Ignition Risk of Hydrocarbon Vapors by Hot Surfaces in the Open Air

API PUBLICATION 2216
SECOND EDITION, JANUARY 1991

American Petroleum Institute
1220 L Street, Northwest
Washington, D.C. 20005

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Safety and Fire Protection Department

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Ignition Risk of Hydrocarbon Vapors by Hot Surfaces in the Open Air

SECTION 1—GENERAL

1.1 Purpose

This publication describes the ignition behavior of flammable hydrocarbon vapors exposed to hot surfaces in the open air.

1.2 Introduction and Scope

The ignition of accidental releases of hydrocarbons in the atmosphere may result in damaging fires. Frequently, hot surfaces in the area where hydrocarbon vapor is released are assumed to be the ignition source; however, hot surfaces, even at temperatures above the published and generally accepted ignition temperature of the hydrocarbon, may not ignite the flammable mixture. Even vehicle exhaust systems, in most instances, do not operate at a sufficiently high temperature to ignite hydrocarbon vapor in the open air.[1] Experimental studies and experience have shown that hot surfaces must be hundreds of degrees above published minimum ignition temperatures to ignite freely moving flammable vapor in the open air. Whether or not flame will develop depends not only on the temperature but also on the extent of the surface, its geometry, and the ambient conditions.[2] This publication covers the technical basis for the study of ignition risk and the practical implications thereof. In particular, fire investigators should understand that ignition of flammable hydrocarbon vapor by a hot surface at published minimum ignition temperatures is improbable. Such knowledge should lead fire investigators to search diligently for other ignition sources where conditions make ignition by a hot surface questionable or unlikely.

When certain confined conditions exist, such as when oil-soaked insulation is in an unventilated, confined area, ignition of hydrocarbons may occur by spontaneous combustion at temperatures below published ignition temperatures. This publication does not include discussion of this phenomenon because the mechanism involved is different from that involved in open-air ignition.

SECTION 2—SUMMARY OF RESEARCH

2.1 Ignition Temperature

The *ignition temperature* of a substance is the minimum temperature required to initiate or cause selfsustained combustion independently of the heating or heated element.[3] Some publications use the terms *autoignition temperature* and *autogenous ignition temperature* (AIT). The term *spontaneous ignition temperature* (SIT) is also used. The term *ignition temperature* is used in this publication and has the same meaning as AIT and SIT.

Although the definition of *ignition temperature* is specific, the value observed depends substantially on the conditions.[4] The occurrence of vapor releases in the open air constitutes conditions that are very different from those of a standard laboratory ignition-temperature test. Therefore, because field conditions differ from laboratory conditions, ignition of such vapor releases requires a surface temperature different from published ignition temperatures.

2.2 Standard Test Method

The standard ignition-temperature test [5] involves heating a glass flask and introducing small measured amounts of a flammable or combustible liquid. If ignition occurs, the flask wall temperature and the time for ignition to occur after introduction of the sample (ignition lag) are noted. The test is repeated with different flask wall temperatures to determine the lowest temperature at which ignition occurs within less than 10 minutes. This temperature is reported as the minimum ignition temperature of the material.

2.3 Open-Air Test

The effect of ignition lag time on several paraffin hydrocarbons in the open air is shown in Table 1.[6] The data in Table 1 indicate that flammable mixtures heated for short periods of time require exposure to higher surface temperatures for ignition to occur. In open air, convection currents near a hot surface and normal wind disturbances move a flammable vapor-air mixture past the hot surface rapidly, so that the time of contact is only seconds or a fraction of a second. Because the contact time under open-air conditions is so short, the surface temperature necessary for ignition is substantially higher than accepted minimum ignition temperatures.

The effect of wind velocity has been measured in wind tunnel tests with kerosene [published ignition temperature 210°C (410°F)] as shown in Table 2.[7]

Small-scale laboratory tests were made on relatively unconfined butane-air and gasoline-air mixtures [published ignition temperatures 287°C (550°F) and 280°C (536°F), respectively]. The tests determined that metal surfaces reached temperatures of about 760°C (1400°F) before ignition occurred. A number of more realistic tests have been made in the

Table 1—Effect of Ignition Lag Time on Ignition Temperature

	Ignition Lag (seconds)					
	100		10		1	
Material	°C	°F	°C	°F	°C	°F
Pentane	215	419	297	567	413	775
Hexane	216	421	288	550	384	723
Heptane	202	396	259	498	332	630

open air where normal wind and convection currents existed.[8] The results of these tests are listed in Table 3. In these tests the results were essentially the same for hydrocarbon droplets sprayed on the surface as for a vapor-air mixture released at the surface.

2.4 Industry Experience

Test data indicate that hot surfaces must be several hundred degrees Fahrenheit above the laboratory-measured minimum ignition temperatures to ignite flammable hydrocarbon vapor in the open air. Years of practical experience support this conclusion. Many small leaks or discharges of flammable or combustible hydrocarbon vapor have occurred in process units without ignition by nearby hot equipment or other uninsulated surfaces with temperatures of up to several hundred degrees Fahrenheit above listed minimum ignition temperatures. Discharges of flammable hydrocarbon vapor that do ignite usually do so because they encounter a fired furnace or a similar source of ignition.

2.5 Oxygenates

With the recent addition of oxygenates, such as ethanol and methanol, to gasoline, preliminary data indicate that gasoline blended with 10 percent ethanol behaves like gasoline, that is, it does not ignite when in contact with a hot metal surface with a temperature of about 265°C (475°F) above the published ignition temperature. However, gasoline containing 10 percent of a methanol/isobutanol blend demonstrated some tendency to ignite at about 200°C (360°F) above the published ignition temperature because it wetted the hot surface more effectively.[9]

2.6 Conclusions

Experimental data and field experience indicate that ignition of flammable hydrocarbon vapors by a hot surface in the open air requires temperatures well above the laboratory-determined minimum ignition temperature of the material involved. *As a rule of thumb, ignition by a hot surface in the open air should not be assumed unless the surface temperature is about 200°C (360°F) above the accepted minimum ignition temperature.*

Fire investigators should recognize the nature of ignition of hydrocarbon vapors by a hot surface in open air. Otherwise, a study of an incident may lead to identification of the wrong source of ignition and result in improper and ineffective remedial action.

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Table 2—Effect of Wind Velocity in Tests on Kerosene

Wind Velocity Over the Hot Surface		Surface Temperature Required for Ignition	
Meters per Second	Feet per Second	°C	°F
0.3	1.0	405	760
1.5	5.0	660	1220
3.0	10.0	775	1425

Table 3—Open-Air Ignition Tests Under Normal Wind and Convection Current Conditions

	Published Ignition Temperature		Hot Surface Temperature Without Ignition	
Material	°C	°F	°C	°F
Gasoline	280–425	540–800	540–725	1000–1335
Lube oil	370	700	650	1200
Light naphtha	330	625	650	1200
Ethyl ether	160	320	565	1050

Order No. 855-22160

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