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Actual and Future Perspectives of Isothermal NSC-Engines

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It is doubtless that the world population, energy consumption and worldwide environment and biosphere pollution are growing almost synchronously and exponentially and this fact is causing enormous environmental problems and will continue to do so (CO_2, NO_X and the consequences; global earth warming, global earth dimming, ozone hole, global climate changes etc. The energy reserves of the planet will be approx. until the end of the actual century well exhausted). One can deduce that the solutions for a number of mentioned problems are in the improvement of some of the primary causal factors, especially the current thermal engines. This can satisfactorily be achieved only:

A) By developing new high efficiency thermal engine concepts, e.g. the newly-developed **"NSC-Concept"** (**NSC**=**N**ew **S**tirling engine **C**oncept [1]), and on this concept based "Isothermal NSC-engines [4]", geared for consequent use of actual conventional and alternative energy sources (e.g. all combustible gases - especially hydrogen, solar energy sources, geothermal and other energy sources and waste heat or waste cold sources).

B) By invention and application of new energy sources and technologies, especially the industrial hydrogen production and in this way to start the "Hydrogen energy age" [3].

This topic and NSC-concept was thoroughly analysed by the first author (PhD Thesis [1]). Both authors reported about it several times and recently in [5], [6] and [12]. The research results show that new isothermal NSC-engines are and will be suitable for nearly all application fields of the actual thermal engines.

The paper presents an overview of the latest results of the above-mentioned research and presents actual and possible future application perspectives of isothermal process based thermal NSC-engines.

Aktualne i buduće perspektive izotermalnih NSC-motora

Izvornoznanstveni članak

Nema sumnje da svjetska populacija, potrošak energije i onečišćenje okoliša i biosfere već dulje vremena rastu usporedno i eksponencijalno i uzrokuju enormne probleme okoliša, i da će se to i nastaviti (porast CO_2, NO_X, i posljedice; globalno zatopljenje Zemlje, globalno zamračenje Zemlje, ozonske rupe, globalne klimatske promjene itd. Rezerve izvora toplinske energije planeta do kraja aktualnog stoljeća bit će znatno istrošene). Na osnovi tih činjenica možemo zaključiti da očito potrebno rješenje većeg broja tih problema treba tražiti u poboljšanju njihovih primarnih uzročnika, posebice aktualnih toplinskih motora. To se može zadovoljavajuće postići samo:

A) Razvojem novih koncepta za toplinske motore visoke termičke korisnosti, npr. nedavno razvijeni "NSC-koncept" (NSC=New Stirling engine concept [1]), i na tome konceptu osnovanim "Izotermalnim NSC-motorima [4]", sposobnih za konzekventno korištenje aktualnih konvencionalnih i alternativnih toplinskih izvora energije (npr. svi gorivi plinovi - posebice vodik, energija sunčeva zračenja, geotermička i drugi izvori energije, otpadna toplina i hladnoća).

B) Iznalaženjem i primjenom novih izvora toplinske energije i njihovih tehnologija, posebice industrijske proizvodnje vodika i na taj način započeti "Vodikovu eru" [3].

Ova tema i na njoj osnovani NSC-koncept nedavno su bili opširno znanstveno istraživani od prvog autora (DDissertacija [1]). Oba autora su o tome znanstvenom istraživanju već više puta izvještavali i u novije vrijeme u [5], [6] i [12]. Rezultati tih istraživanja pokazuju da novi izotermalni NSC-motori već sada jesu i da će, kroz njihov razvoj, biti sve više pogodni za primjenu na svima područjima uporabe aktualnih toplinskih motora.

Ovaj rad daje pregled rezultata ovog istraživanja dobivenih u posljednje vrijeme i informira o aktualno uočenim i o budućim, mogućim perspektivama primjene izotermalnih NSC-motora.

Keywords
Application fields of NSC-engines
Isothermal NSC-engine
Isothermal NSC - process
NSC-concept

Ključne riječi
Izotermalni NSC-motor
Izotermalni NSC-proces
NSC-koncept
Područje primjene NSC-motora

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1. Introduction

The Isothermal NSC-engines conceptually developed and based on results and insights gleaned from investigation on the "Effects of lowering the Stirling engine cold-side temperature" [1] are foreseen among others, for nearly all application niches of actual thermal engines and also preferable for use in the new "alternative" application niches.

The intention of this paper is to inform (general and very condensed) about the actual status of these newly developed Isothermal NSC-engines and to give a probable technical perspective prognosis sketch (actual and near future) of these highly efficient and environmentally highly suitable thermal engines, which are in our opinion the "future thermal engines".

Figure 1 expresses already much known facts:

A) The world's population is exponentially growing (actually, approx. 6 billions),

B) This fact is causing enormous environmental problems and will continue to do so ([1], [2]),

C) The energy reserves of the planet will be very extremely well exhausted [2]),

D) It looks, as if sufficient thermal energy sources for the "world after that time" will be only available from hydrogen and from different alternative energy sources.

Clearly evident is the lack of commercially proven technology for alternative hydrogen production on a large scale [3].

2. The NSC-concept (NSC=New Stirling engine Concept)

The solutions for a number of problems mentioned can satisfactorily be achieved only by developing new high efficiency thermal engines, e.g. the newly developed **NSC-Concept** ([1], [5], [6] [12]) and on this concept based **"Isothermal NSC-engines** [4]**"**, be ready for consequent use of actual conventional and alternative energy sources e.g. all combustible gases- especially hydrogen (mainly the alternative industrial hydrogen production and in this way to start the "Hydrogen energy age" [3]), solar energy sources, geothermal and other energy sources and waste heat or waste cold sources).

The NSC-concept contains **two Measures** for its attempted realization [5]:

1st Measure

The 1st Measure contains a design of a new isothermal cycle process, called "**Isothermal NSC-process cycle**", consisting in an idealized case of two isotherms, two isochoric and one isobaric change of state of working medium.

Figure 2 shows a comparison between the newly designed idealized isothermal NSC- and the idealized Diesel (Sabathé)-process cycle, in which the major difference arising from thermal efficiency and the importantly higher work production of the NSC-process cycle are clearly visible.

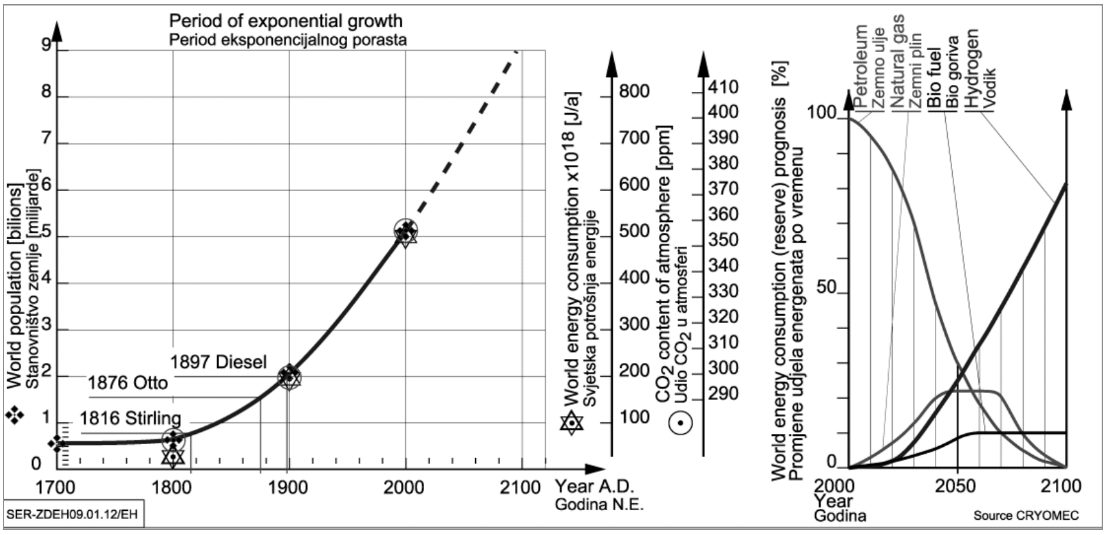


Figure 1. World human population, energy consumption, CO_2 pollution, actual energy reserves and future energy source prognosis ([1]/ Hubbert/ SHELL/ Internet)

Slika 1. Stanovništvo Zemlje, potrošnja zemljine energije, sadržaj CO_2 u atmosferi, aktualne rezerve Zemljine energije i prognoza udjela potrošnje izvora energije ([1]/ Hubbert/ SHELL/ Internet)

2nd Measure

- The 2nd Measure contains instructions for the realization of an Isothermal NSC-process cycle in an "**Isothermal NSC-engine**". This Measure includes the application of new NSC - principles;
- The consequent use of alternative energy sources,
- The benefit of the fact that the NSC-engine cooling can now with advantage be executed, down to the cryogenic temperature range, and
- The definition of instructions for construction and realization of **NSC-engine types** actually named; **PROFIT0, PROFIT1 and PROFIT2 engine types**.

major advantages, and it can cover the additional very attractive new application niches for thermal engines.

In summary it can be started; that the **Isothermal NSC-engines** have the advantage of being able to be used as a substitution for current thermal engines with internal combustion, adding real value for the consumer and to those concerned about the environment. The benefits of isothermal NSC-engines are as follows:

- They save energy (due to the higher efficiency and higher work output, as shown in Figure 2),
- They can use nearly all conventional, waste and alternative (renewable) energy sources (NG, PG and other earth gases, biogases, hydrogen, waste heat and waste cold, solar energy, geothermal energy etc., as shown in Figure 1),
- They are extreme environmentally friendly (due to less noise emissions, less or no NOx emissions and depending on the used fuel no CO2 emissions), and
- They can work as "real zero or class ultra low emissions engines".

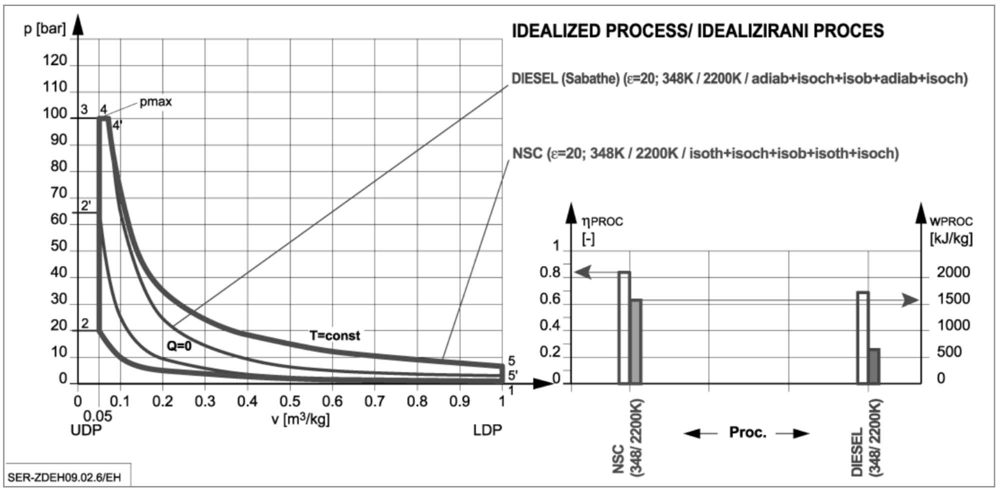


Figure 2. Comparison of the idealized Isothermal NSC-process cycle and the idealized Diesel (Sabathé) process cycle calculated for same; process temperatures, compression ratio and maximum process pressure ($\varepsilon = 20$, $T_{min} = 348$ K, $T_{max} = 2200$ K and $p_{max} = 100$ bar)

Slika 2. Usporedba idealiziranog Izotermalnog kružnog NSC-procesa i idealiziranog kružnog Dieselova (Sabathé) procesa računatih za iste vrijednosti procesnih temperatura, stupnjeva kompresije i maksimalnog tlaka ($\varepsilon = 20$, $T_{min} = 348$ K, $T_{max} = 2200$ K and $p_{max} = 100$ bar)

3. The NSC-engine

The reason why the **Isothermal NSC-engines** are regarded as an optimal solution for realization of the **Isothermal NSC-process cycle** is shown in the illustration "Family trees of the thermal engines", Figure 3. From this figure we can see that realization of the current best possible thermal process cycle (the isothermal NSC-process) can actually be optimally achieved with the help of three NSC-engine types; the PROFIT0, PROFIT1 and PROFIT2 engine types.

The instructions in 2nd Measure for construction and realization of NSC-engine types PROFIT0, PROFIT1 and PROFIT2 are visualized in Figure 4.

By applying both mentioned **two Measures**, the NSC-engines can practically become very serious competitors to the current thermal engines providing

4. Experimental and numerical verification of the NSC-concept foreseen Measures for its attempted achievement

As mentioned before, we assumed that the **Isothermal NSC-process** can be executed and achieved in **Isothermal NSC-engines** through the application of the above-mentioned **two Measures** [1 and 5].

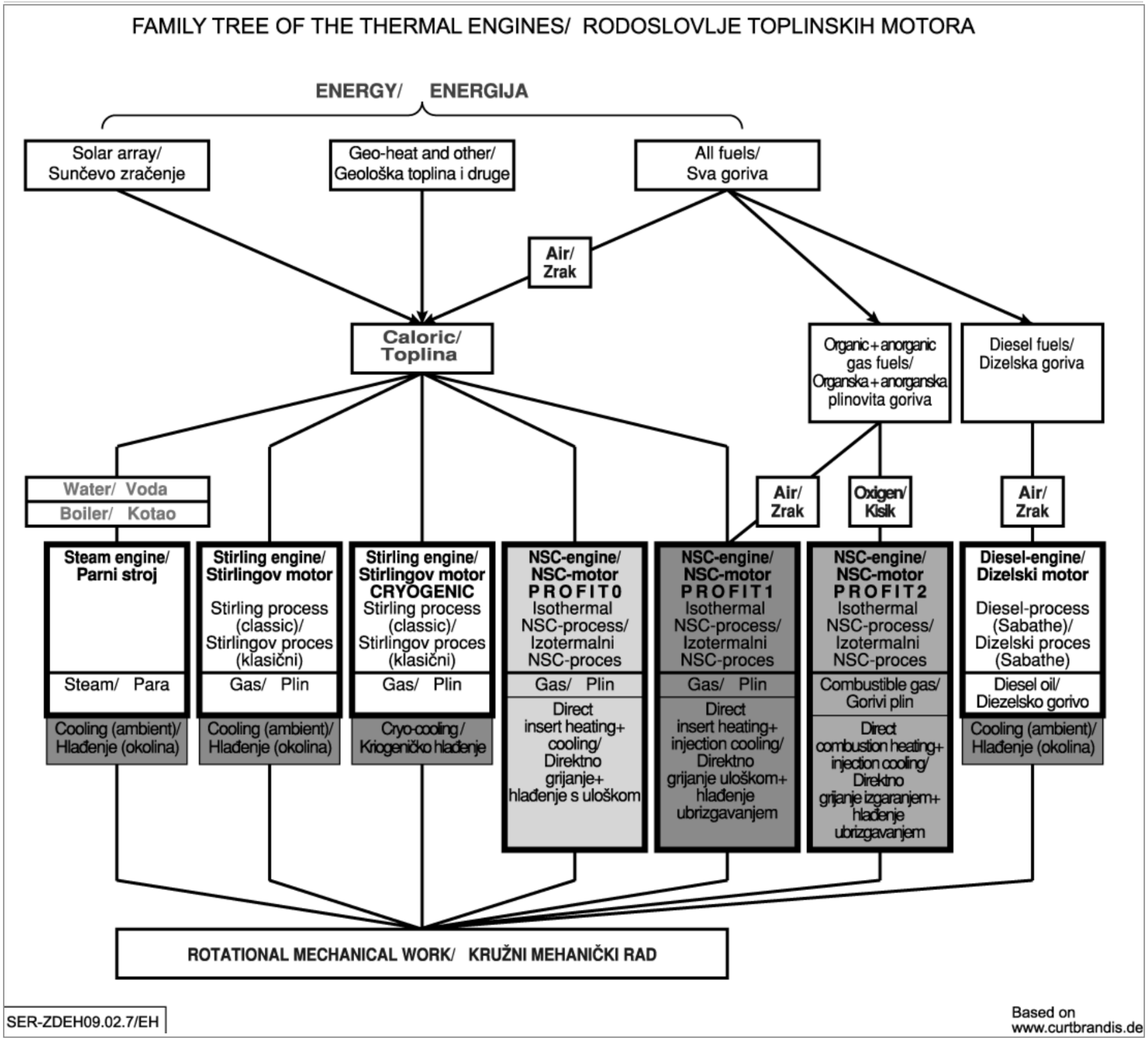


Figure 3. Family trees of the thermal engines and particularly of the Isothermal NSC-engine types

Slika 3. Rodoslovlje toplinskih motora, posebice za tri tipa Izotermalnih NSC-motora

The verification of these assumptions can be done only in an experimental way with the help of experimental engines.

The experimental verification was done with experimental NSC-engines:

- PROBA3A (piston, type PROFIT1**),** and recently with its modified solar version **PROBA3AS**, Figure 5, ([12] and [11])**,** and

- PROBA3D (membrane, type PROFIT0), Figure 6, ([1] and [5]).

The numerical verification of the measured experimental engine data and analysis of developed engines was done at least with two numerical simulation programs;

- The program **EXSIMEL3** (the elementary analysis of zeroed order) and

- The program **SIMPROFIT3** (the analysis of third i.e. the highest order), which both are actually in the third version. The compatibility between the measured and numerically derived process parameters of the researched engines is achieved and validated, see Figure 7.

Such validated numerical models could be used for further numerical simulation of the future NSC-engines (of same engine types) e.g. for the newly introduced solar NSC-engine PROSUN2000 (piston, engine type PROFIT1, [6] and [12]) as shown in Figure 7. This solar engine is expected to produce an alternate electric current. As a hybrid variant an NSC-engine can be combined with a more or less alternative additional heat energy source and, therefore is suitable for electric production at night. A linear solar parabolic trough system foreseen (pressurized steam with nominal temperature of approx. 750 K), as shown in Figure 8 is a primary heat source for the engine.

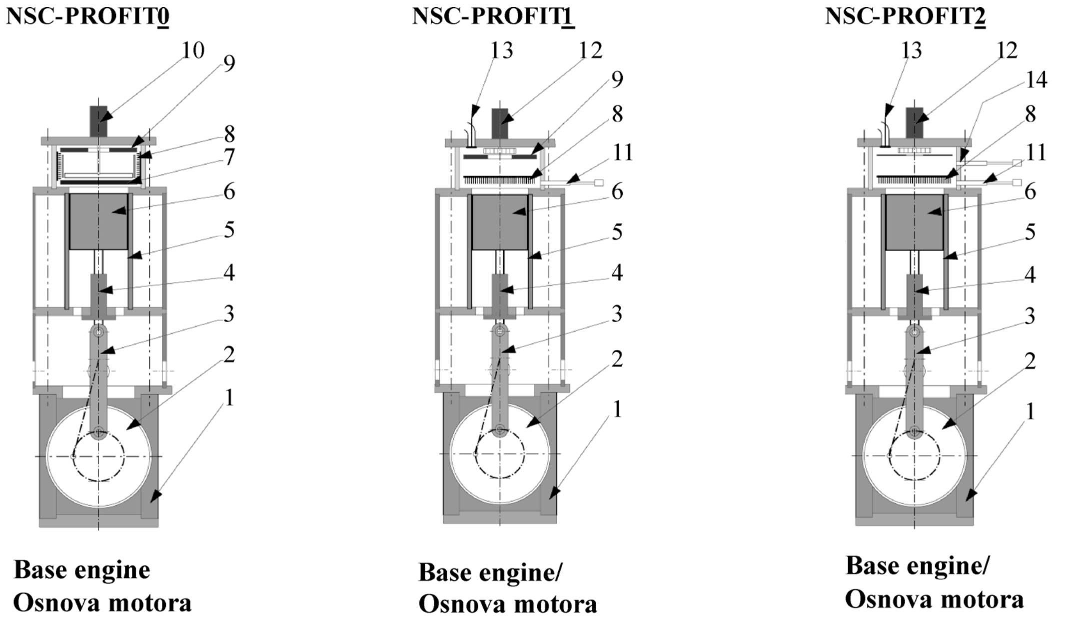
The planned electric engine power output of the engine is nominal P_{ENG} = 2000 W (corresponds to the "**Vision 2000-Watt Society"** [9].

There is no doubt that the same engine configuration is with great advantage suitable for the space interplanetary application (as e.g. hybrid, with nuclear battery, Figure 14).

The presented simulated indicating diagrams and other data (Figure 7) are not optimized here and therefore the real (measured) indicating diagrams, after realization and optimization of the future NSC-engines, will have more or less a different shape.

The typical heating and cooling temperature ranges of NSC-engines applied in the above mentioned numerical calculation are presented in Figure 8. Generally, it can be said that the temperature ranges of NSC-engines will not be limited on the engine side; they depend only on the temperature limits of both the engine heating and engine cooling sources.

Through application of the above-mentioned numerical simulations, it was possible to get provisional possible ranges for power and efficiency for the isothermal NSC-engines in PROFIT0, PROFIT1 and PROFIT2 configuration types, see Figures 9 and 10.



Legend:

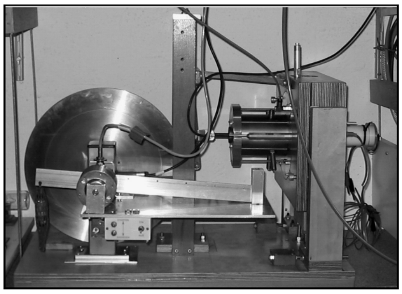
1=Engine housing 1=Kućište motora	2=Flywheel 2=Zamašnjak	3=Connecting rod 3=Ojnica	4=Cross head 4=Križna glava	5=Engine cylinder 5=Cilindar motora
6=Engine piston 6=Klip motora	7=Cooling insert 7=Hladnjak	8=Regenerator 8=Regenerator	9=Heating insert 9=Zagrijač	10=Displacer 10=Istiskivač
11=LG-Injection 11=Ubrizgavanje	12=Dyn. Displacer 12=Dyn. Istiskivač	13=Exhaust 13=Ispuh	14=O_2-Injection 14=O_2-ubrizgavanje	

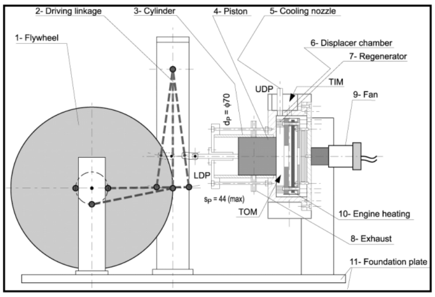
NSC-engines type PROFIT0 uses any kind of heat for direct process heating with **heating insert** and any kind of cold sources for direct process cooling with **cooling insert** .
The engine works with the closed NSC-process cycle and can be used in plants that produce high pressurized re-gasification and distribution of industrial and others usable liquefied gases (oxygen, nitrogen, hydrogen, dangerous gases etc.).

NSC-engines type PROFIT1 uses any kind of heat for direct process heating with **heating insert** and any kind of liquefied gas for direct process cooling through the gas **injection and additional evaporation.**
The engine works with the open NSC - process cy cle and can be used nearly in any application field of Diesel or Otto engines, but also with advantages for terrestrial solar and for space solar based power generation or for submarine AIP application .

NSC-engines type PROFIT2 uses any kind of liquefied combustible gas for direct process cooling through the **injection and additional evaporation** and for direct process heating through the **direct combustion** of injected working gas.
The engine works with the open NSC - process cycle and can be used nearly in any application field of Diesel or Otto engines as e.g. automotive application and with advantage for re-gasification and work production in LNG - plant application.

Figure 4. Isothermal NSC-engine types; PROFIT0, PROFIT1 and PROFIT2
Slika 4. Tipovi Izotermalnih NSC-motora; PROFIT0, PROFIT1 i PROFIT2





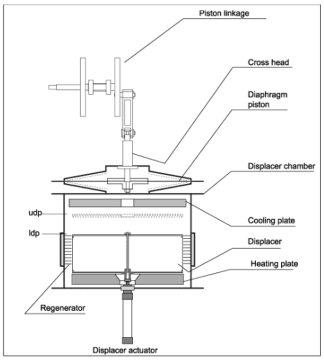
Legend :					
1=Flywheel 1=Zamašnjak	2=Driving linkage 2=Pogonsko polužje	3=Cylinder 3=Cilindar	4=Piston 4=Klip	5=Cooling nozzle 5=Rashladna sapnica	6=Displacer chamber 6=Komora istiskivača
7=Regenerator 7=Regenerator	8=Exhaust 8=Ispuh	9=Fan 9=Ventilator	10=Engine heating 10=Zagrijač	11=Foundation plate 11=Temeljna ploča	

Figure 5a. Photograph of the experimental NSC-engine PROBA3AS (PROFIT1)

Slika 5a. Fotografija eksperimentalnoga NSC-motora PROBA3AS (PROFIT1)

Figure 5b. Geometrical presentation of the experimental NSC-engine PROBA3AS

Slika 5b. Geometrijska prezentacija eksperimentalnoga NSC-motora PROBA3AS



Legend :				
1=Piston linkage 1=Polužje klipa	2=Cross head 2=Križna glava	3=Diaphragm piston 3=Membrana	4=Displacer chamber 4=Komora istiskivača	5=Cooling plate 5=Rashladna ploča
6=Displacer 6=Istiskivač	7=Heating plate 7=Zagrijač	8=Regenerator 8=Regenerator	9=Displacer actuator 9=Pogon istiskivača	

Figure 6a. Photograph of the experimental NSC-engine PROBA3D (PROFIT0)

Slika 6a. Fotografija eksperimentalnoga NSC-motora PROBA3D (PROFIT0)

Figure 6b. Geometrical presentation of the experimental NSC-engine PROBA3D

Slika 6b. Geometrijska prezentacija eksperimentalnoga NSC-motora PROBA3D

5. Perspectives for application of isothermal process based thermal NSC-engines

Actual approved experiences, based both on experiments with the experimental NSC-engines and numerical analysis of NSC-processes cover application of the NSC-engine types PROFIT0 and PROFIT1 (see Figure 4). These engine types cover nearly all conventional thermal engine applications and are suitable for different (specialized) application. Therefore, at first, application of these engine types will probably be realized in the present and near future.

The development of the NSC-engine types PROFIT2 with highest thermodynamically efficiencies and highest power ranges is foreseen (in the near future) for the time after the other two engine types (PROFIT0 and PROFIT1) are established, because the combustion behavior under the PROFIT2 conditions must be studied in detail.

5.1. Actual perspectives for application of isothermal NSC-engines type PROFIT1

5.1.1. Solar NSC-engines application (PROFIT1)

On the Earth`s surface (after traversing the Earth atmosphere) the solar radiation intensity, will be reduced from extraterrestrial values of 1366 W/m² to approximate maximum of 350 W/m², (fluctuation of approx. 6,9 % [8]). Therefore, there is no doubt that rigorous use of

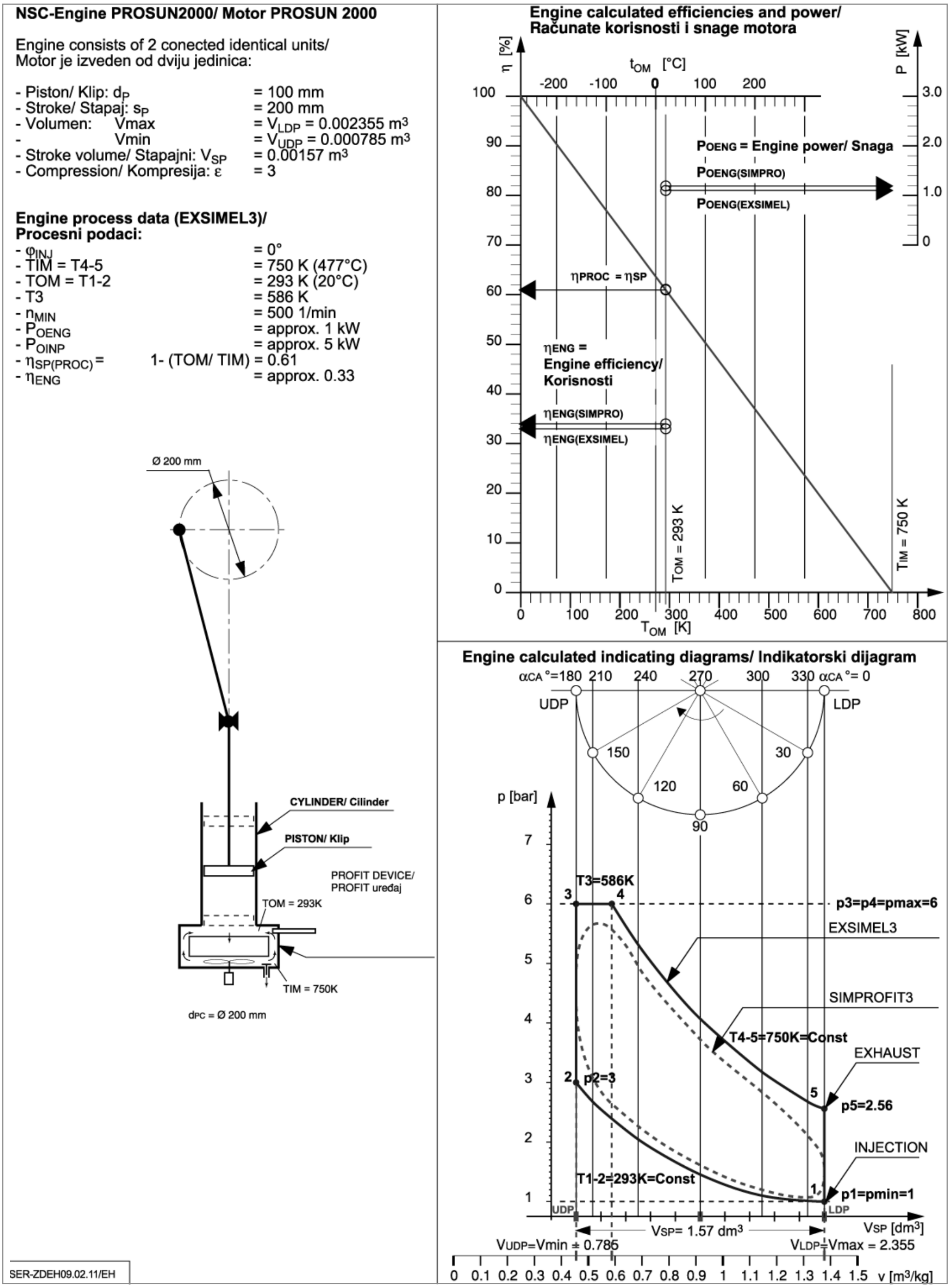


Figure 7. Calculated data of the solar Isothermal NSC-engine PROSUN2000 (piston, PROFIT1, Nominal engine power P_{ENG} = 2000 W)

Slika 7. Računati podaci solarnoga Izotermalnoga NSC-motora PROSUN2000 (klip, PROFIT1, Nominalna snaga motora P_{ENG} = 2000 W)

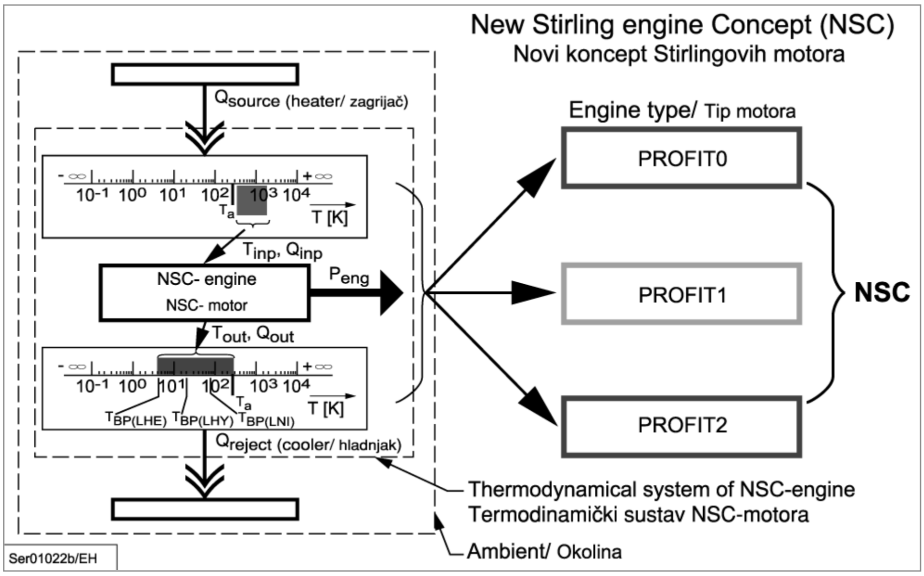


Figure 8. Typical heating and cooling temperature ranges of the Isothermal NSC-engines

Slika 8. Tipična područja temperatura grijanja i hlađenja Izotermalnih NSC- motora

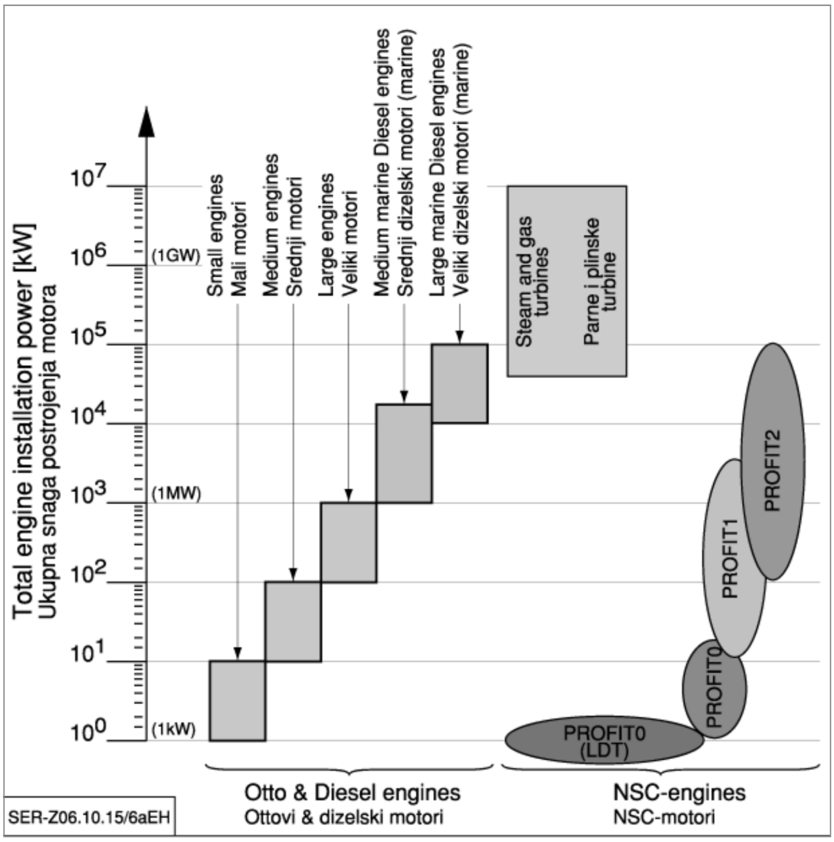


Figure 9. Calculated engine power values of the Isothermal NSC-engines and comparison with conventional thermal engines

Slika 9. Računata područja snaga Izotermalnih NSC-motora i usporedba s konvencionalnim toplinskim motorima

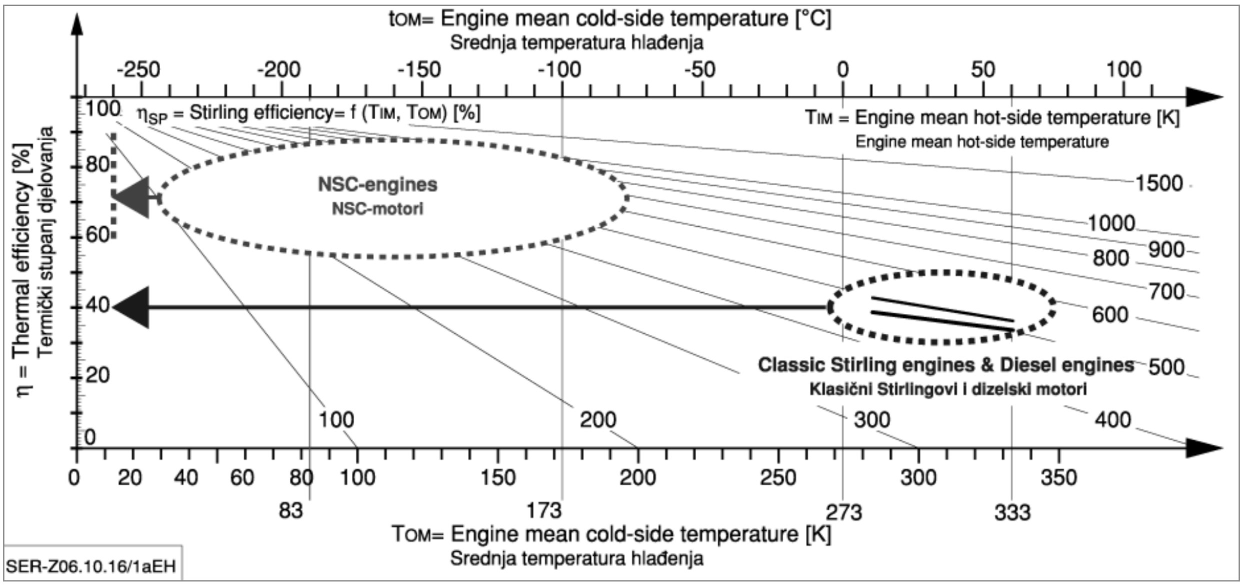


Figure 10. Calculated engine efficiency values of the Isothermal NSC-engines and comparison with classic Stirling and actual Diesel engines

Slika 10. Računata područja korisnosti Izotermalnih NSC-motora i usporedba s klasičnim Stirlingovim i aktualnim dizelskim motorima

solar energy has today a bright future, which is mostly dependent on the prices of the conventional (fossil) energy sources and on existence of suitable technologies (especially on existence of the efficient solar engines, e.g. as solar NSC-engines). The solar radiation intensity higher than 175 W/m² will be obtainable in the regions between 45° north and 45° south Earth geographic latitude.

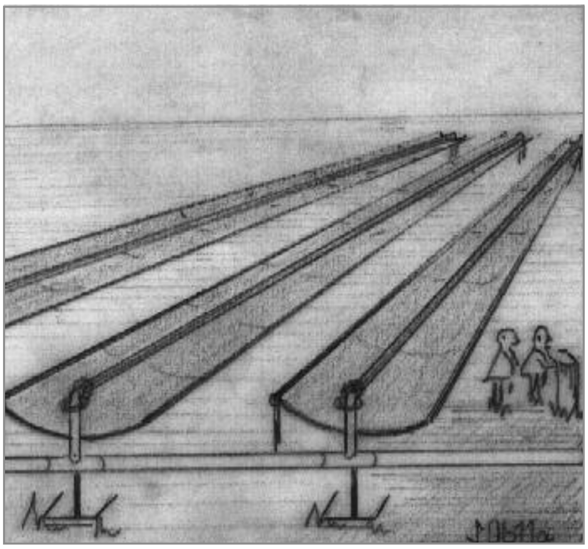


Figure 11. Linear solar parabolic trough systems

Slika 11. Sistem linearnih solarnih paraboličnih korita

For use of solar energy as a heat source for **solar NSC-engines application** only highest temperature solar systems (causing the highest engine thermal efficiencies) with linear focusing concentrators are of interest, these are actually the **Linear solar parabolic trough systems** as shown in Figure 11.

The maximum achieved temperatures depend on used heat transfer fluid and the trough system (e.g. Fresnel), [7 and 8] and will actually not exceed ranges of about 1100 K.

Generally, the linear trough concentrator system can, with advantage, be completed with an adequate tracking system that includes drive, sensors, and controls.

Figure 12 shows the installation scheme of a hybrid solar **NSC-engine** for terrestrial application shown. In this figure (Figure 12) it is very important to perceive that the solar hybrid NSC-engine installation work is a completely autonomic Combined Heat and Power (CHP) system which is able to supply electric power (or mechanical work) and heat (for room heating and hot water).

Based on Figure 12 installation scheme and with the help of the numerical analysis shown in Figure 7, Figure 13 shows a draft of the **hybrid solar isothermal NSC-engine PROSUN2000** elaborated (driven by e.g. Natural gas or Biogas). The engine consists of two identical NSC-engine units (piston, type PROFIT1, terrestrial, nominal power output is P_{ENG} = 2000 W).

Man can imagine that the hybrid heater of the solar NSC-engines can be supplied also by any available heat source, as e.g. waste heat, geothermal heat, etc.

In Figure 14 is the installation scheme of a hybrid solar NSC-engine for space application shown. Here it is **of the highest importance** to perceive that the hybrid i.e. solar and with the nuclear battery driven NSC-engine installation works with the highest possible efficiency (because of the executed process cooling in the deep space cryogenic temperature range) with all positive consequences e.g. long time service.

5.1.2. Common NSC-engines application (PROFIT1)

The NSC-engines can cover nearly all conventional thermal engine applications and are suitable for different (common and specialized) application. One of the very free applications (because of a large number of actual thermal engines in service and the environmental and resources problems) is the automotive application with Hydrogen driven **NSC-engines** (or if necessary with any other combustible gas).

In Figure 15 is the installation scheme of a small and medium combustible gas driven automotive **NSC-engine** shown**.** Here it is important to perceive, that instead of an externally placed heater system a variant with direct in PROFIT1-device placed heating insert is very possible. Such direct water cooled and Hydrogen powered NSC-engines works as steam engines with direct steam production (in the PROFIT1-device) during the isothermal executed process in the engine.

In Figure 16 is the installation scheme (based on the scheme Figure 15) of medium, Hydrogen driven **NSC-engine** for submarine application shown. Here it is important to perceive that a possible variant with the direct, in the PROFIT1-device placed heating insert is very advantageous for this application. As mentioned above, such direct water cooled and Hydrogen powered NSC-engines works as steam engines with direct steam production in the PROFIT1-device during the isothermal executed process in the engine. The condensed water surplus will from time to time be drained from the submarine.

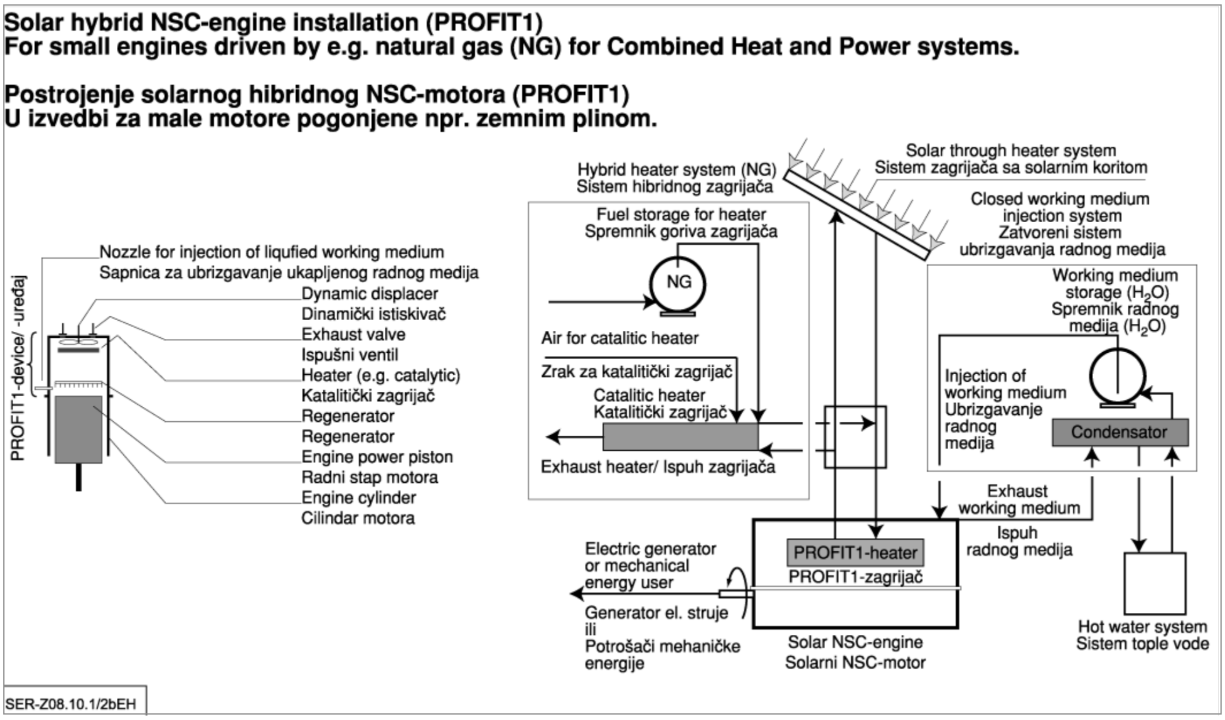


Figure 12. Installation scheme for a small hybrid (NG) solar Isothermal NSC-engine (PROFIT1, Terrestrial application, Engine power Output Range = 10^0 kW, Efficiencies = 0,61/ 0,33)

Slika 12. Shema postrojenja za mali hibridni (NG) solarni Izotermalni NSC-motor (PROFIT1, Zemaljska primjena, Područje snage motora = 10^0 kW, Korisnosti = 0,61/ 0,33)

5.1.3. Large power NSC-engines application (PROFIT1)

The NSC-engines can with advantage cover very specialized applications and in this way utilize the exergy of liquefied gases.

One of the very free applications is re-gasification of LNG (Liquid Natural Gas) in the LNG terminals by simultaneous utilization of the liquefied gas exergy (because of a growing number of LNG terminals in service). In this application, the evaporated NG can be exhausted with high pressure from an NSC-engine and in this way the first stage pipeline NG compressor can be dismissed.

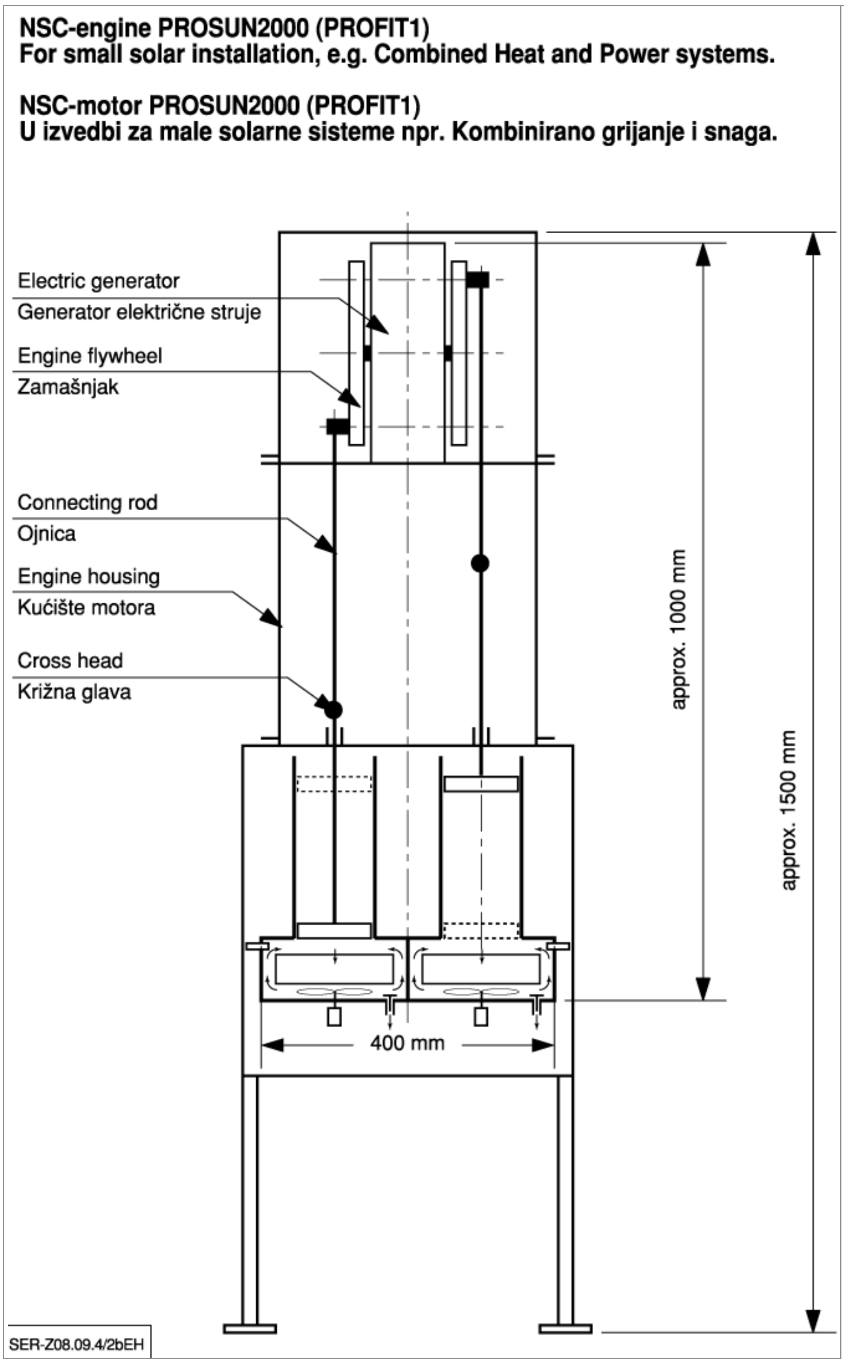


Figure 13. Draft of the small hybrid solar Isothermal NSC-engine PROSUN2000 (two engine units and one DC/ AC-generator. Nominal engine power P_{ENG} = 2000 W, Efficiencies = 0,61/ 0,33 (PROFIT1, Terrestrial application)

Slika 13. Skica malog hibridnog solarnoga Izotermalnoga NSC-motora PROSUN2000 (dvije motorne jedinice, i jedan DC/ AC-generator, Nominalna snaga motora P_{ENG} = 2000 W, Korisnosti = 0,61/ 0,33 (PROFIT1, Zemaljska primjena)

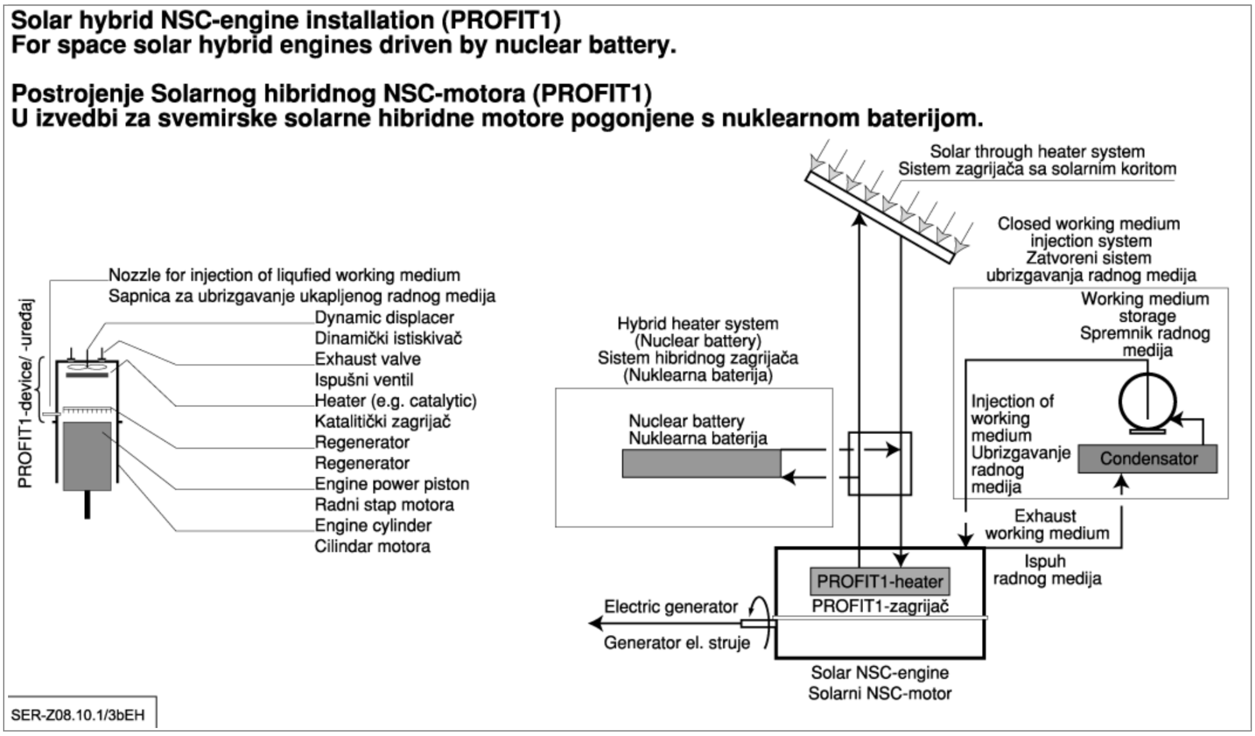


Figure 14. Installation scheme for a small hybrid (Nuclear battery) solar Isothermal NSC-engine (PROFIT1, Space application, Engine power Output Range = up to 10^0 kW)

Slika 14. Shema postrojenja za mali hibridni (nuklearna baterija) solarni Izotermalni NSC-motor (PROFIT1, Izvanzemaljska primjena, Područje snage motora = do 10^0 kW)

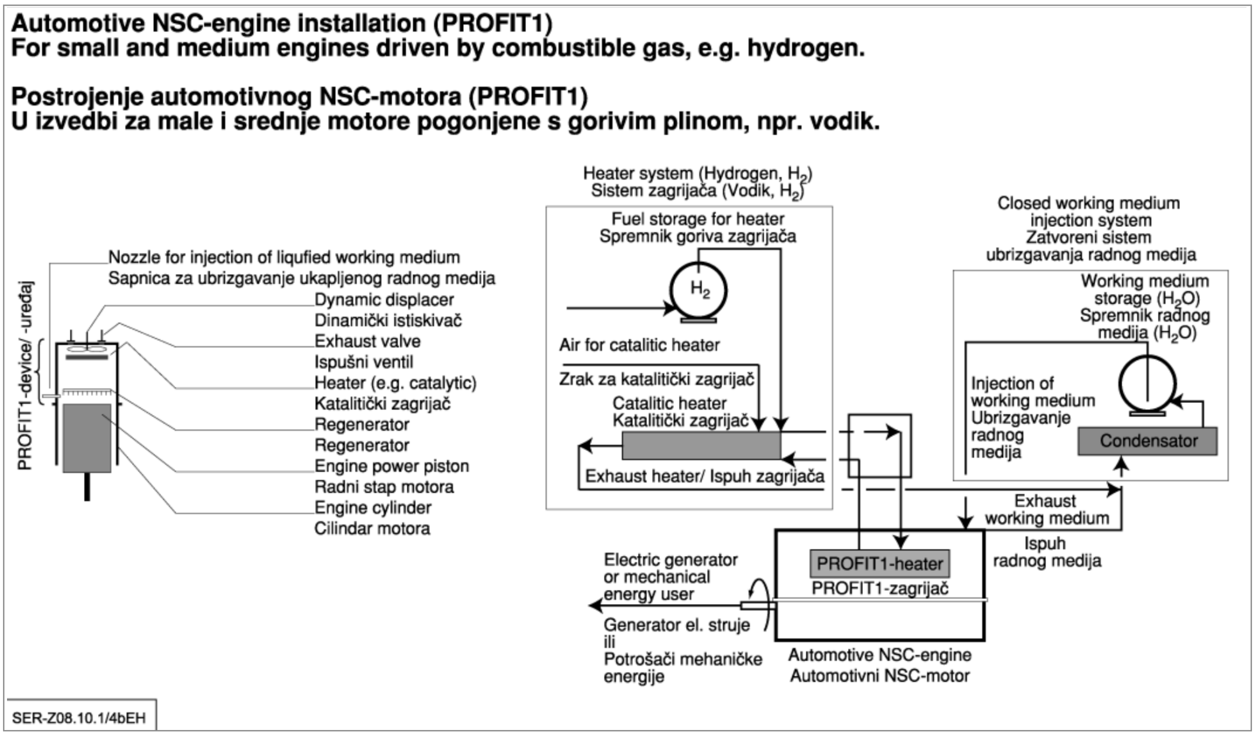


Figure 15. Installation scheme for a hydrogen (H2) driven Isothermal NSC-engine (PROFIT1, Automotive application, Engine power Output Range = 10^1 - 10^2 kW)

Slika 15. Shema postrojenja Izotermalnoga NSC-motora pogonjenog vodikom (H2, PROFIT1, Automobilska primjena, Područje snage motora = 10^1 - 10^2 kW)

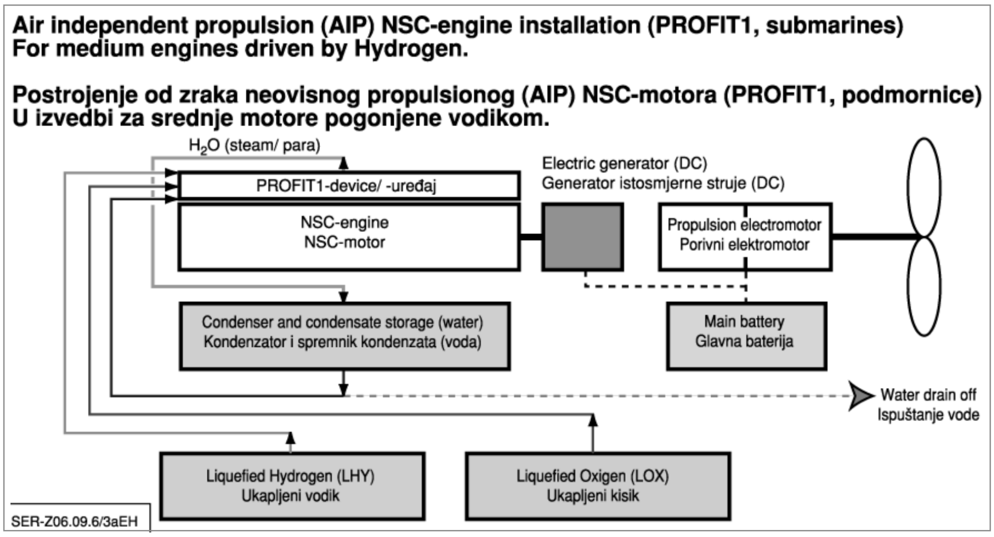


Figure 16. Schematic presentation of Isothermal NSC-engine plant for air independent submarine propulsion with hydrogen (Hidrogen, PROFIT1, AIP)

Slika 16. Shematski prikaz postrojenja Izotermalnog NSC-motora za od atmosferskog zraka neovisnu propulziju podmornica s vodikom (Vodik, PROFIT1, AIP)

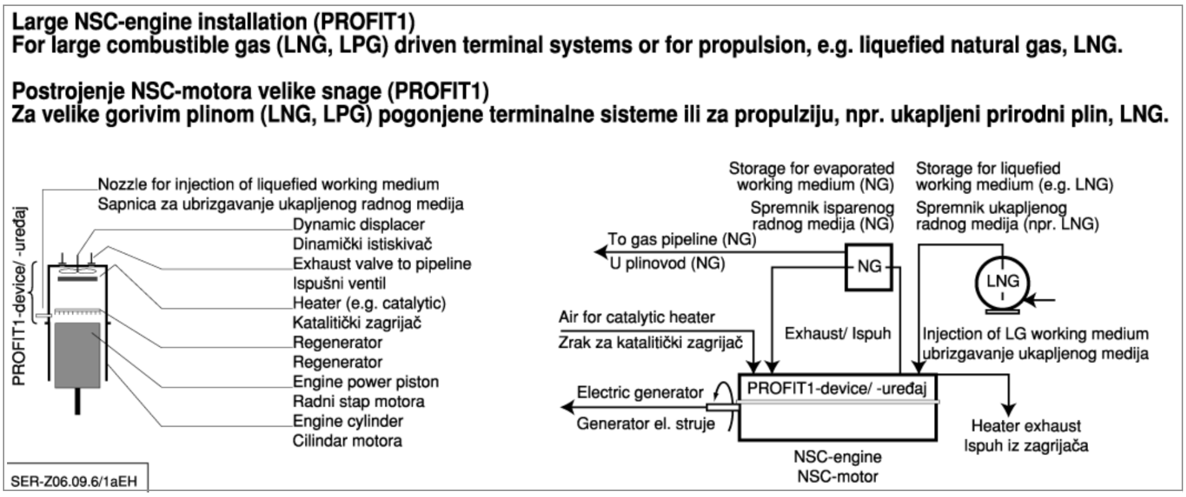


Figure 17. Installation scheme for a large combustible gas driven Isothermal NSC-engine (PROFIT1, LNG (LPG)-terminal application, Engine power Output Range = 10^2 - 10^3 kW)

Slika 17. Shema postrojenja za veliki Izotermalni NSC-motor pogonjen gorivim plinom (PROFIT1, primjena za LNG (LPG)-terminale, Područje snage motora = 10^2 – 10^3 kW)

It is obvious that the same engine configuration can be applied for the LNG or LPG tanker ships` propulsion. Both these engine systems apply exergy of the liquefied gases (e.g. LNG) for direct cooling by liquid gas injection during the engine cycle. For direct heat addition to the working fluid, the catalytic combustor (internal or external) is used. The excess of the evaporated natural gas (bigger part of it, in the case of pipeline application) is exhausted under appropriate pressure directly to the gas distribution pipeline.

In Figure 17 is the installation scheme of a large combustible gas driven **NSC-engine** for LNG-terminal application shown.

6. Conclusion

Based on the performed experiments with the experimental solar NSC-engine PROBA3AS and numerical simulation with two programs (EXSIMEL3 and SIMPROFIT3, both programmes developed by authors) the following can be concluded:

1) The so-called **New Stirling engine Concept (NSC-concept)** based **Isothermal NSC-engines** can be executed. The execution of isothermal NSC-engines can successfully be achieved with the help of NSC-concept based **Two Measures**, which includes:

A - The use of newly-developed **Isothermal NSC-process cycle**,

B - The application of newly-developed **NSC-principles**.

2) The actual approved experiences based both on experiments with the experimental NSC-engines and numerical analysis of NSC-processes cover very well the application of the NSC-engine types PROFIT0 and PROFIT1. These engine types cover nearly all conventional thermal engine applications and are also suitable for different specialized application (e.g. space- and AIP -application). Therefore, these engine types will probably be the first executed application in the present and/ or near future.

The development of the NSC-engine types PROFIT2 with highest thermodynamically efficiencies and highest power ranges (up to 10^5 kW, see Figure 9) is foreseen (in the near future), for the time after the other two engine types (PROFIT0 and PROFIT1) are established, because the combustion behavior under the PROFIT2 conditions must be studied in detail.

3) This paper:

- describes how in this research work the first execution of the NSC-engine, with help of the experimental solar NSC-engines PROBA3D and PROBA3AS was done,
- describes the isothermal NSC-process cycle,
- describes the two Measures based developments and NSC-principales and how they shall be used,
- shows the research work results,
- expresses the necessity to extend this research work.

4) The research work results indicate and show also that the water-cooled **Isothermal NSC-engines**, which are predestined for the use of solar energy or for all Hydrogen driven application, have potential for use in other thermal engine niches (e.g. automotive and AIP), especially as steam engines with the direct steam production during the isothermal executed process cycle in the engine.

5) The research results, experiments done and numerical analysis demonstrated with the schemes show that new isothermal NSC-engines are and will be suitable for nearly all application fields of the actual thermal engines.

6) The achieved results of R&D activities on this topic, presented in this paper, give a reliable basis for further development and application of NSC-engines aiming at rational use of energy resources and prevention of environmental pollution for better future life on the Earth.

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