Exploring New Energy Concepts

Using Teledyne ISCO Syringe Pumps

TELEDYNE ISCO
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Syringe Pump Application Note
AN16

Overview

The world economy depends on energy, which produces our food, builds our homes, and propels our vehicles. Without it, much of what we know would come to a standstill. Energy demands, as well as fossil fuel costs, are steadily increasing as countries such as China and India experience rapid economic growth. To meet this growing demand, development of alternative energy sources is becoming increasingly important.

Research and Development are essential to this process, requiring the highest grade equipment for accurate and reliable results. Teledyne ISCO Syringe Pumps are an excellent tool for development of alternative fuels, from bench scale to pilot plant.

Energy sources or raw materials for fuels and chemicals can be divided into two categories: conventional or non-conventional. Conventional energy sources are those obtained using existing technologies, such as petroleum (crude oil), coal, and natural gas, whereas non-conventional sources require newer and/or more complex technologies, often with greater investments. Non-conventional energy, which has not been cost competitive in the past, may now become a viable alternative as energy prices rise.

Non-conventional energy sources include:

- Shale Oil (USA)
- Oil Sands/heavy oil (Venezuela-Canada)
- Biomass (any plant or animal material)
- Methane Hydrates

Alternative or non-conventional fuels can be derived from any conventional source, such as coal, instead of petroleum. However, the term most often applies to renewable fuels from renewable energy sources such as biomass.

Renewable fuels include:

- Ethanol
- Biodiesel
- Non-fossil methane
- Hydrogen

Petroleum (Crude Oil)

The use of oil has expanded greatly since the first oil well was drilled in 1858 in Oil Springs, Ontario, Canada. Today, 90% of vehicles are powered by oil-derived fuels, and worldwide demand is expected to rise, putting greater pressure on oil production. Oil wells have a life span that peaks at some point in production, then begins to decline. At this point, techniques such as enhanced oil recovery (EOR) can be applied to maintain oil production levels. Evaluating possible techniques requires conducting tests that duplicate oil reservoir conditions such as temperature and pressure. Such testing, known as core flooding, determines rock permeability to various fluids and requires precision equipment such as high performance syringe pumps.

Items we use every day are derived from conventional and non-conventional petroleum. The world's dependence on crude oil extends far beyond the more obvious needs such as gasoline and other fuels. Other products that come from petroleum include many medicines and ointments, plastics, cosmetics, and detergents. Rubber products, preservatives, sealants, and paving materials come from petroleum. The world's oil supply, and our ability to access it, have a profound impact upon the cost and availability of these and many other everyday products.

Oil Shale

Oil shale contains kerogen, a complex mixture of organic compounds found in sedimentary rock, from which liquid hydrocarbons can be extracted. Kerogen is not a crude oil, but can be processed into crude oil substitute, or syncrude, which can then be further processed into common-use petroleum products. This process in itself requires energy investment, which affects its cost competitiveness with crude oil.

Shale oil deposits are located around the world, but 64% of the world's known reserves are concentrated in the U.S. Oil shale will gain more attention as the world energy prices rise.

Oil Sands

Located mostly in Canada and Venezuela, Oil Sands consist of molasses-like oil (bitumen), which is much more difficult to recover and process than conventional oil. Therefore, unconventional techniques are required for extraction, such as surfacing mining and in-situ. The most common in-situ processes involve heating the bitumen by steam, lowering the viscosity and enabling it to be pumped out in a more conventional manner.

After extraction, the bitumen must be upgraded to a lighter syncrude in order to be transported through standard pipelines and further refined.

Recovery and upgrading make Oil Sands an unconventional oil source, as it is more technically challenging and energy-intensive, and therefore more costly.

Coal

Coal supplies 25% of the world's energy needs, in particular the generation of electricity. It is also, unfortunately, the largest source of CO_2 emissions. At current consumption rates, the world's coal reserves could last over an estimated 150 years. Over 50% of the world's coal reserves are located in the United States, Russia, China, and India. With over 25% of recoverable coal, the United States has the largest world reserves. In addition to being the dominant energy source for heat and power generation, coal has the potential for many other uses. For instance, coal is a viable feedstock alternative to crude oil products such as chemical, gasoline, and diesel fuels.

The most common processes for converting coal for use in other products are Coal – To – Liquids (CTL) and gasification (syngas). CTL creates a syncrude that can be further processed by conventional means. Syngas, also known as water gas, can replace natural gas directly, or be further processed into other fuels, chemicals, or plastics through the Fischer-Tropsch Process.

While coal is currently a major source of CO_2 emissions, research is currently underway to reduce these emissions by capturing the CO_2 from power plants, or during conversion processes, and sequestering it in geological formations. Because CO_2 is always contained during the conversion process, removal is relatively easy and therefore cost-efficient. Worldwide, companies employing emission reduction/sequestration technologies may offset their costs with tax savings and/or emission reduction points. CO_2 can then be sequestered or used as an enhanced oil or natural gas recovery technique which has the double benefit of improving recovery and further minimizing CO_2 emissions.

Coal Liquefaction

Coal-To-Liquids (CTL) can be a direct technique, using a solvent to dissolve pulverized coal with heat and pressure, thereby creating a syncrude that can be further processed into fuels and chemicals. Syncrude has the potential advantage of using existing refineries and distribution systems.

Natural Gas

Natural gas consists mainly of 70-90% methane, which is used for power plants, home heating, transportation, and plastics. Nature gas is often located in oil fields, providing some of the oil displacement pressure.

Unconventional Natural Gas

Typically, unconventional natural gas, or unnatural gas, consists of those deposits that are difficult to mine without advanced techniques. Unnatural Gas consists of:

- Deep gas (deposits at depths at or below 15,000 feet)
- Tight gas (confined within geological formations that are impermeable, such as non-porous rock)
- Gas-containing shales
- Coalbed methane
- Methane hydrates

Coal Seams (coalbed methane)

Coal seams or the surrounding rock often contains trapped natural gas, which was once disposed of through incineration, but now has many uses.

Methane Hydrates

Methane Hydrates consist of methane (natural gas) locked inside frozen water crystals. They exist in sediment beneath the ocean floor, and in permafrost regions in Canada and Russia. Also, known as "burning ice," this possible fuel source could potentially provide the world with vast amounts of energy, if the means to recover it can be developed.

Gasification (Syngas)

Gasification is a process in which carbon containing feedstocks such as coal or biomass are converted into a synthetic gas, or syngas, consisting of carbon monoxide and hydrogen. Syngas, once known as "water gas," was commonly used for cooking and heating prior to the 1950s in the U.S., and the 1970s in Britain. Comparable to natural gas, syngas can be used directly as a relatively clean fuel, or further processed into a liquid form by the Fischer-Tropsch catalytic conversion process.

The gasification of coal or biomass is achieved through the following endothermic "water gas" reaction:

$$C + H_2O \rightarrow H_2 + CO$$

Syngas formation may also be an intermediate step in the transformation of natural gas to hydrogen:

$$CH_4 + H_2O \rightarrow CO + 3\,H_2$$

In addition to CO and H_2, Syngas can also contain CO_2 and nitrogen, and must therefore be further purified for use in producing chemicals and fuels. The carbon monoxide and H_2 can be processed into methanol and other chemicals. A downside to liquid gasification is that the purification and conversion processes are energy-intensive, and therefore involve additional cost, for conversion into fuels.

Fischer – Tropsch Process

The Fischer-Tropsch process, which involves the hydrogen reduction of carbon monoxide, converts syngas derived from gasification into various liquid hydrocarbons using a catalyzed chemical reaction:

$$(2n+1)H_2 + nCO \rightarrow CnH(2n+2) + nH_2O$$

(where *n* is a positive integer)

These liquid hydrocarbons can then be further processed into synthetic oils or fuels.

The combination of biomass gasification (BG) and the Fischer-Tropsch (FT) process is of considerable interest due to its great potential for producing renewable biofuels.

Ethanol

Ethanol, or grain alcohol, is largely used as a fuel or fuel additive. Ethanol is produced by fermentation with specific types of yeast that metabolize sugars to produce ethanol and CO_2 through the following reaction:

$C_6H_{12}O_6 \rightarrow 2\ CH_3CH_2OH + 2\ CO_2$

In Brazil, most ethanol is made from sugar cane, while in the USA ethanol is made from corn, which is also a food product in relatively short supply. Currently, research is underway to produce ethanol from lignocelluloses, which are made up of cellulose, hemicelluloses, and lignin. This type of ethanol, called cellulose ethanol, can be made from non-food sources, such as switch grass and woodchips.

Methanol

Methanol can be the raw material for a variety of chemical and fuel products. It also can be used directly as a fuel or as a gasoline additive, similar to ethanol.

Currently, most methanol is produced from syngas derived from fossil fuels like coal and natural gas. It can also be easily expanded to unconventional sources such as oil sands, oil shale, coal bed methane, tight gas, methane hydrates, and bio-mass.

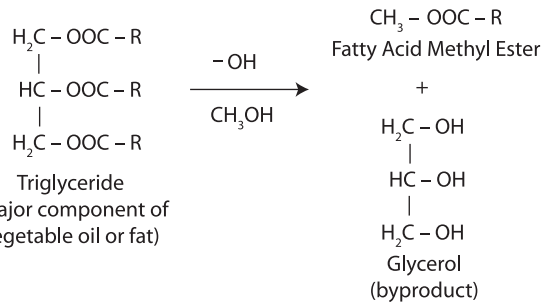
The biomass alternative would make methanol a renewable resource by the following reaction:

Biomass $\rightarrow$ Syngas (CO, H_2) $\rightarrow CH_3OH$

Biodiesel

Biodiesel is a biofuel made by the chemical conversion of vegetable oil or animal fats into fatty acid methyl esters (transesterification), which can be used alone or blended with conventional diesel.

While there are several methods for producing biodiesel, the most common is a batch process involving methanol and sodium hydroxide:



where R = $(CH_2)n - CH_3$

The most common standard for biodiesel, particularly in the United States and Canada, is ASTM D6751. Conformance testing typically requires a gas chromatograph.

Glycerol

The expanding use of biodiesel has produced a worldwide glut of glycerol, a by-product of the transesterification of vegetable oils.

Glycerol has many common uses, including cosmetics, pharmaceuticals, foods and beverages, solvents, soaps, lubrications, and textiles. However, research is underway to identify additional uses, such as hydrogen and ethanol production and fuel additives. Other conversion methods for glycerol include: Oxidation, Hydrogenation, Hydrogenolysis, Etherification, and Condensation.

Pyrolysis/Hydrogenation

In the bio-fuel industry, the fatty acid methyl esters must be converted into hydrocarbons for better compatibility with existing refinery infrastructure.

Pyrolysis is the heating and decomposition of organic materials in the absence of oxygen. Fast Pyrolysis, which involves very rapid heating, is a more efficient version of this process. Carbon-oxygen bonds decompose into the more thermodynamically stable carbon dioxide, thus generating hydrocarbons. An advantage of pyrolysis over gasification is that it requires less heat and therefore less energy. One disadvantage is the high water content, which must be removed before further processing.

Hydrogenation refers to the catalytic reaction of molecular hydrogen to remove oxygen bonds in order to produce hydrocarbons.

Both processes produce the end result of simpler compounds, which can then be further refined into renewable bio-fuels, as well as fine chemicals and fats.

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Product model names have been updated in this document to reflect current pump offerings.

Teledyne ISCO
P.O. Box 82531, Lincoln, Nebraska, 68501 USA
Toll-free: (800) 228-4373 • Phone: (402) 464-0231 • Fax: (402) 465-3091
www.teledyneisco.com