Rocket- Satellite- and Jet- Fuel

1. Introduction

Propulsion is based on a controlled reaction of a fuel mixture. The reaction releases energy and gaseous combustion products. They escape through a nozzle and accelerate the object. This is called thrust. The fuel can be liquid or solid. One part is called the oxidizer the other propellant.
This application note deals with the different propellants and oxidizers being use for different tasks, like civil and military rockets, for navigating satellites and for emergency power in fighter jets.
Fuel escaping through leaks can ignite with the oxygen in air and cause an explosion. Therefore it is important to do combustion monitoring where ever fuel is stored or handled. If cryogenic fuel is being used the safe handling is even more a challenging task.

Following fuel as commonly in use:

- Hydrazine (Oxidizer nitrogen tetroxide N_2O_4)
- Monomethyl hydrazine (MMH) (Oxidizer nitrogen tetroxide N_2O_4)
- Unsym. Dimethyl hydrazine (UDMH) (Oxidizer nitrogen tetroxide N_2O_4)
- Hydrogen (LH2) (Oxidizer: liquid oxygen LOX)
- Aluminum with binder polybutadiene (Oxidizer: ammonium perchlorate)
- Refined Petroleum

Common oxidizers are:

- Liquid oxygen (LOX)
- Hydrogen peroxide (H_2O_2)
- Nitrogen tetroxide (N_2O_4)
- Nitric acid HNO_3

Some examples of types of fuel being used for thrust:

- H_2 / O_2:	Ariane V, Centauer, 2./3. stage Saturn V,
- N_2H_4 / N_2O_4:	seldom,
- AZ50 / N_2O_4:	Titan III,
- UDMH / N_2O_4:	1. stage Ariane IV,
- UDMH / HNO_3:	3. stage Atlas Agena,
- MMH / N_2O_4:	Orbital Maneuvering System in Space Shuttle.

2. Market Segment

- air- and spacecraft, payload rockets
- military Missiles
- Fighter jets
- Satellite makers and satellite engine manufacturers
- Transport and storage of rocket fuel
- Production and processing rocket fuel

3. Description Challenge

Most of the propellants are either combustible, toxic or carcinogenic. People and installations have to be protected by gas monitoring for spills, leaks and exposure. Accidents may happen during transportation, filling and draining of propellants and oxidizer. Cryogenic propellants are kept under very low temperatures and high pressure. Leaks can generate large clouds and have to be detected early.
Combustion products can also be a threat to human health and the environment. The following describes common mixtures of propellants.

3.1 Hydrazine

Hydrazine in combination with oxidizer nitrogen-tetroxide N_2O_4 is a Hypergolic propellant. These are fuels and oxidizers which ignite on contact with each other and need no ignition source. This easy start and restart capability makes them attractive for both manned and unmanned spacecraft maneuvering systems. Hydrazine itself will combust at high temperatures without any oxidizer and generate ammonia and nitrogen.
Another plus is their storability they do not have the extreme temperature requirements of cryogenics. Hydrazine has a low TLV and has to be monitored to avoid human exposure. Besides having a low TLV, Nitrogen-tetroxide as well as NO2 form a corrosive acid when in contact with humidity.
Some jet-fighters are also using hydrazine for an emergency power turbine. In case of an engine brake down the turbine will generate power for the electrical and hydraulic system. This will give the plane about 10 minutes to reach the ground. The hydrazine will have to be filled and refilled for and after the flight which has to be monitored for leaks and spills.

3.2 MMH and UDMH

Other hypergolic fuels include monomethyl hydrazine (MMH) and unsymmetrical dimethyl hydrazine (UDMH). The oxidizer is typically nitrogen tetroxide (N_2O_4) or nitric acid (HNO_3). UDMH is used in many Russian, European, and Chinese rockets while MMH is used in the orbital maneuvering system (OMS) and reaction control system (RCS) of the Space Shuttle orbiter.
TLV thresholds are higher for MMH and UDMH than for pure hydrazine. The Titan family of launch vehicles and the second stage of the Delta use a fuel called Aerozine 50, a mixture of 50% UDMH and 50% hydrazine. Aerozine 50 is cheaper than the pure substances.

3.3 Hydrogen

Cryogenic propellants are liquefied gases stored at very low temperatures, namely liquid hydrogen (LH_2) as the fuel and liquid oxygen (LO_2) as the oxidizer. LH_2 remains liquid at temperatures of -423 degrees F (-253 degrees C) and LO_2 remains in a liquid state at temperatures of -298 degrees F (-183 degrees C).
Because of the low temperatures of cryogenic propellants, they are difficult to store over long periods of time. For this reason, they are less desirable for use in military rockets which must be kept launch ready for months at a time. Also, liquid hydrogen has a very low density (0.59 pounds per gallon) and, therefore, requires a storage volume many times greater than other fuels. Despite these drawbacks, the high efficiency of liquid hydrogen/liquid oxygen makes these problems worth coping with when reaction time and storability are not too critical.

Liquid hydrogen and liquid oxygen are used as the propellant in the high efficiency main engines of the space shuttle e.g.
Spills can easily generate huge clouds of gas due to evaporation. Combustion and oxygen deficiency are the threads to be controlled.

3.4 Aluminum

Unlike liquid-propellant engines, though, a solid- propellant motor cannot be shut down. Once ignited, it will burn until all the propellant is exhausted. Titan, Delta and Space Shuttle vehicles depend on solid rockets to provide added thrust at lift off.
A solid propellant always contains its own oxygen supply. The oxidizer in the Shuttle solids is ammonium perchlorate. The fuel is a form of powdered aluminum with an iron oxidizer powder as a catalyst.
When it burns, aluminum oxide and hydrogen chloride are emitted. Hydrogen chloride becomes hydrochloric acid in the presence of water thus the emissions cause acid precipitation.

3.5 Nitrogen tetroxide N2O4

Nitrogen tetroxide (formula N_2O_4) actually is a dimer (a molecule formed from two similar constituents called monomer) that dissociates into two molecules of nitrogen dioxide (formula NO_2). As a yellow-brown liquid it evaporates into a colorless gas. Then it dissociates it forms nitrogen dioxide (NO_2), a reddish-brown gas.
Nitrogen tetroxide **(**N_2O_4**)** is a hypergolic propellant often used in combination with a hydrazine-based rocket fuel. Nitrogen tetroxide is an oxidizer and highly toxic and corrosive. When it is combined with water the resultant is nitric acid. It is also called dinitrogen tetroxide. Applied TLV is the one from NO2.

4. Substances

name	Hydrazine	Monomethyl hydrazine	Dimethyl hydrazine	Nitrogen tetroxide / nitrogen dioxide
Formula	N_2H_4	CH_3-NH-NH_2	$(CH_3)_2$-N-NH_2	N_2O_4 / NO_2
MAK[1]				5 ppm
TWA[2]	0,1 ppm	0,2 ppm	0,5 ppm	3 ppm
STEL[2]				5 ppm
IDLH	50 ppm		15 ppm	20 ppm
UEG	4,7 Vol%	2,5 Vol%	2 Vol%	12,5 Vol%
OEG	100 Vol%	97 Vol%	95 Vol%	100 Vol%
Proper-ties	- toxic, colorless, liquid with ammonia-like odor - boiling point 113°C - carcinogenic - explosive odor threshold - 4 ppm	- toxic, colorless, hygroscopic liquid with strong odor - forms explosive mixtures with air - boiling point 87,5°C	- toxic, colorless, liquid with ammonia-like odor - boiling point 63°C - heavier than air - self igniting at contact with air	- toxic, brownish, very little odor - - acidic, corrosive - heavier than air

Name	Hydrogenchloride	Hydrogenperoxide	Ammonia
Formula	HCl	H_2O_2	NH_3
MAK[1]	5 ppm	1 ppm	50 ppm
TWA[2]	5 ppm	1 ppm	25 ppm
STEL[2]			35 ppm
IDLH	50 ppm	75 ppm	300 ppm
UEG		40 Vol%	15,4 Vol%
OEG		100 Vol%	30,2 Vol%
Proper-ties	- toxic, colorless, acidic gas - corrosive	- toxic, colorless, acidic gas - explosive in air	- toxic, colorless, acidic gas - explosive

[1]all values from 2003, subject to changes [2]TLV-values

5. Dräger Solution

5.1 Measuring devices

5.1.1 Transmitter

Depending on application requirements it can be chosen between two intrinsically safe transmitters: Polytron 3000 and Polytron 7000, and the explosion prove transmitter Polytron XP Tox. All devices can be combined with all different sensors.

5.1.2 Sensors

DrägerSensor Hydrazine	6810180
DrägerSensor NO_2	6809655
DrägerSensor H_2	6809685
DrägerSensor O_2-LS	6809630
DrägerSensor O_2	6809720
DrägerSensor NH_3	6809680
DrägerSensor H_2O_2	6809705
DrägerSensor AC	6810595

5.2 Recommendation

5.2.1 Hydrazine derivatives and nitrogen tetroxide

For Hydrazine monitoring the Drägersensor N2H4 can be used. Methyl hydrazine MMH and Dimethyl hydrazine UDMH are included as additional target gases in the memory of the sensor and can be selected in suitable transmitters on demand. For Aerozine 50 Hydrazine as target gas has to be selected.
Calibration is performed with hydrazine in the factory.

Nitrogen-tetroxide N_2O_4 and Nitrogen dioxide NO_2 can be measure with the DrägerSensor NO_2. One molecule N_2O_4 dissociates when measured into two NO_2 molecules.

5.2.2 Aluminum

When Aluminum or Ammoniumperchlorate is used the exhaust coming from an engine should be monitored for Hydrogenchloride HCl with DrägerSensor AC-Sensor.

6. Advantage of the Dräger Solution

Dräger has the most robust and sensitive Hydrazin-Sensor: Lower detection limit 20 ppb. It was developed for best performance to replace the former sensor used by NASA for 20 years. Cross-sensitivity on ammonia is very low. The sensor has been tested and is qualified by NASA.

7. Restrictions

Hydrazine calibration is a challenge. Cal-gas in not available in cylinders. A set-up with permeation tubes is an investment of about 10 T€. A more economical solution for small installations is a sensor exchange after a constant time-period of about half a year to a year depending on application.
Unfortunately because of good selectivity there is no surrogate gas know which could do the job.
Pump operation:
Hydrazine, NO_2 and H_2O_2 should not be drawn by pump over a distance of more than a couple of meters. Because of their interaction with the tubing material it may delay the time to alarm.
Hydrazine detecting devices fall under export restriction of the German government. An application for certain countries has to be filed in time.

8. References

NASA	Hydrazine, NO_2	since 1975
Mecon India	Hydrazine, NO_2	2002
Confidential military projects in US	Hydrazine	2003

9. Sources:

http://www-pao.ksc.nasa.gov/kscpao/nasafact/count2.htm
http://www.braeunig.us/space/propel.htm