France
Member of ICHMT, AIHTC, EUROTHERM
(1) Overview

(Central European Time Zone, CET: UTC+1 (winter) and UTC+2 (summer), Population: 67.4 million)

1. Organizations

Most scientists and and engineers specialized in thermal sciences and heat transfer in France belong to Société Française de Thermique (SFT).

SFT was founded in 1961 as a non-profit organization.
The organization published "La Revue Générale de Thermique" until 1995, before its publication by Elsevier as the "International Journal of Thermal Sciences".

Its purpose is :

- Development and enhancing the influence of thermal sciences,
- Study of miscellaneous problems, of public interest linked to thermal sciences in a direct or indirect way, such as the study of the use of diverse energy sources for example
- Link to associations and French groups of thermal scientists, as well as to other scientific fields
- Animation and promotion within the community of thermal sciences in industry, teaching and research
- Exchanges and diffusion of knowledge between their creators and their users
- The representation of thermal sciences and of thermal scientists at the national, European and international levels

President of SFT (2021-2023): Christophe Le Niliot, Aix-Marseille University (christophe.leniliot@univ-amu.fr)

2. Members

- 450 individual members in the year book
- 30 collective members: University /CNRS research labs, and companies

3. Structure and communication

SFT is organized around an administration board, a scientific committee and thematic groups. The main organization is described below

- An elected board, with a two year mandate for the President and for the head of the scientific committee with four meetings per year.
- A scientific council in charge of the congress
- 3 organic commissions for:
  - Scientific foresight
  - Programs to organize the scientific seminars
  - Communication and education to promote the association and the scientific activities
- 19 thematic groups in charge of the animation of a scientific activity such as: radiation, heat exchangers, transfers in porous media … The list of the topics is presented on the website https://www.sft.asso.fr/)
- A website with upcoming meetings and open access to proceedings of the yearly conference, of seminars and advanced schools, as well as a directory of members: https://www.sft.asso.fr/

- A LinkedIn Page:

https://www.linkedin.com/company/sftasso/?viewAsMember=true

- A YouTube channel: https://www.youtube.com/watch?v=7oTIDvlAA8U&t=53s
- Edition of four newscasts per year containing all the informations about the association: minutes of meetings, conclusion of the commissions, calls for papers from national and international upcoming conferences and seminars

4. Major meetings

- One 3.5 day yearly conference (late May, early June) organized by about 15 rotating labs in different cities of France,
- Prize and awards: during the yearly conference, the scientific committee awards the best paper-oral presentation to a young scientist. This award called "*the Biot-Fourier award*" was created in honor of two French scientists: Jean-Baptiste Biot (1774-1862) and Joseph Fourier (1768-1830), both known for their major contribution in thermal sciences.
- about ten scientific *SFT seminars* of 1 or 2 days per year within the scope of the thematic groups or with other organizations: companies or academic associations such as the SFGP (Chemical Engineering) or AFM (Mechanics)
- participation to the organization of advanced schools, with CNRS, Eurotherm, ICHMT. In the past years SFT sponsored international seminars in the domain of: nano heat transfer, inverse techniques and thermal measurements, radiation …

5. Education

- The French University system is based on the *Bologna Process* introduced to harmonize higher education in European Union. It is based on three levels:
  - The first (lowest) level is a bachelor's degree, typically lasting three to four years.
  - The second level is a master's degree, typically lasting one to two years.
  - The final level is a doctorate (PhD) which usually lasts three years
- The French University system is supplemented by engineering schools specializing in the major fields of engineering including thermal sciences. These studies lead to an engineer's degree equivalent to a Master's degree.

6. Major Public/Private Research Institutes

- Most major labs in thermal sciences and heat transfer depend both on their local University and on the National Center for Scientific Research (CNRS)
- The National Research Agency (ANR) is a public administrative establishment, placed under the supervision of the Ministry of Higher Education, Research and Innovation. The Agency implements the funding of research projects, for public operators in cooperation with each other or with companies.
- The Investments for the Future Program (PIA), steered by the General Secretariat for Investment (SGPI), was set up by the State to finance innovative and promising investments in the territory, in order to enable France to increase its potential for growth and jobs.

By D. Lemonnier (ICHMT/Eurotherm), D. Maillet (AIHTC) and C. Le Niliot (SFT/Eurotherm)

France, Member of ICHMT, AIHTC, EUROTHERM (2)

200th Anniversary of the publication of "Reflections on the Motive Power of Fire" by Sadi Carnot

200th Anniversary of the publication of "Reflections on the Motive Power of Fire" by Sadi Carnot

Michel Feidt
Emeritus Professor, Université de Lorraine, Vandoeuvre-lès-Nancy
Michel.Feidt@univ-lorraine.fr

1. The Young Man and his Research

Nicolas Léonard Sadi Carnot[1] was born on 1 June 1896. His father[2] was an eminent engineer involved in mathematics and mechanics (he was probably an example for his son). S. Carnot graduated from Ecole Polytechnique (Paris) in 1814. He was always interested in learning some courses at the Ecole des Mines and Sorbonne (1818-1821) and worked on the theory of thermal engines from 1821 to 1823, a date at which he probably completed his reflection on the book that was published in 1824.

He continued to work on thermal engines and also on economics until his death in 1832. He formulated the main ideas relating to the first law of thermodynamics (conservation principle) in *Notes*. These *Notes* were only rediscovered in 1878 for the part related to thermodynamics and in 1976 for the part related to economics. Due to these recovered notes, a new tombstone was created, presenting S. Carnot as the father of a new science: thermodynamics, a word that was not known to him.

Nicolas Léonard Sadi Carnot (1796-1832)

2. The Technical Evolution

Since the eolipile, the first machine actuated by water vapor (Heron of Alexandria, 2nd century B. C.) and until the 18th century, mechanical forces were the only ones used by man: human and animal power, hydraulics, and windmills.

Attempts to develop internal combustion engines began in the early 18th century: fire machines (N. Niepce, 1807), steam engines (J. Watt, 1775; J. Cugnot, 1770-1771; D. Papin, 1707).

[1] There is another famous *Sadi Carnot* in the French history: Marie François Sadi Carnot, who was also commonly called Sadi Carnot, like his uncle the physicist. M.F.S. Carnot was a French statesman, who served as the President of France from 1887 until his assassination in 1894.
[2] Lazare Carnot (1788-1841) was a French military engineer and politician.

The improvement of the steam engine (condenser) coincided with other ones (Stirling engine; Otto-Beau de Rochas; Lenoir; Diesel). But Sadi Carnot was more concerned with the fundamental aspects of engines.

3. The Birth of a Science

During the same period, many scientists developed the studies of gazes (J. Charles, L. J. Gay-Lussac, N. Clément and C. Desormes, P. Dulong and A. T. Petit). For Carnot, the aim was to show that the nature of the cycled medium did not influence the maximum useful effect of the engine.

In the same period, J. Joule established the equivalence between mechanical work and heat. This coincides with the end of the phlogiston theory and the emergence of the concept of heat. Sadi Carnot thus extended the conservation of matter principle (Lavoisier) to energy conservation (first law of thermodynamics).

Other major contributions of Sadi Carnot (but in the frame of equilibrium thermodynamics or *thermostatic*) are using the reversibility hypothesis:

- The proposal of the Carnot cycle with two isotherms and two isentropic;
- The efficiency of the perfect machine (upper bound). This efficiency is an extension of the mechanical efficiency (well known to his father).


REFLEXIONS
PUISSANCE MOTRICE
DU FEU
SUR LES MACHINES
Par S. CARNOT,
A PARIS,

Front page of the first edition of S. Carnot's book.

$$\eta = 1 - \frac{T_F}{T_C}$$

One of the first thought experiments was the concept of macroscopic entropy (extensity corresponding to absolute temperature):

$$dS = \delta S_E + \delta S_I = \frac{\delta Q}{T} + \delta S_I$$

where S_E stands for the heat transfer entropy and S_I for the production of entropy, a non-conservative quantity. The concept of entropy was unknown at the time of Carnot. It was later refined by R. Clausius and more recently by I. Prigogine, who was awarded the Nobel Prize in 1977.

4. Extensions of Thermodynamics

4.1 Phenomenological extension

As presented at the end of the previous section, the developments of thermodynamics are recent. Significant contributions regarding the near-equilibrium situation are due to L. Onsager and linear approximation before Prigogine's work on dissipative structures.

More recently, an extended irreversible model of Carnot engine was developed, with new results on power and efficiency. A schematic example can be found in Reference [7].

4.2 Other extensions

To these phenomenological results are associated other extensions, mainly:

- statistical thermodynamics (L. Boltzmann)
- relativistic thermodynamics (L. de Broglie)
- quantum thermodynamics

These fundamental developments are adapted to, whatever the scale of the system:

- large structures (universe, multiverses, black holes)
- living systems (dissipative structures, biology)

The final goal of I. Prigogine and I. Stenger was also to extend the thermodynamics to human and social sciences, and even philosophy. But this proved difficult, as it did for psychoanalysis. In contrast, as stated by Carnot, interesting developments have been made in the field of economy and environment (N. Georgescu-Roegen).

5. Some Conclusions and Perspectives

Sadi Carnot's time was the premise of the Industrial Revolution. It led to the practical realization of a great variety of machines and engines in particular.

Carnot appears as the father of what is now called thermodynamics, with a wonderful insight into the fundamental aspects of this new science: heat, efficiency, power, Carnot cycle.

Since then, a second revolution seems to be emerging: the information revolution, and qubits are linked to thermodynamics. A great deal of research is in progress, always related to Sadi Carnot's work (Shannon entropy).

Nevertheless, Carnot's approach can always evolve and diversify. The future will probably confirm new trends not only in applications but also in fundamental aspects. Reference [7] provides an illustration of the current state of the art and the perspectives to be consolidated.

SUGGESTED REFERENCES

[1] S. Carnot, *Réflexions sur la puissance motrice du feu et sur les machines propres à développer cette puissance*, J. Gabay Editions, 2005 (ISBN 2-87647-069-1), Paris

[2] S. Carnot, *Reflections on the Motive Power of Fire (And Other Papers on the Second Law of Thermodynamics)*, Dover Publications Inc., 2005 (ISBN 978-0486446417), N. Y.

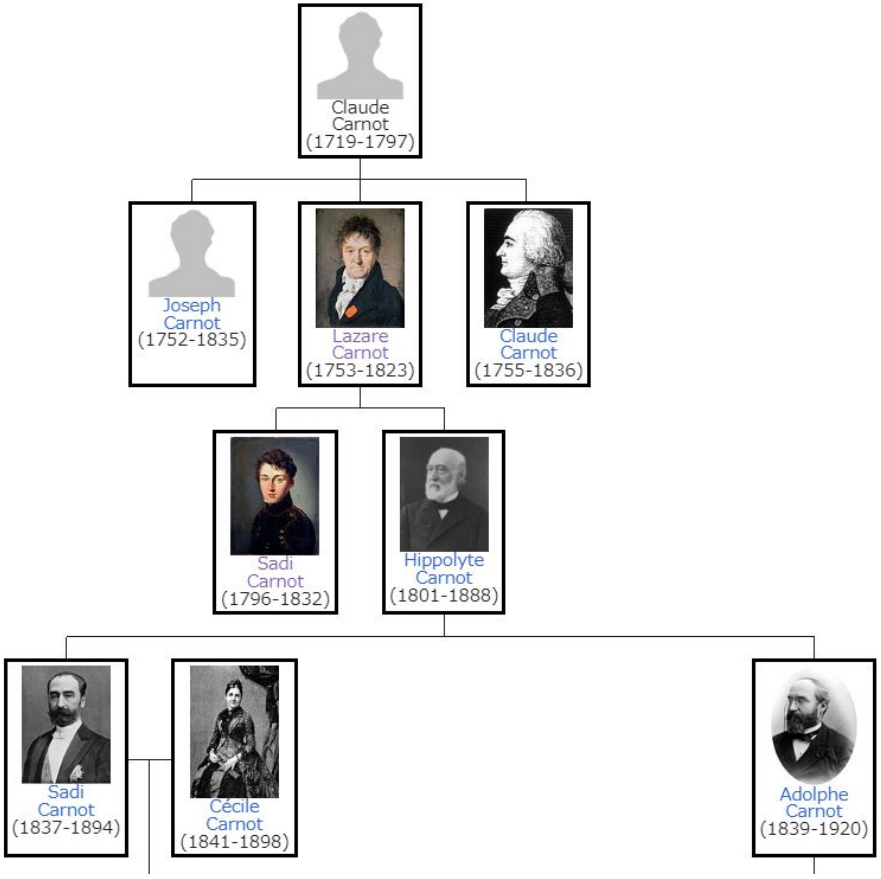
[3] E. Bertrand, *Extension du domaine de la thermodynamique. Anatomie d'une controverse*, Classiques Garnier Ed., 2023 (ISBN 978-2-406-14784-8), Paris

[4] L. Onsager, Reciprocal Relations in Irreversible Processes. I., *Phys. Rev.* **37**, 405, 1931

[5] L. Onsager, Reciprocal Relations in Irreversible Processes. II., *Phys. Rev.* **38**, 2265, 1931

[6] S. Ferrari, *Nicholas Georgescu-Roegen et la bioéconomie*, Le Passager Clandestin Ed., 2023 (ISBN 978-2369352075)

[7] M. Feidt, *Finite Physical Dimensions Optimal Thermodynamics, FDOT:*
1 *Fundamentals*, ISTE-ELSEVIER Ed., 2017 (ISBN 978-1-78548-232-8)
2 *Complex Systems*, ISTE-ELSEVIER Ed., 2018 (ISBN 978-1-78548-235-5)



Généalogie détaillée de la famille Carnot
from https://fr.wikipedia.org/wiki/Famille_Carnot