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HYDROGEN AS A FUEL IN INTERNAL COMBUSTION ENGINE

Saket Bhishikar
B.Tech Mechanical Engineering, SVKM's NMIMS Mukesh Patel School of Technology Management & Engineering (MPSTME), Mumbai, Maharashtra

ABSTRACT
A petrol engine, known as Gasoline in many countries, which runs on spark-ignition designed to run on volatile fuels. Otto introduced an engine cycle with four piston strokes: an intake stroke, then a compression stroke before ignition, an expansion stroke when power was delivered to crank shaft, and finally an exhaust stroke. His prototype was first run in 1876. There was enormous reduction in engine weight and volume. This was the breakthrough which effectively founded internal combustion engine.

Keywords- *Hydrogen as a fuel, Internal combustion engine etc.*

I. INTRODUCTION
A petrol engine, known as Gasoline in many countries, which runs on spark-ignition designed to run on volatile fuels. Otto introduced an engine cycle with four piston strokes: an intake stroke, then a compression stroke before ignition, an expansion stroke when power was delivered to crank shaft, and finally an exhaust stroke. His prototype was first run in 1876. There was enormous reduction in engine weight and volume. This was the breakthrough which effectively founded internal combustion engine.

In 1892, German engineer Rudolf Diesel (1858-1913) presented his concept by injecting the liquid fuel into air heated solely by compression permitted a doubling of efficiency over internal combustion engine. Much greater expansion ratio without detonation and knock were possible now.

The automotive air pollution became major concern during the 1940's.in 1952, it was demonstrated by prof. A.J. Hagen-Smit that smog problem was resulted due to reaction of oxides of nitrogen and hydrocarbon compounds in presence of sunlight. As a result of this emission standards were introduced in 1960 in America and Japan, this lead to reappearance of unleaded gasoline as an additive to spark ignition to reduce the emissions, thus leading various creative minds to be ignited with their respective ideas, one of which have been described as below. Hydrogen as a Fuel in Internal Combustion Engine as a concept evolved in late 21st Century, with the continuous input by research & development methods have been developed to use & store hydrogen in an automobile. This paper focussed primarily on production of hydrogen which can be implemented on a large scale.

II. WORKING OF HYDROGEN POWERED IC ENGINE
Working of hydrogen powered IC Engine is similar as that of a Petrol Engine, which is briefly described as below. A four-stroke engine, is an internal combustion engine in which the piston completes four separate strokes—intake, compression, power, and exhaust—during two separate revolutions of the engine's crankshaft, and one single thermodynamic cycle.

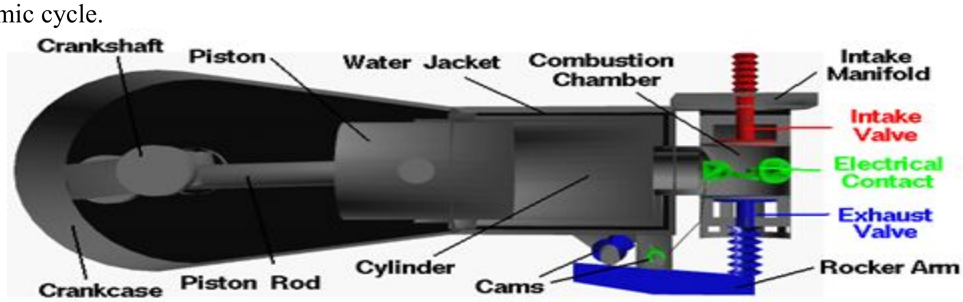

Fig 1: A Typical IC Engine

Intake Stroke
The engine cycle begins with the intake stroke as the piston is pulled towards the crankshaft. In this stroke, the intake valve is open, and fuel and air are drawn into the combustion chamber through the valve. The exhaust valve is closed and the electrical contact switch is open. The fuel/air mixture is at a relatively low pressure (near atmospheric) and is coloured blue in this figure. At the end of the intake stroke, the piston is located at the far left and begins to move back towards the right.

The cylinder and combustion chamber are full of the low pressure fuel/air mixture and, as the piston begins to move to the right, the intake valve closes.

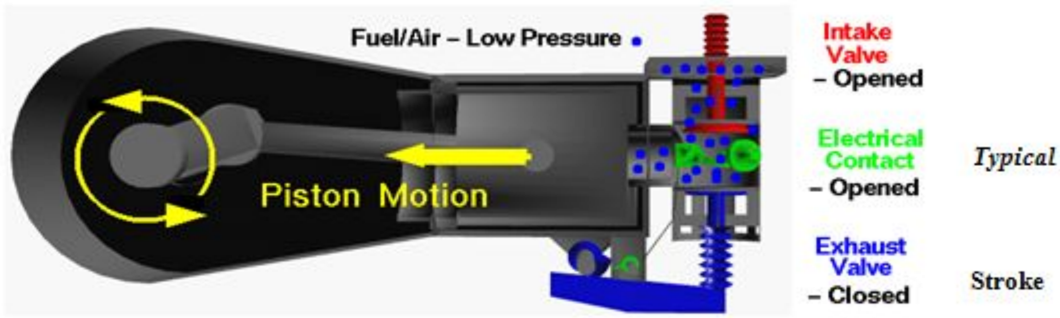

Fig 2: Intake Stroke

Compression Stroke
With both valves closed, the combination of the cylinder and combustion chamber form a completely closed vessel containing the fuel/air mixture. As the piston is pushed to the right, the volume is reduced and the fuel/air mixture is compressed during the compression stroke.

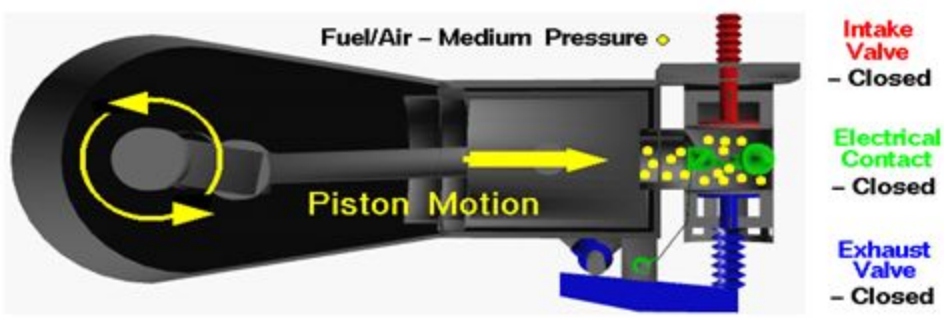

Fig 3: Compression Stroke

During the compression, no heat is transferred to the fuel/air mixture. As the volume is decreased because of the piston's motion, the pressure in the gas is increased, as described by the laws of thermodynamics. In the figure, the mixture has been coloured yellow to denote a moderate increase in pressure. To produce the increased pressure, we have to do work on the mixture, just as you have to do work to inflate a bicycle tire using a pump. During the compression stroke, the electrical contact is kept opened. When the volume is the smallest, and the pressure the highest as shown in the figure, the contact is closed, and a current of electricity flows through the plug.

Power Stroke

At the beginning of the power stroke, the electrical contact is opened. The sudden opening of the contact produces a spark in the combustion chamber which ignites the fuel/air mixture. Rapid combustion of the fuel releases heat, and produces exhaust gases in the combustion chamber.

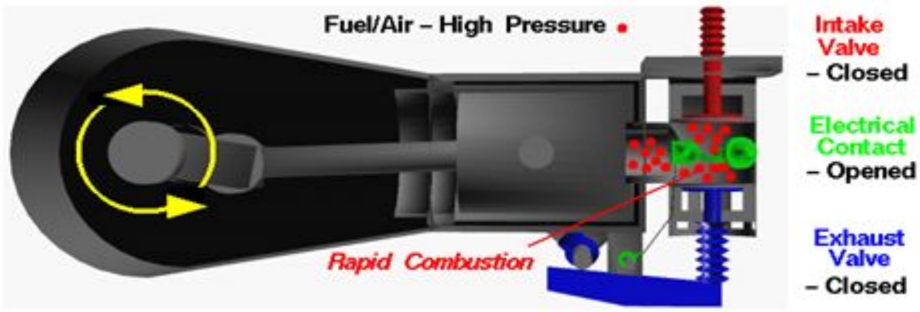

Fig 4: Power Stroke

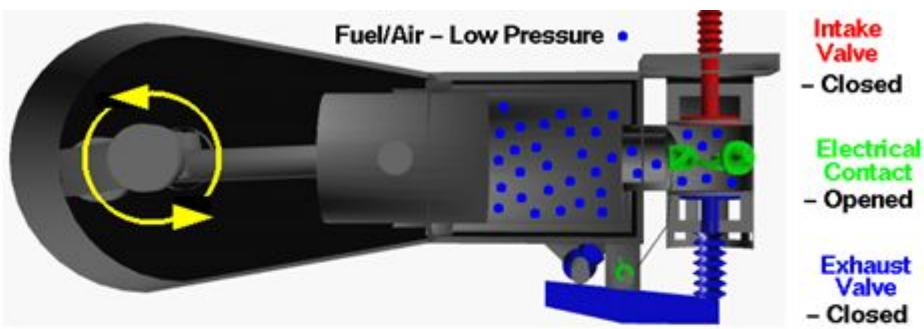

Fig 5: Rapid Combustion in Power Stroke

The combustion increases the temperature of the exhaust gases, any residual air in the combustion chamber, and the combustion chamber itself, as the combustion takes place in a fully enclosed vessel. We have coloured the gases red in the figure to denote the high pressure. The high pressure of the gases acting on the face of the piston causes the piston to move to the left which initiates the power stroke.

During the power stroke, the volume occupied by the gases is increased because of the piston motion and no heat is transferred to the fuel/air mixture. As the volume is increased because of the piston's motion, the pressure and temperature of the gas are decreased. We have coloured the exhaust "molecules" yellow to denote a moderate amount of pressure at the end of the power stroke.

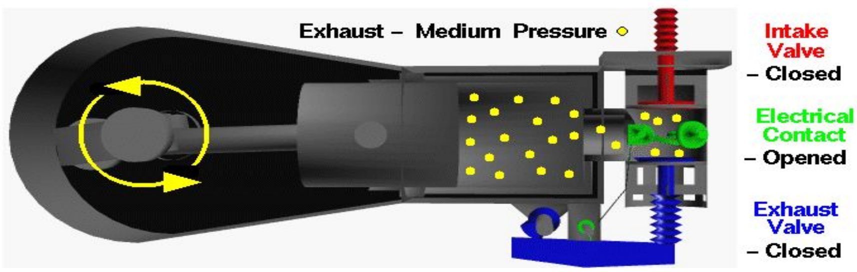

Fig 6: Moderate Pressure in Power Stroke

Exhaust Stroke
At the end of the power stroke, the piston is located at the far left. Heat that is left over from the power stroke is now transferred to the water in the water jacket until the pressure approaches atmospheric pressure. The exhaust valve is then opened by the cam pushing on the rocker arm to begin the exhaust stroke.

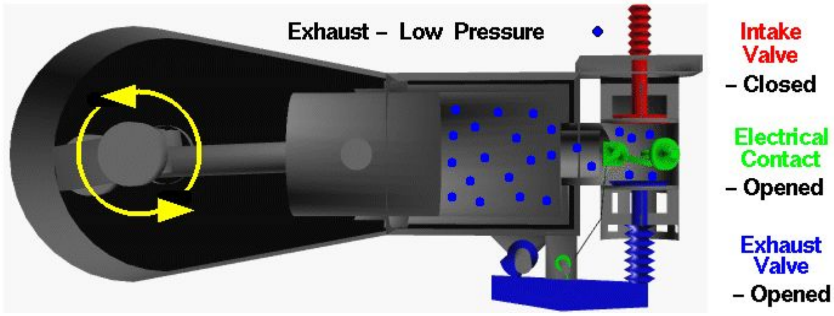

Fig 7: Exhaust Stroke

As the exhaust stroke begins, the cylinder and combustion chamber are full of exhaust products at low pressure (coloured blue), since the exhaust valve is open, the exhaust gas is pushed past the valve and exits the engine. The intake valve is closed and the electrical contact is open during this movement of the piston. At the end of the exhaust stroke, the exhaust valve is closed and the engine begins another intake stroke.

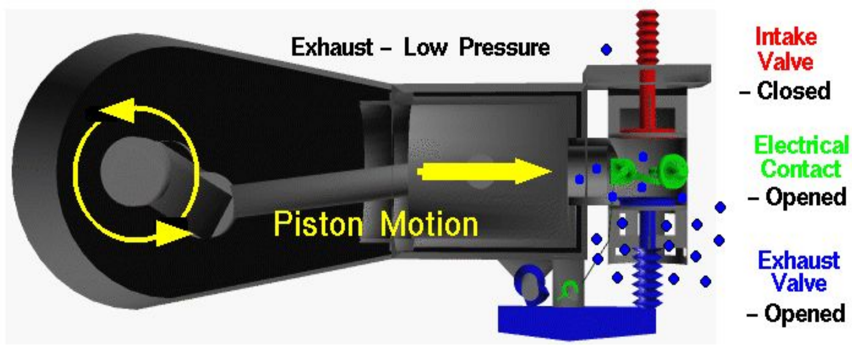

Fig 8: Exhaust Stroke

III. PROPERTIES OF HYDROGEN

In recent years, the concern for cleaner air, along with stricter air pollution regulation and the desire to reduce the dependency on fossil fuels have created interest in hydrogen as a vehicular fuel.
The combustive properties of hydrogen are as follows:
- Wide range of flammability
- Low ignition energy
- Small quenching distance
- High auto-ignition temperature
- High flame speed at stoichiometric ratios
- High diffusivity
- Very low density

IV. HYDROGEN INTERNAL COMBUSTION ENGINE (HICE)

A HICE operates similarly to a conventional internal combustion engine except that it is powered by hydrogen gas, but with some important modification as there is wide difference between combustive properties of hydrogen and gasoline.
The main problem which was encountered in the development of HICE was "Pre-Ignition".

Pre-Ignition Problem:-

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The primary problem that has been encountered in the development of operational hydrogen engines is premature ignition (or Pre-Ignition).
Premature ignition is a much greater problem in hydrogen fuelled engines than in other IC engines, because of hydrogen's lower ignition energy, wider flammability range and shorter quenching distance.

Solutions for Pre-Ignition Problem:

a. Fuel Delivery Systems:

Adapting or re-designing the fuel delivery system can be effective in reducing or eliminating pre-ignition.
Hydrogen fuel delivery system can be broken down into three main types: central injection (or "carburetted"), port injection and direct injection.

b. Thermal Dilution:

Pre-ignition conditions can be curbed using thermal dilution techniques such as exhaust gas recirculation (EGR) or water injection.

c. Engine Design:

The most effective means of controlling pre-ignition and knock is to re-design the engine for hydrogen use, specifically the combustion chamber and the cooling system.
A disk-shaped combustion chamber (with a flat piston and chamber ceiling) can be used to reduce turbulence within the chamber. The disk shape helps produce low radial and tangential velocity components and does not amplify inlet swirl during compression.

d. Ignition Systems:

Ignition systems that use a waste spark system should not be used for hydrogen engines. These systems energize the spark each time the piston is at top dead centre whether or not the piston is on the compression stroke or on its exhaust stroke. For gasoline engines, waste spark systems work well and are less expensive than other systems. For hydrogen engines, the waste sparks are a source of pre-ignition.

e. Crankcase Ventilation:

This is more important, as with gasoline engines, unburnt fuel can seep by the piston rings and enter the crankcase. Since hydrogen has a lower energy ignition limit than gasoline, any unburnt hydrogen entering the crankcase has a greater chance of igniting. Hydrogen should be prevented from accumulating through ventilation.

V. NEW METHODS TO PRODUCE HYDROGEN

Production of Hydrogen from Aluminum and Gallium Alloy

Researchers from Purdue University in Indiana have developed a method that uses an aluminum alloy to extract hydrogen from water. The hydrogen may be used for running fuel cells or internal combustion engines, which in turn could be used to replace gasoline.
In this method there is no need to store hydrogen, it can be produced as and when required, said Jerry Woodwall, a distinguished professor of Electrical and Computing engineering.
One of the key issues with hydrogen fuel is that it is expensive to manufacture and is complicated to transport over long distances due to its explosive nature. With the newly developed technique hydrogen is generated on demand and only in the amount needed at the time.

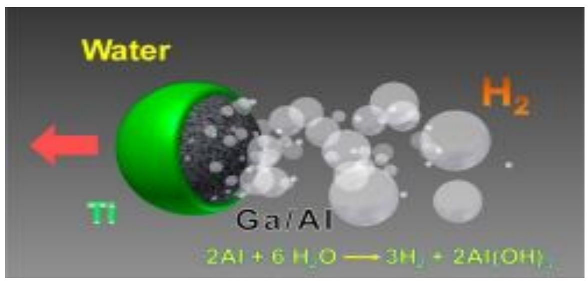
The process for producing the hydrogen is remarkably simple: water is added to a liquid alloy of aluminum and gallium to produce hydrogen, which can be fed directly to an engine. The process generates a chemical reaction which splits the oxygen and hydrogen contained in water, releasing hydrogen in the process.

According to the scientists, the addition of gallium is critical to the process because it hinders the formation of a skin normally created on aluminum's surface after oxidation. This skin usually acts as a barrier that prevents oxygen from reacting with aluminum. Preventing the skin's formation allows the reaction to continue until all of the aluminum is used.

The discovery was accidently made by one of the scientist who was cleaning a crucible containing liquid alloys of gallium and aluminum. When the researcher added water to the alloy a violent explosion occurred (probably caused by the creation of highly explosive hydrogen in the tank).

Currently, the biggest obstacle to this technology is cost. By recycling the aluminum, it will be possible to reduce the cost in the future. This process still requires a lot of energy that must be produced in an environmentally friendly way (using wind power, solar power, or at worst nuclear power plants. If these problems will be resolved the new process will offer a way for producing cheap hydrogen which does not need to be transported across the country, eliminating the two major problems currently facing the hydrogen economy. You would simply dive into your local refueling station and fill the tank of your car with aluminum-gallium alloy that would be mixed with water to create small quantities of hydrogen to be used as you drive along.
Working

"When water is added to the pellets, the aluminum in the solid alloy reacts because it has a strong attraction to the oxygen in the water," Woodall said. Hydrogen is generated spontaneously when water is added to pellets of the alloy, which is made of aluminum and a metal called gallium. The researchers have shown how hydrogen is produced when water is added to a small tank containing the pellets. Hydrogen produced in such a system could be fed directly to an engine, such as those on lawn mowers. The gallium is critical to the process because it hinders the formation of a skin normally created on aluminum's surface after oxidation. This skin usually prevents oxygen from reacting with aluminum, acting as a barrier. Preventing the skin's formation allows the reaction to continue until all of the aluminum is used.



$2Al + 3H_2O \rightarrow 3H_2 + Al_2O_3$ + heat
The waste products are gallium and aluminum oxide, also called alumina. Combusting hydrogen in an engine produces only water as waste. The aluminum oxide product of the reaction can be recycled back into aluminum. The recycled aluminum would be less expensive than mining the metal, making the technology more competitive with other forms of energy production, Woodwall said.

Composition of aluminum and gallium
In recent research, the engineers rapidly cooled the molten alloy to make particles that were 28% aluminum by weight and 72% gallium by weight. The result was a metal stable solid alloy—able to be handled like a solid, rather than a liquid—that also readily reacted with water to form hydrogen, alumina and heat, Woodall said.
If the alloy is slowly cooled, then molten alloy produced particles that contain 80% aluminum and 20% gallium. *"*Particles made with this 80-20 alloy have good stability in dry air and react rapidly with water to form hydrogen. This alloy is under intense investigation, and, in our opinion, it can be developed into a commercially viable material for splitting water", Woodwall said.

"If I can economically make hydrogen on demand, however, I don't have to store and transport it, which solves a significant problem," Woodall said
The Purdue Research Foundation holds title to the primary patent, which has been filed with the U.S. Patent and Trademark Office and is pending. An Indiana startup company, AlGalCo LLC., has received a license for the exclusive right to commercialize the process.

Hydrogen Production from Butterfly wings

Scientists have developed pioneering technology that doubles hydrogen gas production after studying the structure of black butterfly wings. Researchers studied two swallowtails, the Heng-chun birdwing (Troides aeacus) and the Red Helen (Papilio helenus Linnaeus) butterflies, the American Chemical Society's (ACS) National Meeting, in San Diego, USA, heard. Dr. Tongxiang Fan and his team at China's Shanghai Jiao Tong University studied butterfly wings to discover ways to increase the amount of useful light gathered by solar collectors. Hydrogen, which is a

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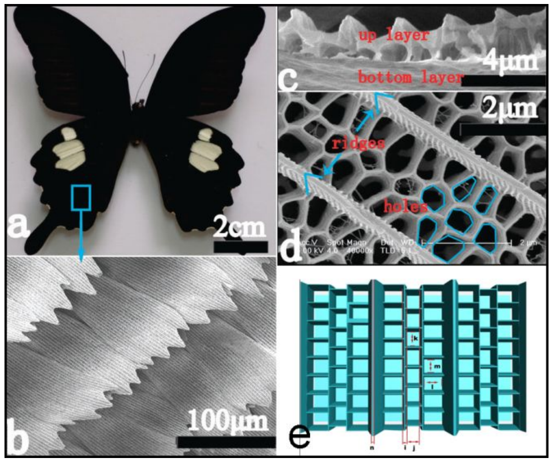
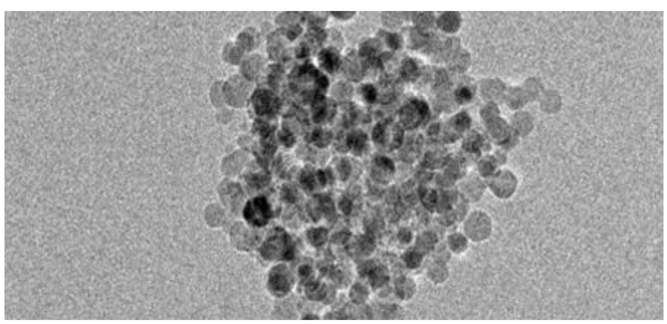
renewable energy source, can be produced from water and sun. Developing technology can employ sunlight to increase the activity of catalysts that separate water into hydrogen and oxygen. The more powerful the solar collector, the better the technology works, says Dr. Fan.



Butterfly wings include miniature scales that help butterflies collect sunlight so they can stay active in cold weather. Dr. Fan's researchers studied the wings of black butterflies through an electron microscope to study the make-up of their scales. The black color absorbs the highest levels of sunlight. Researchers first believed the secret was in the melanin pigment that caused the black coloring, but they recently began to investigate the role played by the scales.
The elongated scales are set in an overlapping pattern, like roof tiles. The pattern on the swallowtails differed a little, but each scale possessed ridges up the length along with tiny holes on each side that opened to a layer underneath.
Working
The researchers copied the butterfly wing structures to produce solar collector templates. They used a dip-calcining process to change them to titanium dioxide, which they used as a catalyst to separate the water molecules.
The titanium dioxide scales were joined with platinum nanoparticles to boost their capability to split water. The result was that twice as much hydrogen gas was produced from water.
Dr. Fan says the results show the potential of copying nature is creating renewable energy technology.
The study was financed by the National Natural Science Foundation of China and the Shanghai Rising-star Program.

Hydrogen Production from Silicon Powder



According to University of Buffalo scientists super small particles of silicon react with water to produce hydrogen almost instantaneously. Scientists created silicon particles with about 10 nanometers diameter. When combined with water these particles reacted to form silicic acid (a non-toxic by product) and hydrogen.
The reaction didn’t require any light, heat, or electricity and produced hydrogen about 150 times faster. The scientists were able to verify that hydrogen made was relatively pure by testing it in a small fuel call that powered a fan. “When it comes to produce hydrogen, nanosized silicon may be better obvious choices than aluminum” said researcher Mark Swihart, professor at that university.

"With further development, this technology could form the basis to 'just add water' approach to generate hydrogen on demand," said researcher Paras Prasad, executive director at the University of Buffalo.

Swihart said the discrepancy is due to geometry. As they react, large particles form non-spherical structures whose surfaces show fewer tendencies to react with water with less uniformity than spherical surfaces. Although significant energy and resources to produce super small silicon balls, the particles could help power portable devices at lower cost.

"Safe storage of hydrogen has been a problem even though hydrogen is an excellent candidate for alternative energy, and one of the practical applications would be supplying hydrogen for fuel cell power. Hydrogen cell and some plastic cartridges of silicon powder mixed with activator are preferable over gasoline and diesel," Swihart said.

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