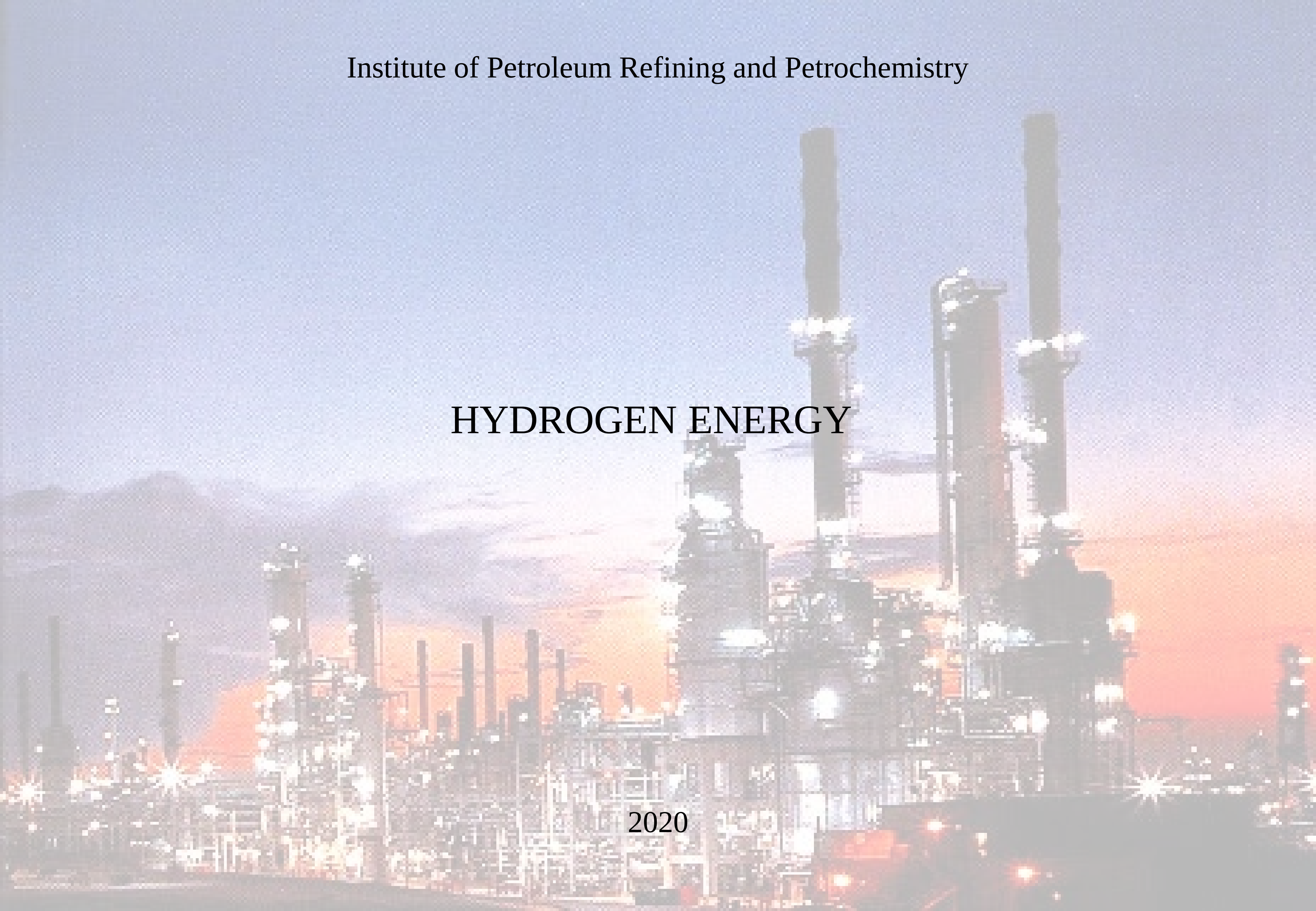


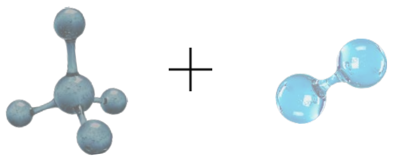
Institute of Petroleum Refining and Petrochemistry

HYDROGEN ENERGY

2020

Methane-hydrogen mix (HYTHANE)

Methane Hydrogen



A methane-hydrogen mixture is a fuel consisting of a mixture of H^2 and natural gas,
With hydrogen content of 5-10 wt%. (20-40% vol.)

Advantages of use

- Easy Integration of Hydrogen Generation Units in Operation Automotive Gas Filling Compressor Stations
- No retrofitting of gas-ball transport is required
- Fuel consumption reduction by 30%
- Reduction of air emissions

Reduction of emissions
when hydrogen (10% by weight) is added to methane

NO_x ▼ 50 % **CH_4 ▼ 16 %**

C_nH_m ▼ 23 % **CO_2 ▼ 7 %**

Fuel consumption reduction by 30%

Flow rate per 100 km:

Gas motor fuel	Methane-hydrogen mix
15 m^3	*10,5 m^3*

Average annual run of the bus:

55 000 km

Gas motor fuel: 2062 $

Methane-hydrogen mix: 1353 $

Innovation of technology solutions

One method of producing hydrogen is a process called "steam reforming," which is widely implemented in the industry and includes steps such as:

- Steam reforming (in the example of methane):
  $CH_4 + H_2O = CO + 3H_2$
- Reaction of water shift:
  $CO + H_2O = CO_2 + H_2$

In industry, reactions occur in different reactors at elevated pressure.

Pilot tests were carried out on small-volume installations (more than 20,000 hours).
Modern modeling methods have been applied:

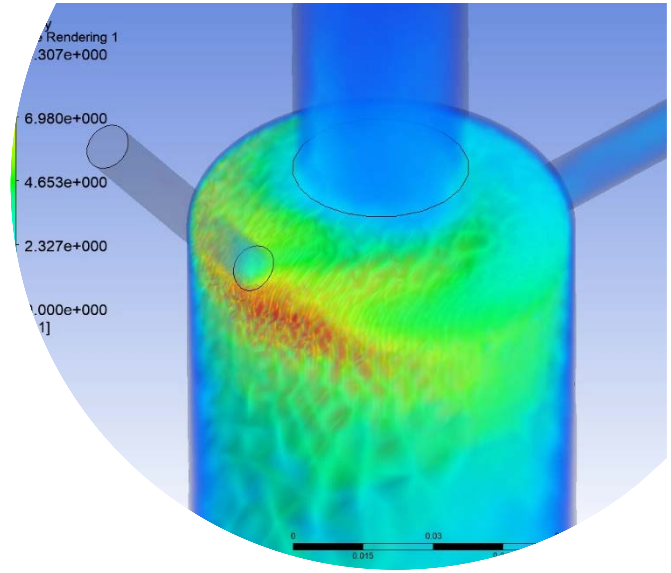
- CFD-simulation of reactor design,
- Static and dynamic modeling of all stages of hydrogen production process, from sulfur purification to short-cycle adsorption stage.

On the basis of the research data, a special form of reactor design has been developed, allowing to carry out all stages of the process in one reactor:

- heating the raw material from the central burner;
- steam generation,
- steam reforming,
- water shear reaction (low and high temperature).

At the same time:

- output streams are only combustion gases with a temperature of 80-100 °C and hydrogenous gas (with the maximum content of hydrogen and residual content of monoxide of carbon - no more than 1% about.);
- total metal consumption is reduced by 40% compared to the traditional design of hydrogen production process.

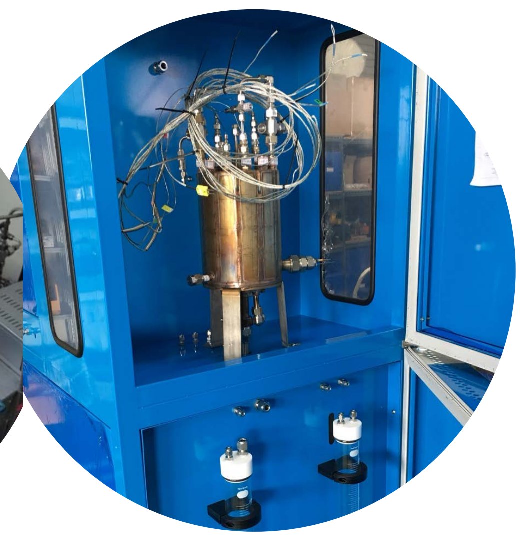


The use of CFD modeling allowed:

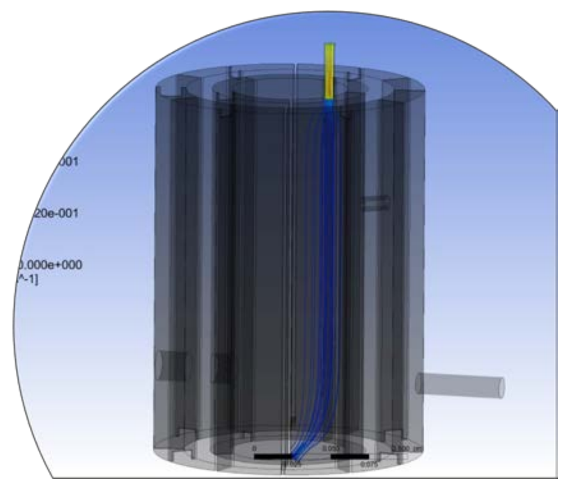
- optimize the geometrical dimensions of the reactor;
- intensify the process by changing internal devices;
- detect stagnant zones and zones with non-optimal temperature, reduce formation of by-products.

The model considers:

- change in reactor volume of component concentrations during chemical transformations;
- temperature and pressure change along reactor cross-section due to thermal effect of reactions.



Reactor of pilot plant, capacity 1 nm^3/h
Resource tests of more than 10,000 hours



Stages of project implementation in the format EPCm

Realization stage	Name of works	Realization term
Predesign research / development of the feasibility study	Define the object to be implemented, introduction potential assessment	1 to 2 months
Development of design documentation and working documentation	Development of technical documentation	up to 3 months
Turnkey delivery	Production of knots, installation assembly, testing, delivery to customer platform	up to 8 months
Start-up and integration	Commissioning	2 weeks - 1 month
Technical Support and service	Replacement of catalysts/sorbents, individual high-load nodes	the whole period or 2 years after commissioning

Composition of a hydrogen power generation unit:

- Hydrogen production unit
- Hydrogen separation and purification unit (purity level 99.998%)
- Hydrogen storage and supply unit (optional)
- PEMFC (Proton Exchange Membrane Fuel Cell) and inverter

Unit capacity: 100 kWt・h

Dimensions, m (length x width x height)*	2(6 x 2,4 x 2,6)
Gas consumption (CH_4)**, m^3/year	400 609, 8
H_2 production, nm^3/year	1 095 000
Demineralized water after fuel cells, m^3 / year	876
CO_2 m^3/year	365 000

Unit capacity: 400 kWt・h

Dimensions, m (length x width x height)*	8(6 x 2,4 x 2,6)
Gas consumption (CH_4)**, m^3/year	1 602 439, 2
H_2 production, nm^3/year	4 380 000
Demineralized water after fuel cells, m^3 / year	3 504
CO_2 m^3/year	1 460 000

* 6 x 2.4 x 2.6 - 20 feet container size, a 100 kW/hr unit consists of two 20 feet containers

Parameters	Meanings
Dimensions, m (length x width x height)	1,8 x 2 x 1 м
Unit weight less than (up to)	300 kg
Hydrogen purity, %	99, 998

Pilot plant launched in July 2018

Comparison with major suppliers of hydrogen stations

Characteristic	Air Liquide, France	Hydrogenics, Canada	ITM-Power, England	**JSC «INHP», Russia**	Mitsubishi Gas Chemicals, Japan	ErreDue S.p.A., Italy
Raw materials	Natural gas, propane, butane, aqueous-alkaline with inorganic Ion-exchange membrane	aqueous-alkaline with inorganic Ion-exchange membrane	solid-polymer electrolyte with proton-exchange membrane	**natural gas, LPG, naphtha**	natural gas, propane, butane, naphtha, kerosene	membrane electrolysis of aqueous alkali solutions
Way of receiving hydrogen	electrolysis and steam reforming of methane	water and alkaline electrolysis	electrolysis of water on solid-polymer electrolyte	**steam reforming of hydrocarbon feedstock**	steam reforming of hydrocarbon feedstock	compressed or liquid hydrogen introduced
Plant power, nm^3/h	20-100	10-60	2-50	**1-1500**	50-300	40-85
Cost of installation, $ million	1,5 – 5,0	1,2-2,5	0,25-0,7	**0,2-10,0**	4 - 7,5	1,0-1,2

Competitive edge

- Low hydrogen cost
- No domestic counterparts
- High yield and purity of the hydrogen
- Block-modular design
- Small dimensions
- Use of raw materials from methane to the diesel is possible