution or not at all. Those who think otherwise will soon find themselves in the hospital. **BE CAREFUL WITH THESE CHEMICALS**

Instruction	**Comments and Warnings**
The 2N solutions of the pH-changing chemicals can be made as follows: • 2N H_2SO_4 (sulfuric acid)—210 milliliters (7 fluid ounces, or about one cup) of concentrated H_2SO_4 per gallon of water yields 2N H_2SO_4. • 2N NaOH (sodium hydroxide, or caustic)—11 ounces (308 grams) of NaOH pellets per gallon of water. • 2N KOH (potassium hydroxide)—15 ounces (420 grams) of KOH pellets per gallon of water. • 10% lime $Ca(OH)_2$ (calcium hydrate, or slaked or hydrated lime) slurry. This is a safer compound, and it helps in the addition of needed calcium.	Store chemicals in glass or plastic bottles, properly labeled and out of reach of children (the chemicals are deadly). When mixing acid with water, **add the acid to the water,** not the water to the acid. Heat is generated when these chemicals are mixed with water. If they get on clothes or skin, wash immediately in cold water. Either an emergency shower stall or a powerful hose should be handy for emergency washing.
The chemicals can be purchased in various forms. If they are already liquid, look for the "N," or "normality," designation. The normality designation will be preceded by a number; the greater the number, the stronger the solution. If solutions stronger than 2N are used, smaller volumes will be needed to change the pH of the mash; but stronger solutions are also **much more dangerous.**	We do not recommend the use of high-concentration chemicals for pH adjustments.
Rather than give a hard-and-fast rule about the amount of 2N solution of base or acid to be added to bring about a specific pH change, we suggest a simple trial-and-error method. It will be necessary to add small amounts of the chemicals **(1 pint of 2N solution per 100 pounds of mash in any one addition)** and to check the pH with the pH meter or papers after every addition until the proper pH is reached. **The amount of the chemical used should be recorded so that the same amount can be used in future batches.** Measure the mash's pH at the end of this procedure, and adjust it with small amounts of 2N solution.	The trial-and-error method is just that: it means pouring in small amounts until finally the pH meter (or papers) reads as the enzyme manufacturer says it should. **Do not overshoot if you can help it!** If you do, it can be fixed by adding a solution of the opposite type (acid or base). However, this also adds to the amount of water in the mash, which should be avoided if possible.
7 **Adding Trace Elements.** This is a good time to add any trace elements that may be necessary, such as calcium and zinc. The water testing will have shown what trace elements are present.	Keep mixing the mash. To weigh the trace elements, use the gram scale called for in the list of equipment.

About 50 to 400 parts per million (ppm) of calcium will help protect the enzymes and keep them working, and about 3 ppm of zinc will help the yeasts perform well. If the mash has more than these amounts of calcium and zinc (up to 500 ppm), it will not be harmful. If the mash has less than these amounts, 330 milligrams, or 0.33 grams, of zinc sulfate and 8 to 64 grams of calcium sulfate may be added per 100 pounds of mash to bring the levels up.

8 **Hydration and Dextrinization.** The mash is ready to be dextrinized, the first step in converting starch to fermentable sugars. If you have not added water to your potatoes, you have about 17 pounds of starch per hundred pounds (11 gallons) of mash. Use this number, or convert it to the unit the manufacturer requires, to determine how much alpha-amylase to add. For instance, one manufacturer asks for 0.15% alpha-amylase by weight of starch. Multiply 17 pounds of starch by 0.0015 to get 0.0255 pound (11.6 grams) of enzyme for each 100 pounds of potatoes. Multiply this number by the actual number of 100-pound units in your mash to get the proper amount of alpha-amylase.

There are two possible procedures, depending on whether you have bacterial (A) or fungal (B) alpha-amylase. Always check our recommendations against those of the manufacturer:

A. **For bacterial alpha-amylase—**
   A1. Add 25% of the amount of bacterial alpha-amylase specified by the manufacturer, and heat the mash **slowly** to about 130 °F (54.5 °C).

Actually, the amount of starch per 100 pounds of mash varies somewhat, depending on conditions and feedstock: 17 lb—or slightly more—is a good estimate for this calculation. If you added water to the mash, you have less than 17% starch: it is necessary for you to calculate how much starch you have and to use this number from Step 8 on. For instance, if you have added 14% by weight water to the potatoes, your percentage starch is 17% x 86% = 14.6%.

Do not burn the mash. Burnt mash is indicated by a color change. Always heat the mash **slowly;** about 2 °F (1 °C) per minute. The alpha-amylase is added partially to keep the mash fluid enough to mix it. Effective mixing at all times is absolutely necessary for proper heating, hydration, and enzyme activity. 130 °F is an especially sensitive temperature where viscosity problems may frequently occur. Using the wrong pH range or overheating will inactivate or destroy the enzymes. The faster (more efficiently) you can perform your process—following **all** the instructions carefully—the less the chance of contamination and the less overall costs and energy use.

Instruction	**Comments and Warnings**
A2. Continue to heat **slowly to 160°F** (71°C) while adding the rest of the alpha-amylase to equal the manufacturer's recommended amount; raise the temperature slowly to 194°F (90°C), and hold while mixing continuously for the time specified by the manufacturer, usually one to two hours.	Some bacterial alpha-amylase is destroyed at this temperature, and others can actually work better at higher temperature, even boiling: check your manufacturer's instructions.
B. **For fungal alpha-amylase—**	
B1. Add 25% of the amount of the fungal alpha-amylase specified by the manufacturer, and heat the mash **slowly** to about 130°F (54.5°C).	
B2. Heat the mash **slowly** to 190°–212°F (88°–100°C). Hold for about one half hour.	
B3. Cool the mash **slowly** to 131°–140°F (55°–60°C), add the rest of the fungal alpha-amylase, and hold for two to three hours.	
9 **Check Reduction to Dextrins.** To see if this part of the process is complete, check for liquefaction (reduction of starch to dextrins) with an iodine solution. To do this, place a drop or two of the mash on a white surface and apply a drop of iodine solution to it. The mixture will be blue if starch is present, purplish if some dextrins are present, and red or yellow if all the starch has become dextrin. If starch is still present, hold the mash for a longer period or, if necessary, add more enzyme. Tincture of iodine, obtainable from a drugstore, can be used. One part tincture of iodine should be diluted with nine parts of water before it is used to test for the presence of starch. Prepare a new solution every month and store it in a dark place in a brown bottle.	Keep mixing the mash continuously. Potatoes mash will turn an ugly grayish-black during cooling. This is normal and in no way a cause for alarm.
10 **Completing the Starch Conversion.** At this point, the dextrinization is complete. There are now usually two ways to proceed, depending on your choice of fungal glucoamylase. Either you have fungal glucoamylase that is added to the **cooker** (A) or you have fungal glucoamylase that is added directly with	Mix the mash continuously. Always check and follow the manufacturer's instructions if they differ from those given here.

the yeast to the **fermenter** (B). The first is faster because most of the starch becomes fermentable sugars before fermentation begins, accelerating the fermentation; the second is easier because the process is done entirely in the fermenter. Start by calculating the amount of glucoamylase you will add, using the amount of starch per 100 pounds of mash and the manufacturer's instructions. Remember, there are about 17 pounds of starch per 100 pounds of potatoes (no dilution). Then proceed with A or B:

A. **For fungal glucoamylase working in the cooker—**

A1. Begin cooling to 140 °F (60 °C) the now-liquefied mash and adjust the pH to 4.0 to 4.5 with 2N H_2SO_4, mixing continuously. The same trial-and-error procedure for adjusting pH as outlined before (but not the same amount) should be used.

A2. When the temperature reaches 140 °F (60 °C), add the glucoamylase as the manufacturer recommends, based on the 17 pounds of starch per hundredweight present in the original mash.

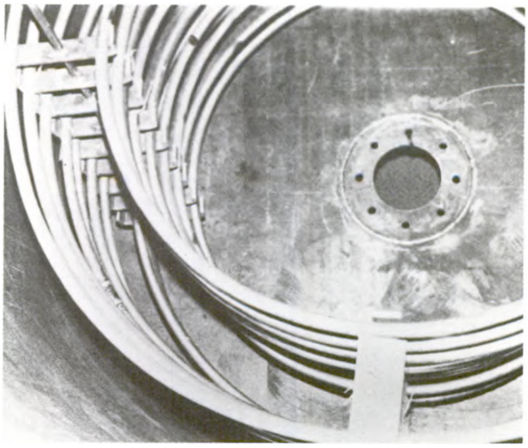
A3. Continue agitating the mash at 140 °F (60 °C) for two hours while the dextrins are broken down into fermentable glucose molecules.

A4. Cool the mash to 85 °F (30 °C), which is the fermentation temperature.

This concludes Step 10 for this enzyme; go to Step 11, fermentation.

B. **For fungal glucoamylase working only in the fermenter—**

B1. Begin cooling the mash. Check the pH, and adjust it to 4.5 to 4.7 if necessary (it will be, if

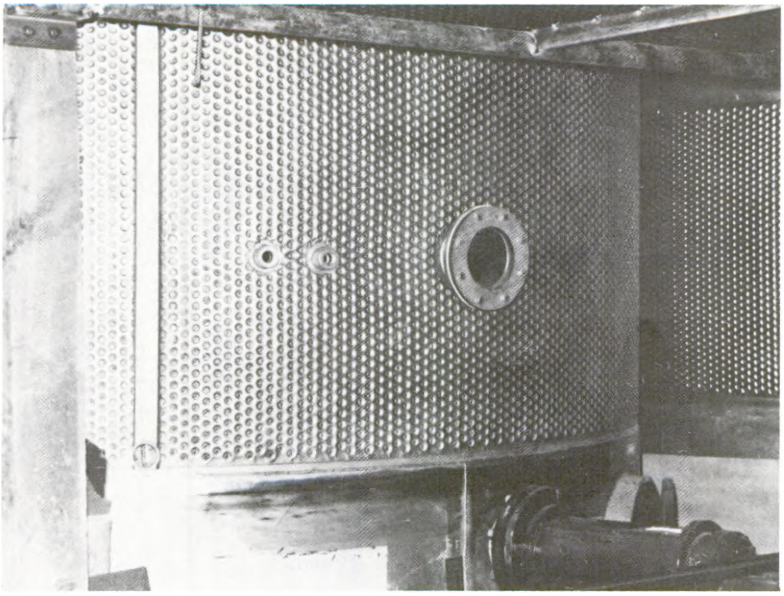


Rapid cooling of the mash can be done by heat exchange piping inside the cooker. Cold water running through the pipes carries away the heat. Mash contamination can result if cooling is not done quickly. The hole at the bottom of the tank is for the agitator.

Cooling should be done in less than two hours to minimize the possibility of **Lactobacillus** infection. **Lactobacillus** is especially dangerous if the mash stays at about 100 °F (38 °C) for several hours. Clean tanks will help avoid contamination if circumstances prevent cooling from being completed quickly.

Cooling should be done in less than two hours to minimize the

Instruction	**Comments and Warnings**
you have used bacterial alpha-amylase), using 2N H_2SO_4. Mix continuously. B2. Cool to 85 °F (30 °C). Add the proper amount of fungal glucoamylase, as calculated on the basis of starch weight per 100 pounds of mash as the manufacturer recommends.	possibility of **Lactobacillus** infection. **Lactobacillus** is especially dangerous if the mash stays at about 100 °F (38 °C) for several hours. Clean tanks will help avoid contamination if circumstances prevent cooling from being completed quickly.
11 **Fermentation.** The mash is now ready to be fermented. The pH of the mash should be 4.5 to 5.0, and its temperature should be about 86 °F (30 °C). Distiller's yeast can be purchased in the dry form from several suppliers; it is generally called distiller's active dried yeast. About 0.5 to 1.0 ounce (14 to 28 grams) of the dried yeast per 100 pounds of mash will provide enough cells to start the fermentation. For fast fermentation, this amount should be increased three- or fourfold. It is a good idea to wet the cells in a volume of tepid (less than 100 °F) water equal to about five times the weight of the cells before they are added to the mash; a 5- to 10-minute soak is enough.	Baker's yeast will not work. Fermentation should be begun **as quickly as possible** to minimize the growth of contaminating organisms.
Yeast is rather delicate and must be handled correctly. The dried yeast should be stored in a cool, dry area. Excessive humidity could wet the yeast, causing it to become active and die if it is not used almost immediately. When wetting the yeast, just the amount needed for one batch should be used, and it should be added to the mash within 10 minutes of wetting. Liquid yeast cannot be stored well, even if refrigerated, unless it has nutrients to live on. Yeast in water will begin to consume itself if it is not supplied with food. Healthy, vigorous yeast cells are very important to successful, fast fermentation.	
Once the yeast cells have been added, the cell population will increase and fermentation will begin. Fermentation generates about 500 Btu of heat per pound of ethanol produced. This heat must not be allowed to raise the temperature of the mash beyond 97 °F (36 °C). Carbon dioxide will also be generated, and it should be vented to the outside air, not inside a closed building. If the fermentation vessel is closed, the mash can be continually mixed as it ferments. If	Dissipating heat from fermentation almost always requires mechanical cooling such as the circulation of cold water in (preferably external) cooling pipes. Begin water circulation at about 90°F (32°C). CO_2 can be dangerous in closed buildings. It should be vented to the



the vessel is open, mixing should be **very** gentle to avoid mixing oxygen into the mash.

Fermentations should be completed within 48 hours depending upon the type of glucoamylase used. Longer fermentations (up to 96 hours) are very costly. Use of glucoamylase exclusively in the fermenter tends to lengthen fermentation time. Check for completed fermentation using a hydrometer, as explained in the refinements section p. 29. Another way to check for unconverted glucose is with a urine enzymatic glucose test tape or kit (as indicated in the list of equipment).

This completes the steps of conversion and fermentation. This booklet does not cover the distillation and storage necessary to produce high-proof ethanol.

Fermentation is very sensitive to temperature variation, especially after the yeast has been acclimated to the mash. Temperature variations of even 4 °F can be enough to disturb the yeast. To control temperature in the fermenter, it is necessary to have a cooling system such as the water jacket shown here because fermentation produces heat that must be dissipated.

outside air continuously during fermentation. Unvented CO_2 buildup in a closed tank can cause it to rupture.

Refinements

In what follows, refinements are given that could be applied to enhance enthanol yield.

Instruction	Comments and Warnings
1 **Water Treatment.** It may be necessary to treat water for hardness or excess trace elements. Excess hardness can be treated in a relatively simple manner. The well-known water softeners found in private homes will work if your process uses only small amounts of water. The same principles apply to large softeners that deal with greater water amounts. **All that is necessary is to purchase an industrial-sized water softener (as per your own needs).** Basically, the material in the softener, called zeolite, traps the metal ions of the salts that are making the water hard. When all the zeolite has been reacted, a strong salt (sodium chloride) solution is automatically forced through the softener, causing the zeolite to become regenerated and ready to soften more water.	Use judgment about water treatment. If the water to be used in the fermentation process is fit for human consumption, it probably will not need to be treated, except perhaps to soften it to prevent added zinc, calcium, or magnesium from forming salts, which would make these needed nutrients unusable by the yeast or enzymes.
Methods for treating alkalinity involve precipitating the dissolved salts causing the alkalinity; they are brought out of solution by physical or chemical means and settle. Boiling the water will convert bicarbonates to carbonates, which will precipitate. Hot lime solutions [CaO or $Ca(OH)_2$] also precipitate carbonates. Hot soda ash (Na_2CO_3) solutions precipitate sulfates. Calcium chloride ($CaCl_2$) and sodium phosphate (Na_3PO_4) can also be used to precipitate these materials. After the precipitates settle, the water is decanted (poured off), leaving the solids on the bottom of the tank. In some cases, it is necessary to further filter the decanted water to clarify it again.	Excess alkalinity may cause scaling on equipment.
If it is necessary to eliminate specific metals from the water, for instance excess copper, ion exchange resins may be used. These are available from commercial suppliers, who will set up the system and detail its use.	
11 **Yeast for Fermentation.** It may not be necessary to use a new portion of dried yeast for every new fermenter batch. About one-third of an ongoing fermentation may be pumped into a fresh fermenter along with fresh mash to "seed" the new batch, thereby adding the yeast necessary to carry out fermentation. More than one fermenting vessel is	

necessary when using this method, and all vessels, pipes, and pumps must be kept very clean.

Yeast cells often reach a high population level in potatoes mashes after about 12 to 15 hours of fermentation. This is the time to transfer about one-third of the volume of the ongoing fermentation into a clean, empty fermenter and to fill the remaining two-thirds of the volume of the new fermenter with fresh mash. Be certain the temperature of the incoming fresh mash is at fermentation temperature (86° to 90°F; 30° to 32°C); temperatures over 100°F (38°C) will harm the yeast. The first vessel from which the one-third-volume working mash came is then refilled with fresh mash. Both vessels are then working, and the process can be repeated 12 to 15 hours later, using the second vessel as the source of the "seed" yeast for a third vessel. If this method is used, it is vital to maintain good cleanliness, as any infection will be spread rapidly.

Spontaneous mutations and general weakening of the yeast can also be a problem when using this method over a long period of time, so it is a good idea to add fresh, commercially dried yeast cells to a fermenter once every week to initiate a new population.

11

Checking for Unfermented Sugars. Finished fermentation mashes (beers) should be checked to see if there is any unfermented sugar. This can be done with glucose test strips (as mentioned in the text) or with a hydrometer, which is discussed here. Sugar solutions have specific gravities (weight per milliliter of solution), which can be measured using hydrometers. There are three types of hydrometers that can be used—°Plato, °Brix, and the regular specific gravity. °Plato and °Brix hydrometers are calibrated to directly read percent by weight of sugar in solution, or grams of sugar per 100 grams of mash; a 0% to 10% calibration is adequate for this work. Specific gravity hydrometers are calibrated to read direct weights of milliliters of solution; for example, a specific gravity of 1.07 to 1.08 reveals a sugar concentration of 17% to 20%. Measurement of the solutions must take place in a cylinder specific to the type of hydrometer; the cylinders can be purchased with the hydrometer. Hydrometers are effective on

The cylinder must be large enough for the hydrometer to float freely.

filtered (clear) solutions. Beer samples for testing should be filtered using coarse filter paper or fine cheesecloth in a funnel (a large-sized coffee filter works but is slow). Then the filtered liquid should be tested.

When a beer has been considered to be finished—that is, 48 to 96 hours have passed since the onset of fermentation—it can be tested for the amount of sugar remaining, if any. A good fermentation should leave little or no residual sugar. The sample is filtered, the liquid placed in the measuring cylinder, and the hydrometer dropped into the liquid and allowed to stabilize. A °Plato or °Brix hydrometer should show 1.0% or less of sugar remaining. The specific gravity hydrometer should show a reading of 1.004 **or less.** If readings are higher than this, the fermentation can be left for 8 to 12 more hours and checked again. If readings are very much higher (2.0° Brix or 1.008 specific gravity), more yeast can be added (which sometimes helps) and/or the fermentation can be left for another 12 hours and retested. If no change occurs after this treatment, further fermentation may not be achievable, and the mash should be sent to distilling.

Because ethanol weighs less than water and glucose, it interferes with the °Brix reading. Ask the retailer for instructions specific to fermentation. Negative °Brix readings can actually indicate the continued presence of sugar. The formula is

$$^\circ\text{Brix}_{\text{actual}} = {}^\circ\text{Brix}_{\text{measured}} + (0.3 \times \%\ \text{Ethanol}),$$

i.e., if there is 10% ethanol present, $^\circ\text{Brix}_{\text{measured}}$ can be as low as −3°, indicating a $^\circ\text{Brix}_{\text{actual}}$ of zero (no sugar).

12 **Checking Proof after Distillation.** It is possible to measure the ethanol content (proof) of the liquid from the finished distillation; it should be mostly ethanol. The proof of the distillate can be checked rapidly using a hydrometer. The hydrometer is calibrated to directly read proof from 0 to 200 (0% to 100% ethanol). The distillate must be placed for measurement in a special cylinder purchased with the hydrometer. The still should be delivering at least 150-proof ethanol.

13 Calculating Yield.

To judge the efficiency of your process by comparing it with a maximally efficient process, it is necessary to

A. Assay the potatoes at a local agriculatural lab for:

   a. starch
   b. protein
   c. fiber
   d. ash
   e. moisture

   a and **e** are the most important.

These amounts will often be reported as % by weight of potatoes. One problem—many methods for measuring starch actually measure glucose. The lab should specify what is actually being reported so that step **D** below (multiplying by 1.11) does not give a higher value than actual.

B. Multiply the weight of potatoes (100 lb, if not diluted) you used as specified in Step 5 for 100 lb of mash times the starch percentage **a** found above. This is the amount by weight of starch you have in 100 lb of mash. (We have been using 17 lb in the procedural section.)

C. Multiply the amount of starch found in **B** by the efficiency by which starch is converted to sugar. This will vary, depending on how well your process performs. A good conversion efficiency, and one you can use for an estimate, is 90%.

D. Fermentable sugars weigh slightly more than starches (they incorporate a water molecule for each molecule of glucose produced during conversion). Multiply the number found in **C** by 1.11 to account for this effect. This is the weight of fermentable sugars in 100 lb of mash.

E. Multiply the weight of fermentable sugars found in **D** by 0.47. This is the efficiency (47%) of the conversion from sugar to ethanol via fermentation, including some loss in efficiency due to yeast cell maintenance and production of some by-products other than ethanol.

F. Multiply the figure calculated in **E** by the recovery efficiency of your still. This is 50%-97%; use the latter for an estimate.

G. Divide the number found in **F** by 6.6 lb/gal to get the number of **gallons** of 200-proof ethanol produced from your feedstock per 100 lb of mash.

When combined into a formula, the above is

$$\overset{\text{(B)}}{\text{wt. of feedstock in 100-lb mash multiplied by the percentage of starch in the whole tubers}} \times \overset{\text{(C)}}{\text{starch-to-sugar conversion efficiency: 90\%}}$$

$$\times \overset{\text{(D)}}{(1.11)} \times \overset{\text{(E)}}{\text{sugar-to-ethanol conversion efficiency: 47\%}} \times \overset{\text{(F)}}{0.97}$$

$$\overset{\text{(G)}}{\div\ 6.6 \text{ lb of ethanol/gal}} = \text{gal of 200-proof ethanol/100 lb of mash}$$

These formulas can be simplified somewhat. Since the **C** to **G** terms are constant, they can be combined by multiplying them together. The formula from **A** through **G** for the number of gallons of 200-proof ethanol produced by each 100-lb unit of mash then becomes

$$\text{wt. of feedstock in your 100-lb mash} \times \text{\% of starch in the whole tubers} \times 0.069$$

$$= \text{gallons of 200-proof ethanol/100 lb of mash.}$$

This result is the ethanol yield you **should** be getting. If you are not getting this yield, your process can be improved. With 17 lb of starch per 100 lb, and no water dilution, this is 1.17 gallons.

Equipment, Chemical, Enzyme, and Yeast Suppliers*

Many of the following companies have sales offices throughout the nation. Addresses and telephone numbers of the office in your area can be obtained by writing to them.

General Products

Fisher Scientific
Corporate Headquarters
711 Forbes Ave.
Pittsburgh, PA 15219

Scientific Products
General Office
1430 Waukegan Rd.
McGaw Park, IL 60085

Sargent-Welch
Sales Service Center
8709 Grovemont Circle
Gaithersburg, MD 20760

Enzyme Manufacturers

Miles Laboratories, Inc.
Enzyme Products Division
P.O. Box 932
Elkhart, IN 46515
(219) 264-8111

Novo Laboratories, Inc.
59 Danbury Road
Wilton, CT 06897
(203) 762-2401

Premier Mal Products, Inc.
1037 W. McKinley
Milwaukee, WI 53201
(414) 347-7300

Biocon (U.S.), Inc.
261 Midland Ave.
Lexington, KY 40507
(606) 254-0517

Scientific Products Co.
North Kansas City, MO 64116
(816) 221-2533

ColorpHast Plastic Indicator Sticks

EM Laboratories, Inc.
500 Executive Blvd.
Elmsford, NY 10523

MC/B Manufacturing Chemists, Inc.
2909 Highland Ave.
Cincinnati, OH 45212

Yeast Suppliers

Red Star Yeast
Fermentation Products Division
Universal Foods Corporation
433 East Michigan St.
Milwaukee, WI 53201
(414) 271-6755

Biocon (U.S.), Inc.
261 Midland Ave.
Lexington, KY 40507
(606) 254-0517

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*This list is necessarily not all inclusive and is meant neither as a recommendation nor to eliminate other, well-qualified sources.

Appendix I

Glossary

Acetaldehyde—a low-boiling industrial chemical used in the synthesis of other compounds.

Acid hydrolysis—decomposition or alteration of a chemical substance by means of an acid.

Acidity—the measure of how many hydrogen ions a solution contains.

Aflatoxin—a substance produced by certain strains of the fungus *Aspergillus flavus*, which contaminates corn and is a carcinogen.

Alcohol—the family name of a group of organic chemicals comprising carbon, hydrogen, and oxygen, which are differentiated by their number of carbon molecules.

Aldehydes—a group of highly reactive organic-chemical compounds obtained by oxidation of the primary alcohols, and characterized by their carbon, hydrogen, oxygen (CHO) group. They are used in the manufacture of resins, dyes, and organic acids.

Alpha-amylase—an enzyme which converts starch into sugars.

Amino acids—the naturally occurring, nitrogen-containing building blocks of protein.

Anaerobic digestion—a type of bacterial degradation of organic matter that occurs only in the absence of air (oxygen).

Anyhdrous—a compound that does not contain water.

ATF—see BATF.

Atmospheric pressure—pressure of the air (and the surrounding atmosphere), which changes from day to day.

Azeotrope—the chemical term for two liquids that, at a certain concentration, boil at the same temperature; alcohol and water cannot be separated further than about 95% because at this concentration, alcohol and water form an azeotrope and vaporize together.

Bagasse—the crushed remains of sugarcane after the juice has been extracted; may be used as a fuel for process heat, as a source of carbohydrate, for processes such as paper production, or as an addition to animal feed.

Batch fermentation—fermentation conducted from start to finish in a single vessel.

BATF—Bureau of Alcohol, Tobacco and Firearms; under the U.S. Department of the Treasury. Responsible for the issuance of permits, both experimental and commercial, for alcohol production. Also known as ATF.

Beer—the product of fermentation by microorganisms; the fermented mash, which contains about 11% to 12% alcohol; usually refers to the alcohol solution remaining after yeast fermentation of sugars.

Beer still—the stripping section of a distillation column for concentrating ethanol.

Biomass—plant material which stores energy gained from the process of photosynthesis; all plants are, in effect, natural solar-energy storehouses.

British thermal unit (Btu)—the amount of heat required to raise the temperature of one pound of water one degree Fahrenheit under stated conditions of pressure and temperatures (equal to 252 calories, 778 foot-pounds, 1,055 joules, and 0.293 watt-hours); it is a standard unit for measuring quantities of heat energy.

Calorie—the amount of heat required to raise one gram of water one degree Centigrade.

Carbohydrate—a chemical term describing compounds made up of carbon, hydrogen, and oxygen; includes all starches and sugars.

Carbon dioxide—a gas produced as a by-product of fermentation; CO_2.

Cassava—a starch-root crop used for tapioca; can be grown on marginal croplands along the southern coast of the United States.

Cellulase—an enzyme capable of splitting cellulose.

Cellulose—the main polysaccharide in living plants. Forms the skeletal structure of the plant cell wall; can be hydrolyzed to glucose.

Celsius (centigrade)—a temperature scale commonly used in the sciences; at sea level, water freezes at 0°C and boils at 100°C.

Centrifuge—a rotating device for separating liquids of different specific gravities, or for separating suspended colloidal particles according to particle-size fractions by centrifugal force.

Cetane number—the measure of the ignition value of diesel fuel.

Column—vertical, cylindrical vessel used to increase the degree of separation of liquid mixtures by distillation or extraction.

Compound—a chemical term denoting a combination of two or more distinct elements.

Concentration—ratio of mass or volume of solute present in a solution to the amount of solvent.

Condenser—a heat-transfer device that reduces a thermodynamic fluid from its vapor phase to its liquid phase.

Continuous fermentation—a steady-state fermentation system that operates without interruption; each stage occurs in a separate section of the fermenter, and flow rates are set to correspond with required residence times.

Denaturation—the process of adding a substance to ethyl alcohol to make it unfit for human consumption; the denaturing agent may be gasoline or other substances specified by the Bureau of Alcohol, Tobacco and Firearms.

Desiccant—a substance having an affinity for water; used for drying purposes.

Destructive distillation—a process in which high cellulose-content organic wastes, such as wood wastes, are heated in the absence of oxygen to decompose them, and then are distilled to produce methanol.

Dextrins—a polymer which is intermediate in complexity between starch and maltose, and is formed by hydrolysis of starches.

Disaccharides—the class of compound sugars which yield two monosaccharide units upon hydrolysis; examples are sucrose, mannose, and lactose.

Distillate—that portion of a liquid which is removed as a vapor and condensed during the distillation process.

Distillation—the process of separating the components of a mixture by using their differences in boiling point; a vapor is formed by heating the liquid in a vessel. The vapors are then successively collected and condensed into liquids.

Distillers dark grains (DDG)—the mixture which results when distillers dried grains (which are also called DDG) are combined with the solubles obtained from fermentation stillage. This product is similar to DISTILLERS DRIED GRAINS WITH SOLUBLES.

Distillers dried grains (DDG)—the coarse-grain fraction of fermentation stillage, which is separated from the liquid and dried.

Distillers dried grains with solubles (DDGS)—the mixture remaining after condensing and drying at least three-fourths of the solids in fermentation stillage. This product is similar to DISTILLERS DARK GRAINS.

Distillers dried solubles (DDS)—the condensing and drying of the thin stillage, which is the water-soluble fraction of fermented mash plus the mash water.

Distillers grain—the nonfermentable portion of a grain mash comprising protein, unconverted carbohydrates and sugars, and inert material.

Ensilage—see silage.

Enzymes—the group of catalytic proteins that are produced by living microorganisms; enzymes mediate and promote the chemical processes of life without themselves being altered or destroyed.

Ethanol (C_2H_5OH)—the alcohol product of fermentation that is used in alcoholic beverages and for industrial purposes; the alcohol blended with gasoline to make gasohol; also known as ethyl alcohol or grain alcohol.

Ethyl alcohol—also known as ethanol or grain alcohol; see ethanol.

Fahrenheit—a temperature scale in which the boiling point of water is 212 and its freezing point is 32; to convert °F to °C, subtract 32, then divide by 1.8.

Feedstock—the base raw material for industrial processes; in the case of ethanol fermentation it consists of monomeric or other fermentable sugars derived from specific crops.

Fermentable sugar—sugar (usually a monomeric sugar such as glucose) derived from starch and cellulose that can be converted to ethanol (also known as reducing sugar or monosaccharide).

Fermentation—a microorganically mediated enzymatic transformation of organic substances, especially carbohydrates, generally accompanied by the production of a gas.

Fermentation ethanol—ethyl alcohol produced from enzymatic transformation or organic substances.

Flash point—the temperature at which a combustible liquid will ignite when a flame is introduced.

Flocculation—the aggregation of fine suspended particles which form floating clusters or clumps.

Fossil fuel—any naturally occurring fuel of an organic nature such as coal, crude oil, or natural gas.

Fractional distillation—a process of separating alcohol and water (or other mixtures).

Fructose—a fermentable monosaccharide (simple) sugar with the chemical formula $C_6H_{12}O_6$. Fructose and glucose are optical isomers, that is, their chemical structures are the same, but their geometric configurations are mirror images of one another.

Fusel oil—a clear, colorless, poisonous liquid mixture of alcohols obtained as a by-product of grain fermentation; generally amyl, iso-amyl, n-propyl, and iso-butyl alcohols, and acetic and lactic acids.

Gasohol—registered trade name by the Nebraska Agricultural Industrial Utilization Committee for a blend of 90% unleaded gasoline with 10% agriculturally derived fermentation ethanol.

Gasoline—a volatile, flammable liquid obtained from petroleum that has a boiling range of approximately 29°–216°C and is used as fuel for spark-ignition internal combustion engines.

Gelatinization—a process in which starch granules are heated, causing them to rupture and form a gel of soluble starch and dextrins.

Glucose—a monosaccharide and the most common sugar.

Grain alcohol—see ethanol.

Heating value—the amount of heat obtainable from a fuel, expressed in Btu per unit measurement of the fuel.

Hexose—various simple sugars with six carbon atoms per molecule.

Hydrated—chemically combined with water.

Hydrocarbon—a chemical compound containing hydrogen, oxygen, and carbon.

Hydrolysis—the alteration of a compound into other compounds by the addition of a water molecule.

Indolene—a petroleum fuel used in comparative tests of automotive fuels.

Inoculum—a small amount of yeast produced from a pure culture that is used to start a new culture.

Inulin—a polymeric carbohydrate made up of fructose monomers found in many plants, including the Jerusalem artichoke.

Kilopascal—a unit of pressure measurement; kPa.

Lactose—also called milk sugar; it is a white disaccharide derived from milk products such as whey.

Lean fuel mixture—an excess of air in the air/fuel ratio.

Lignin—a substance that with cellulose forms the woody cell walls of plants. It is a polymeric material characterized by a higher carbon content than cellulose, and by propyl-benzene units, methoxyl groups, and hydroxyl groups.

Lignified cellulose—cellulose polymer wrapped in a polymeric sheath with linkages called lignin, which makes it resistant to hydrolysis.

Liquefaction—the process of changing a substance into the liquid state; in fermentation, specifically converting water-insoluble carbohydrate to water-soluble carbohydrate.

Malt—barley softened in water and allowed to germinate; used especially in brewing and distilling.

Mash—a mixture of any grain feedstocks and other ingredients with water in preparation for fermentation.

Methanol—also known as methyl alcohol and wood alcohol; the simplest alcohol, CH_3OH, formed by the destructive distillation of wood, from biomass, or from coal gasification. It is used as an antifreeze, a solvent, a fuel, and in production of other chemicals.

Methyl alcohol—see methanol.

Michaelis constant—the concentration of substrate at which the speed of the reaction is one-half of maximum velocity.

Millimolar—the number of millimoles of substrate per liter in a reaction; mM.

Molecular sieve—a column which separates molecules by selective adsorption of molecules on the basis of size.

Molecule—the chemical term for the smallest pa cle of matter that is the same chemically as whole mass.

Monomer—a simple compound which is cap combining with other like or unlike mole form a polymer.

Monosaccharides—fermentable sugar

glucose, and derived from starch, cellulose, or other sugars.

Motor octane number—a rating measuring the tendency of an engine to knock when a motor fuel is used in standardized testing situations.

Octane number—a rating which indicates the tendency of an engine to knock when a motor fuel is used in a standard spark-ignited internal combustion engine. See also motor octane number and road octane number.

Osmosis—the tendency of a liquid to pass through a semipermeable membrane into a solution where its concentration is lower, thus equalizing conditions on either side of the membrane.

Osmotic pressure—the pressure necessary to prevent passage of a solvent across a membrane (which could be a cell wall), thereby separating solutions of different concentrations.

pH—a term used to describe the free hydrogen-ion concentration of a solution; a solution of pH 0 to < 7 is acid, 7 is neutral, > 7 to 14 is alkaline.

Polymer—a substance made of long-chained molecules or cross-linked simple molecules.

Polysaccharide—a carbohydrate decomposable by hydrolysis into two or more molecules of monosaccharides or their derivatives.

Proof—a measure of alcohol content; one percent equals 2 proof.

Proof gallon—a U.S. gallon of liquid which is 50% ethanol by volume.

Protein—any of a class of nitrogenous high molecular-weight polymer compounds which yield amino acids required in animal metabolism to carry out life processes.

Pump octane rating—the Road Octane Rating plus the Motor Octane Rating divided by two.

Pyrolysis—the breaking apart of complex molecules into simpler units by heating in the absence of oxygen.

Rectification—in distillation, the selective increase of a concentration of the lower volatile component in a mixture by successive evaporation and conden-
tion.

g column—the portion of a distillation col-
ve the feed tray in which rising vapor
ith a countercurrent falling stream of
or.

f the product stream which is
ss to assist in increasing con-

s, such as for energy
replaced through

natural means (e.g., wind, solar, biomass).

Rich fuel mixture—an excess of fuel in the air/fuel ratio.

Road octane number—a numerical rating for automotive antiknock properties of a liquid fuel determined by operating a car over a level road.

Saccharification—the process of changing or hydrolyzing a complex carbohydrate into a simpler soluble fermentable or monomeric sugar, such as glucose.

Saccharomyces—a class of single-cell yeasts which selectively consume simple sugars.

Silage—fodder, such as field corn or hay, which has undergone an acid fermentation to retard spoilage and is used as a livestock feed. Also called ensilage.

Starch—a carbohydrate polymer consisting of glucose monomers linked together in a particular pattern (a glycosidic bond organized in repeating units), which is found in most plants, and is the principal energy-storage form of photosynthesis.

Still—an apparatus for distilling liquids, particularly alcohols, consisting of a vessel in which the liquid is vaporized by heat, and a cooling device in which the vapor is condensed.

Stillage—the nonfermentable residue, both solids and liquids, from the fermentation of mash to produce alcohol.

Stoichiometric—the exact calculation of the chemical elements or compounds necessary for a particular reaction to occur.

Stover—the dried stalks and leaves of a crop remaining after the grain has been harvested.

Streptomyces—a genus of the family *Streptomycetaceae*, which are higher order bacteria.

Sucrose—a crystalline disaccharide carbohydrate found in some plants, mainly sugarcane, sugar beets, and maple trees; $C_{12}H_{22}O_{11}$.

Substrate—a substance acted upon in a reaction; a source of reactive material.

Thermophilic—capable of growing and surviving at high temperatures.

Vaporize—to change from a liquid or a solid to a vapor, as in heating water to steam.

Whey—the watery part of milk separated from the curd in the process of making cheese.

Wort—the liquid remaining from a brewing mash preparation following the filtration of fermentable beer.

Yeast—single-cell microorganisms (fungi) that are capable of changing sugar to alcohol by fermentation.

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