Executive Summary

Literature Review

Impact of Gasoline Blended with Ethanol on the Long-Term Structural Integrity of Liquid Petroleum Storage Systems and Components

JUNE 2002

Copyright American Petroleum Institute
Reproduced by IHS under license with API
No reproduction or networking permitted without license from IHS
Not for Resale
Full document details: API Executive Summary. Literature Review. Impact of Gasoline Blended with Ethanol on the Long-Term Structural Integrity of Liquid Pe...

Documents
Document Sharing Hub

Copyright American Petroleum Institute
Reproduced by IHS under license with API
No reproduction or networking permitted without license from IHS
Not for Resale
Full document details: API Executive Summary. Literature Review. Impact of Gasoline Blended with Ethanol on the Long-Term Structural Integrity of Liquid Pe...

EXECUTIVE SUMMARY

Literature Review

Impact of Gasoline Blended with Ethanol on the Long-Term Structural Integrity of Liquid Petroleum Storage Systems and Components

sponsored by

American Petroleum Institute
Washington, DC

Fiberglass Tank and Pipe Institute
Houston, Texas

Steel Tank Institute
Lake Zurich, Illinois

Western States Petroleum Association
Glendale, California

prepared by

Simpson Gumpertz & Heger Inc.
297 Broadway
Arlington, Massachusetts 02474
Tel.: 781-643-2000
Fax: 781-643-2009

Comm. 20667 June 2002

Documents
Document Sharing Hub

Copyright American Petroleum Institute
Reproduced by IHS under license with API
No reproduction or networking permitted without license from IHS
Not for Resale
Full document details: API Executive Summary. Literature Review. Impact of Gasoline Blended with Ethanol on the Long-Term Structural Integrity of Liquid Pe...

SPECIAL NOTES

API publications necessarily address problems of a general nature. With respect to particular circumstances, local, state, and federal laws and regulations should be reviewed.

API is not undertaking to meet the duties of employers, manufacturers, or suppliers to warn and properly train and equip their employees, and others exposed, concerning health and safety risks and precautions, nor undertaking their obligations under local, state, or federal laws.

Information concerning safety and health risks and proper precautions with respect to particular materials and conditions should be obtained from the employer, the manufacturer or supplier of that material, or the material safety data sheet.

Nothing contained in any API publication is to be construed as granting any right, by implication or otherwise, for the manufacture, sale, or use of any method, apparatus, or product covered by letters patent. Neither should anything contained in the publication be construed as insuring anyone against liability for infringement of letters patent.

Generally, API standards are reviewed and revised, reaffirmed, or withdrawn at least every five years. Sometimes a one-time extension of up to two years will be added to this review cycle. This publication will no longer be in effect five years after its publication date as an operative API standard or, where an extension has been granted, upon republication. Status of the publication can be ascertained from the API Standards department telephone (202) 682-8000. A catalog of API publications, programs and services is published annually and updated biannually by API, and available through Global Engineering Documents, 15 Inverness Way East, M/S C303B, Englewood, CO 80112-5776.

This document was produced under API standardization procedures that ensure appropriate notification and participation in the developmental process and is designated as an API standard. Questions concerning the interpretation of the content of this standard or comments and questions concerning the procedures under which this standard was developed should be directed in writing to the Director of the Standards department, American Petroleum Institute, 1220 L Street, N.W., Washington, D.C. 20005. Requests for permission to reproduce or translate all or any part of the material published herein should be addressed to the Director, Business Services.

API standards are published to facilitate the broad availability of proven, sound engineering and operating practices. These standards are not intended to obviate the need for applying sound engineering judgment regarding when and where these standards should be utilized. The formulation and publication of API standards is not intended in any way to inhibit anyone from using any other practices.

Any manufacturer marking equipment or materials in conformance with the marking requirements of an API standard is solely responsible for complying with all the applicable requirements of that standard. API does not represent, warrant, or guarantee that such products do in fact conform to the applicable API standard.

All rights reserved. No part of this work may be reproduced, stored in a retrieval system, or transmitted by any means, electronic, mechanical, photocopying, recording, or otherwise, without prior written permission from the publisher. Contact the Publisher, API Publishing Services, 1220 L Street, N.W., Washington, D.C. 20005.

Copyright © 2002 American Petroleum Institute

Documents
Document Sharing Hub

Copyright American Petroleum Institute
Reproduced by IHS under license with API
No reproduction or networking permitted without license from IHS
Not for Resale
Full document details: API Executive Summary. Literature Review. Impact of Gasoline Blended with Ethanol on the Long-Term Structural Integrity of Liquid Pe...

FOREWORD

The contents and findings of this document and its supporting research are the work of an independent contractor and do not necessarily reflect the views of API. API does not warrant the accuracy or validity of findings or supporting research contained in this document, and disclaims any liability for reliance thereon.

API publications may be used by anyone desiring to do so. Every effort has been made by the Institute to assure the accuracy and reliability of the data contained in them; however, the Institute makes no representation, warranty, or guarantee in connection with this publication and hereby expressly disclaims any liability or responsibility for loss or damage resulting from its use or for the violation of any federal, state, or municipal regulation with which this publication may conflict.

Suggested revisions are invited and should be submitted to API, Standards department, 1220 L Street, NW, Washington, DC 20005, standards@api.org.

Documents
Document Sharing Hub
Copyright American Petroleum Institute
Reproduced by IHS under license with API
No reproduction or networking permitted without license from IHS
Not for Resale
Full document details: API Executive Summary. Literature Review. Impact of Gasoline Blended with Ethanol on the Long-Term Structural Integrity of Liquid Pe...

Documents
Document Sharing Hub

Copyright American Petroleum Institute
Reproduced by IHS under license with API
No reproduction or networking permitted without license from IHS
Not for Resale
Full document details: API Executive Summary. Literature Review. Impact of Gasoline Blended with Ethanol on the Long-Term Structural Integrity of Liquid Pe...

Table of Contents

CONTENTS **Page**

1. INTRODUCTION 1

2. LITERATURE REVIEW 1

3. FINDINGS 1
   - 3.1 Overview of Ethanol in Gasoline Fuel 1
   - 3.2 Phase Separation and Water Bottoms 2
   - 3.3 Fiberglass Reinforced Plastic (FRP) Tanks 4
   - 3.4 Steel Tanks 6
   - 3.5 Coatings/Linings 8
   - 3.6 Piping 9
   - 3.7 Other Components 10

4. CONCLUSIONS AND RECOMMENDATIONS 12
   - 4.1 Summary of Findings 12
   - 4.2 Research Needs 14

REFERENCES

APPENDIX A – Literature Review

--`,,``,`-`-`,,`,,`,`,,`---

Documents
Document Sharing Hub

Copyright American Petroleum Institute
Reproduced by IHS under license with API
No reproduction or networking permitted without license from IHS

Not for Resale

Full document details: API Executive Summary. Literature Review. Impact of Gasoline Blended with Ethanol on the Long-Term Structural Integrity of Liquid Pe...

--`,,``,,`-`-`,,`,,`,`,,`---

Documents
Document Sharing Hub

Copyright American Petroleum Institute
Reproduced by IHS under license with API
No reproduction or networking permitted without license from IHS
Not for Resale
Full document details: API Executive Summary. Literature Review. Impact of Gasoline Blended with Ethanol on the Long-Term Structural Integrity of Liquid Pe...

1. INTRODUCTION

This report summarizes the results of a literature review conducted for the American Petroleum Institute on the impact of gasoline blended with ethanol on the long-term structural integrity of liquid petroleum storage systems and components.

It is anticipated that the use of ethanol in motor fuels will continue to increase. This has generated interest about the potential long-term structural effects of ethanol on liquid petroleum storage systems, including underground storage tanks (USTs), underground piping, and associated components.

The objective of the literature review is to determine the state of industry knowledge and research on the effects of ethanol/gasoline blends on the long-term structural integrity of UST systems and components. This review is intended to assist decision-makers on further research requirements and needed changes or supplements to existing standards for underground storage systems and components used for storing and dispensing gasoline blended with ethanol.

2. LITERATURE REVIEW

Attached in Appendix A are the synopsis' and bibliographic information for all articles reviewed for the project. The report is organized by article index numbers. Reference numbers cited in this report refer to the article index number.

3. FINDINGS

3.1 Overview of Ethanol in Gasoline Fuel

Ethanol is an alcohol produced through the fermentation of biomass, typically corn, although other sources may be used. Ethanol containing some water is called "hydrated"; ethanol that is further processed to remove all water is called "anhydrous". As a fuel oxygenate, ethanol is blended with gasoline to increase the oxygen content of the fuel. The resulting mixture is typically a blend of 10% ethanol and 90% gasoline, conventionally termed "gasohol," although other mix proportions have been used. Ethanol is also used as a volume extender and octane enhancer in gasoline fuels. The term "ethanol fuel" refers to the use of ethanol as the primary

Documents
Document Sharing Hub

Copyright American Petroleum Institute
Reproduced by IHS under license with API
No reproduction or networking permitted without license from IHS
Not for Resale
Full document details: API Executive Summary. Literature Review. Impact of Gasoline Blended with Ethanol on the Long-Term Structural Integrity of Liquid Pe...

energy containing substance. Storage systems may be called upon to store any concentration of ethanol. Therefore, while focusing on gasohol, this literature search examines all ethanol blends. Furthermore, studies pertaining to higher concentrations of ethanol are relevant when examining effects of the lower layer of a phase-separated ethanol/gasoline blend.

Methanol, an alcohol produced from natural gas, is also used as an oxygenate or fuel substitute. It has been suggested that methanol studies may be indicative of worst case limits for ethanol compatibility; however, this has not been proven for all materials. Multiple sources indicate that methanol is much more aggressive than ethanol to materials used in fuel storage (49, 97, 130).

Ethanol has been used as an oxygenate in the Midwest for over 20 years (239). Relatively few material compatibility problems have been reported with the use of 10% ethanol blends (56) and no recorded major leak or failure has been directly attributed to ethanol use (248). The most often reported problems are swelling, hardening, or minor leakage of elastomeric seals and o-rings (66). Notwithstanding this experience, there is interest to determine the long-term effects of exposure of storage system materials to ethanol/gasoline blends and to determine if there are legitimate concerns about possible leaks in the system due to shrinkage and cracking of seals and o-rings in dispensing equipment in systems that are switched from ethanol service to non-ethanol service.

3.2 Phase Separation and Water Bottoms

Water and gasoline are immiscible, and phase separation will result from almost any quantity of water in gasoline, separating into water and gasoline layers. The lower water phase is termed “water bottom” in fuel tanks. Unlike gasoline, alcohol is a polar molecule and will therefore mix readily with water, up to various levels of saturation depending on other soluble and suspended components in the mixture. Alcohol is also miscible with gasoline but has a higher affinity to water than to gasoline and will adhere preferentially to the water. If sufficient water is present, the ethanol and water will separate from the gasoline. This process is called phase separation and will occur at approximately 0.5% water content for 10% ethanol / 90% gasoline blends (58, 106). The blend separates into an alcohol/water lower phase (water phase) and an upper phase consisting of gasoline with a slightly reduced alcohol concentration (hydrocarbon phase) (186). No study reports the exact composition of each phase, but one paper states that the

Documents
Document Sharing Hub
Copyright American Petroleum Institute
Reproduced by IHS under license with API
No reproduction or networking permitted without license from IHS
Not for Resale
Full document details: API Executive Summary. Literature Review. Impact of Gasoline Blended with Ethanol on the Long-Term Structural Integrity of Liquid Pe...

lower layer consists of 75% ethanol, cosolvents, and 25% water (124, 135).

Phase separation is a concern because it creates an alcohol rich water bottom, which can increase the potential for localized corrosion of steel tank walls (50, 124). Higher corrosivity has been attributed to increased oxygen content and increased conductivity of the ethanol/water phase (50, 73, 135). No test data are available to quantify the change in the conductivity and associated corrosion rate in alcohol-rich water bottoms. Other effects include the dissolution of corrosion by-products by the alcohol (55, 56, 58), thus exposing the metal to continued corrosive activity, and the presence of other fuel components in the ethanol/water phases (such as acetic acid) that accelerate corrosion rates (161). Conversely, one study indicates that alcohol-rich water bottoms are no more corrosive than non-alcohol water bottoms (55). However, the study did not include the effects of impurities in the solution. The higher alcohol content in water bottoms may be locally detrimental to FRP tank walls that are qualified only for low alcohol blends; however, no such problems have been reported or evaluated in the literature.

In order to reduce the likelihood of phase separation, efforts must be taken to avoid water infiltration into systems containing ethanol/gasoline blends (44). Tanks should be free of water prior to initial filling and all precautions should be taken to minimize the potential for water infiltration and condensation in the tank (58). Removal of the water layer is recommended by API (132). Manual and automatic methods are available to detect the presence of a water phase in buried tanks (177).

One article suggests that the presence of ethanol reduces the likelihood of water bottoms by maintaining the water in solution (295). The dissolved water is carried out of the system with fuel consumption. This mechanism relies on small quantities of water entry as required by current specifications such that the water quantity does not exceed the threshold for phase separation.

Microbial growth in storage tanks can be fostered by water bottoms (177, 243). Microbial contamination can affect both certain metallic and non-metallic materials. Microbes, both bacterial and fungal, can enter a storage system through fuel transfers, vents, and equipment and can grow wherever water is present, for example at the fuel/water interface in water-bottoms and on the upper walls and ceilings of tanks where condensation is prevalent.

Documents
Document Sharing Hub
Copyright American Petroleum Institute
Reproduced by IHS under license with API
No reproduction or networking permitted without license from IHS
Not for Resale
Full document details: API Executive Summary. Literature Review. Impact of Gasoline Blended with Ethanol on the Long-Term Structural Integrity of Liquid Pe...

Microbial growth can be controlled through cleaning and use of biocides (254, 243). Existing literature suggests that ethanol may increase the occurrence of microbial attack, but provide no specifics on the extent of reported increase (243).

3.3 Fiberglass Reinforced Plastic (FRP) Tanks

FRP tank laminates are composites of thermosetting resins and glass fibers. Some thermosetting resins (e.g. orthophthalics) do not perform well in alcohols and alcohol fuels (20, 201), and are not known to have been used for this service. Resins typically used in FRP tanks (e.g. isophthalics, terephthalics, and vinyl esters) exhibit some level of swelling (with weight gain) and softening when exposed to alcohols, including ethanol (20, 50, 56). Methanol produces more pronounced effects than ethanol (148), and ethanol/gasoline mixtures may be more aggressive than pure ethanol (20, 50). Softening can be measured as reduction in hardness and material stiffness, which can be measured by mechanical tests for Barcol surface hardness and modulus of elasticity. These physical changes are a function of permeation, which can be measured by absorption and swelling tests, and are largely reversible if the laminate is allowed to dry (18, 22, 24). After desorption of alcohol, some permanent loss of mechanical properties may occur, but the mechanism is not well defined (22). Reduced stiffness, along with creep, results in a lower resistance to buckling, a key design criterion for FRP tanks. This behavior may affect the adequacy of safety factors for buckling design of FRP tanks exposed to ethanol/gasoline blends (50).

The U.S. standard governing the manufacturer of FRP underground storage tanks (UST) is Underwriters Laboratories (UL) 1316 “Glass-Fiber-Reinforced Plastic Underground Storage Tanks for Petroleum Products, Alcohols, and Alcohol-Gasoline Mixtures” (107). The standard was first published in 1983. Since 1987 this standard has required long term (180 days) immersion tests on FRP tank laminates in ethanol and ethanol/gasoline blends for tanks intended for that service. Prior to the 1987 edition, the standard did not require testing for ethanol or other alcohol exposure. The current standard does not require tanks intended for petroleum products only to be tested for alcohol immersion. For tanks intended for ethanol/fuel mixtures, after high-temperature, double-sided exposure of test specimens, the material must retain 50% of its short-term flexural strength and stiffness, and impact resistance when test results are extrapolated to 270 days (107).

Documents
Document Sharing Hub
Copyright American Petroleum Institute
Reproduced by IHS under license with API
No reproduction or networking permitted without license from IHS
Not for Resale
Full document details: API Executive Summary. Literature Review. Impact of Gasoline Blended with Ethanol on the Long-Term Structural Integrity of Liquid Pe...