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安徽工程大学
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硕士学位论文

题目　《能源与二氧化碳》（十二章、十三章）英汉翻译实践报告

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专业学位类别　翻译硕士
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A Report on the E-C Translation Practice of *Energy Versus Carbon Dioxide* (Chapters 12, 13)

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A Report on the E-C Translation Practice of *Energy Versus Carbon Dioxide* (Chapters 12, 13)

Tang Yankai

A thesis submitted in conformity with the requirements

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摘　要

近年来，能源短缺和环境保护问题作为与人们日常生活密切相关的议题，相关科普作品在全世界范围内备受关注。本文是一篇英汉翻译实践报告，原文节选自康纳尔·斯坦(Cornel Stan)所著的《能源与二氧化碳》(*Energy versus Carbon Dioxide*)一书，全书共十八章，本次翻译实践节选了其中的第十二章和十三章，主要论述了氢能内燃机和氢燃料电池的可行性，翻译此部分对于加强人们对全球能源现状的认识以及环保意识具有实践意义。

原文中有大量的半技术词、较多的文化负载词、大量的复杂句，句子之间逻辑严谨，衔接与连贯性较好。根据纽马克的文本类型理论，该文本属于科普类的信息型文本，因此在翻译过程中不仅要保证信息传递的准确性，还要考虑其通俗性和可接受性，同时还要兼顾一定的文学性。对于半技术词，译者从专业领域、语法功能和联立关系三个方面对词义进行精确锁定。对于文化负载词，译者采用了音译、直译和意译三种方法，其中不仅涉及翻译方法的纵向选择，也包括词义的横向选择。而对于复杂句子的翻译，译者则利用逆译法、分译法和综合法等方法进行适当处理，确保以目的语读者最熟悉最易接受的方式重现句子信息。在译文句子间的衔接与连贯方面，译者采用转换和重组法对原文的内在逻辑和外在结构进行了调整，以提高译文的可读性和可接受度。

译者在此次翻译实践中加深了对科技翻译的理解，翻译能力得到了较大提升，但同时也意识到自己对其他领域专业知识的了解不够全面，将来会不断实践，力求不断进步。

关键词：《能源与二氧化碳》；科技翻译；文化负载词；半技术词；衔接与连贯

Abstract

Recently, the popular science texts in close association with energy shortage and environment problems spread themselves influentially and become more and more popular worldwide. This thesis comes out to be a report on the E-C translation practice of the twelfth and thirteen chapters of *Energy versus Carbon Dioxide* by Cornel Stan, which consists of eighteen chapters and explores the feasibility of internal combustion engine with hydrogen as well as fuel cell with hydrogen. Thus, the translation of the text practically enriches people with information of energy shortage and environmental protection.

The source text contains a large number of semi-technical and culture-loaded words, as well as complex sentences, featuring strict logics and smooth cohesion and coherence. The text typology of Reiss classifies the source text as informative text of popular science, which urges the translator to convey the literariness, popularity and acceptability of source text based on the accuracy of information. For the abundant semi-technical words, the translator locates the precise meanings from their special fields, grammar functions and collocations. And the translator employed transliteration, literal, and free translation methods to address culture-loaded words, by suiting proper methods to different problems and choosing appropriate meanings of words. As for the conversion of

complicated sentences, methods including the reverse, division and comprehensive are all applied to arranging different components properly within sentences, ensuring the reappearance of original information by the most familiar and acceptable way for the target reader. Finally, for the cohesion and coherence, the translator localizes the inner logics and outer structures of the source text through conversion and rearrangement, so as to achieve readability and acceptability of the popular science text.

During the translation practice, the translator has strengthened his understanding towards the translation process, enhanced translation ability, and realized practice makes perfect. Besides, the translator fails to deepen his understanding of the specialized details for lack of comprehensive knowledge of other special fields.

Key Words: *Energy versus Carbon Dioxide*; scientific translation; culture-loaded word; semi-technical word; cohesion and coherence

Contents

Chapter 1 Task Introduction

The source material of the translation practice report is an excerpt from the book *Energy versus Carbon Dioxide,* which is mainly about counterbalancing the energy need and the emission of carbon dioxide, written by Cornel Stan and published by Springer-Verlag in 2022. Heretofore, there is no Chinese version. The selected parts consist of Chapter 12, *The last weapon: nuclear power*, and Chapter 13, *The energetic water cycle: nature-electrolysis-machine-nature*, which mainly talks about the advantages and disadvantages of nuclear power and hydrogen energy, as well as the possibility to supplant the traditional energy. The translated Chinese version is approximately 10800 words.

1.1 Background

On November 15th, 2022, the world witnessed a newborn baby who contributed the last effort to the world population of 8 billion. According to the forecast of United Nations Population Division (UNPD), the total number will reach 10 billion in thirty years. In the meantime, the per-capita energy consumption is upsurging rapidly on account of the development of technology and economy. Under the circumstances, the energy need is growing explosively. However, the current issue is not about narrowing the gap between energy need and supply, but about the alleviation of the problem of global warming led by massive emission of carbon dioxide in energy consumption. Thereupon, some aggressive experts advocate the prohibition of all coal-fired and nuclear power plants, even the use of internal combustion engines in ships, planes, engineering machinery and cars, which is evidently not so realistic. Thus, energy transition and carbon neutrality become a requisite option. This book is exactly about meeting the developing energy need and simultaneously reducing the discharge of

greenhouse gas through energy transition, as well as recycling the existing and prospective carbon dioxide by carbon neutrality.

1.2 Significance

The source text strives to address the energy problems through figuring out the answers to 59 questions, concerning anthropology, sociology, environmental engineering, as well as climatology. By analyzing the advantages and disadvantages of a variety of energy types, the author has redressed a multitude of prevalent misunderstandings, contributing new opinions to energy transition and carbon neutrality. The selected material gives particular solution to that problem——the energetic water cycle, which is to develop the huge potential of hydrogen energy. And the development can diverge into two directions: hydrogen combustion engine and hydrogen fuel cell.

The translation introduces the attitudes and efforts of other nations toward the energy problem, promoting the achievement of the consensus among a myriad of countries. Meanwhile, the translation helps the professionals as well as ordinary people get acquaintance with carbon neutrality and energy transition, thus makes them pay attention to the establishment of environment-friendly society. In this globalized society, the settlement of the energy crisis necessitates common efforts of the whole world. Adding to that, the translation features faithful language style and easy-to-understand professional knowledge in order to cater to the cognitive ability of mundane readers, thus inheriting merits from both technology and popular science articles.

During the translation process, the translator can build experience and gain skills in translating the popular science articles, especially energy-related texts, then deepen the understanding of miscellaneous translation theories, principles and skills. Finally, the translation helps the translator better combine theory with practice.

Chapter 2 Pre-translation Preparations

Sufficient preparation may quicken the speed in doing work. Therefore, the translator scanned the whole passage of the source text and analyzed its writing style and linguistic features prior to translation. After comprehending the gist of the source text, the translator gathered some introductions about the topic and acquired general understanding of the energy field. As far as the choice of assisting tool is concerned, there are mainly corpus analysis tools, computer aided translation software and terminological dictionaries.

2.1 Source Text Features

From the macroscopic aspect, the popular science text translation is the bridge traversing between literary and non-literary translation, featuring characteristics of both sides. The author employs plain expressions to elucidate the professional knowledge. Under the circumstances, the popular science text may have simple structure, but esoteric content, being endowed with expressive function, informative function, vocative function. It is a combination of informative text, expressive text, and vocative text. As an informative text, it conveys objective and serious professional knowledge, putting emphasis on content in comparison to structure. As an expressive text, it also involves subjective opinions and literary expressions of the author. And as a vocative text, it aims to make the ordinary people familiar to some specific knowledge and appeal for acceptance and support.

From the microscopic aspect, the popular science text is one of the constituent parts of the scientific and technological text, featuring objectivity, logicality, normativity, complexity and stylization (王振平,2006:35). At the word level, the source text incorporates a myriad of abstruse specialized vocabulary, including terms, technical and semi-technical words with the characteristics of polysemy in meaning,

intricacy of word-formation and flexibility in collocation. Besides, there are also some culture-loaded words with complicated connotations. And at the sentence level, the author applies assorted long, compound and complex sentences to illustrate subjective standpoints, featuring frequent use of passive voice, non-subject sentences, imperative sentences, subjunctive sentences and nominalized structures. As for the textual level, the article is composed with spiral logics and uses a multitude of conjunctions among different paragraphs. After all, the author adopts a humorous and casual writing style.

2.2 Parallel Text Collection

Parallel texts are those with similar contents to the source material and written by monolingual or bilingual language. It helps in advancing the translation quality by making the writing style of the target texts more faithful and words more authentic and concise. There are mainly three types of parallel texts: source and target texts with same form, source and target texts with equal function, and source and target texts under same circumstance (Hartmann, 1980: 25).

The source material of the paper comes from *Energy versus Carbon Dioxide* by Cornel Stan. So, the translator selected some of the author's other masterpieces as well as articles in the same field, such as *Alternative Propulsion for Automobiles* and *Future Fire Forms* which is quite similar to the selected translation materials, trying to get acquainted with his linguistic habits. Besides, the translator searched substantial numbers of relative texts about energy transition and carbon neutrality by other experts, such as *China's Road to Carbon Peaking and Carbon Neutrality*, which matches the gist of the source text. Furthermore, some speeches and minutes of meetings recorded with bilingual language are also sorted out, such as *Responding to Climate Change: China's Policies and Actions*, which provides relevant standard descriptions. By this way, a large quantity of relative materials is collected, which provides a good reference for translation.

2.3 Glossary Building

The popular science text, as a kind of scientific and technical texts, contains a plenty of terminologies, for this practice, energy-relating terminologies. In order to translate the source text accurately and consistently, the translator gathered those terminologies one by one during the translation process, and the located the precise meanings of them by referring to terminological dictionaries, parallel texts and experts. At last, a glossary was built (see Appendix II).

2.4 Translation Tools

The first step of translation is locating the specific text with no Chinese version. Thus, the translator selected some illustrious foreign experts in the energy and environment field through Microsoft Edge and researched their names in Google after getting the access to the international internet through VPN link. By this way, the translator acquired the names of their latest books to make sure there were no Chinese versions, and then put those names in Z-Library for more details. After deciding the target text, what the translator got was a PDF file, and had to convert it into .docx version through Adobe Acrobat.

As for the computer aided translation software, the translator mainly employed Snowman, a domestic computer aided translation software which is quite easy to use and has concise operating interfaces.

During the translation process, the translator had to turn to many kinds of dictionaries for checking the specific connotations of words, such as the English-Chinese Dictionary by Lu Gusun, Practical illustrated English-Chinese Automobile Dictionary by Zhang Jinzhu, the Chinese-English Dictionary of Science and Technology by Wu Guanghua, and online dictionary Youdao.

Chapter 3 Case Analysis

During the translation process, miscellaneous difficulties came into existence and the translator gathered them together and then divided them into different groups according to their features. Finally, there were four main categories coming out from a variety of levels: connotation determination of semi-technical words, appropriate translation of culture-loaded words, precise translation of complex sentences, and the re-embodiment of cohesion and coherence in E-C translation.

3.1 Connotation Determination of Semi-technical Words

The Sci-tech English special words are divided into two parts: technical words and semi-technical words. Technical words stem from other cultures as well as word-building, featuring unambiguous connotation and single application to some special field. Semi-technical words refer to those originally for common use but possess a variety of miscellaneous meanings while appearing in different fields. (何燕, 梅明玉, 2021: 5) The location of the meanings of the technical words is achieved by referring to the terminological dictionaries, parallel texts or consulting the professionals. For example, the translator searched the chemical terminological dictionary for the word "polybenzimidazole", and finally located the meaning as "聚苯并咪唑." The word "transuranium" means "铀后元素" in the ordinary dictionary, but usually known as "超铀" in the nuclear field by consulting my supervisor who has the background of science and technology, and further being verified with the help of relative parallel texts. In the source text to be translated, there exists much more semi-technical words than technical words. Therefore, my focus is placed on the translation of semi-technical words. Apart from the approach of turning to parallel texts or the professionals, the translator determined the meanings of semi-technical words by adopting the following three methods: judging from the special field, grammatical function, and collocation.

3.1.1 Judging from the Special Field

After the advent of Spinning Jenny by English inventor James Hargreaves in 1764, technologies in nearly all fields experienced huge development, during which many common words together with a few new coinages came onto stage, leading to rich meanings of them and, at the same time, severe difficulties for translators. For example, those common words used in technical fields involve not only the original meaning but also miscellaneous professional explanations in different special fields, even in different occasions. (韦孟芬, 2014: 5) While translating, the translator has to analyze both the precise description and the appropriate field.

Example 1:

ST: Hydrogen flows from a tank through the left **column**, air from the environment, which contains about 21% oxygen, flows through the right **column**.

TT 1: 氢气从储氢罐中流出，经过左边的**圆柱**，含有 21%氧气的环境中的空气则流经右边的**圆柱**。

TT 2: 氢气从储氢罐中流出，经过左边的**柱形槽**，含有 21%氧气的环境中的空气则流经右边的**柱形槽**。

In Collins, “column” mainly refers to something that has a tall and narrow shape, which baffles the translator so much because the internal structure of the hydrogen fuel cell is definitely neither “tall” nor “narrow.” After painstaking analysis towards the original text, content of this paragraph concerned physics, materials science, chemistry and especially the manufacturing of battery. But no matter what field it belonged to, the fuel cell involved no such configuration as “圆柱” at all in TT 1, which often showed itself as a long, round and straight stick in Chinese, even though it appeared in the preceding part of the text “…for example in an automotive body——spars, columns, spaces between exterior and interior cladding…” and did mean “圆柱.” Under the circumstances, the translator observed the configuration picture attached on the article and searches a myriad of professional papers as well as books about this kind of battery, finding that the “column” existed between the membrane and the two lids of the fuel

cell. It was used to take control of the movements of both hydrogen from the tank and oxide from the air, ensuring as large as possible contact surface by devious labyrinth-like paths between hydrogen and the membrane, and between oxide and the membrane. So, the “column” is actually a path. In materials science, this kind of path is usually translated to “沟槽” in Chinese, showing itself as a long narrow cut in the surface of something hard and happening to chime in with the structure of “column.” However, the English counterpart of “沟槽” is “groove”, usually seen as the lines on tires of vehicles. Therefore, the translator had to gather more videos about the cell to get details of the “column” and finally recognized its semicircular shape if witnessing from the cross section. The semicircular shape can help reduce the friction between gases and lids, balance the pressure felt by the cell walls and avoid the turbulence as a result of permanent flow reversals through the labyrinths, which is also why it is called “column.” So, inheriting partial meaning of “圆柱” from “column” and “沟槽” from “groove,” the translator finally decided the explanation as “柱形槽” in accordance with the special field.

Example 2:

ST: The hydrogen was simultaneously injected into the **intake manifold** and into the head of the engine.

TT 1: 氢气被同时注入**各种各样的进口**和发动机头。

TT 2: 氢气被同时注入**进气歧管**和发动机缸盖中。

The word “intake” means a place where liquid, air, etc. enter a machine in Oxford Dictionary, which is just equal to the Chinese explanation “进口.” The word “manifold” is usually used as an adjective to describe a multitude of different types of something, which the translator explained as a postpositive attributive following “intake” and then translates into “各种各样的” in Chinese to modify the word “进口” in TT 1. And the expression “各种各样的进口” actually quite chimes in with the stereotype of the translator about the complicated engine. However, after inputting the above Chinese expression into C-E dictionaries as well as browsers, the results were unexpectedly different from the translator’s anticipation. The expression “各种各样的进口” is more

about “various air inlets,” not “intake manifold,” which is not in line with the criteria of technical translation about monosemy and professionalism. The technical translation requires adequate professional knowledge, in-depth analysis towards the context, sufficient understandings about relevant majors and subjects, for finally averting ambiguity or even fault. (韩琴, 2007: 5) And to be more accurately speaking, the word “intake” is similar to “inlet” once mentioned above and its professional expression should be “进气口”, but not “进口.” As for the word “manifold,” it can be also used as a noun apart from its part of speech as adjective, especially connoting a pipe or chamber with several openings for taking gases in and out of a car engine, and its Chinese professional counterpart is “歧管.” Under the circumstances, the professional expression “进气歧管” finally comes out to be the right answer.

3.1.2 Judging from the Grammatical Function

To all languages, grammar is what the frame to the building. During the process of analysis toward the source text, grammar is a tool dealing with the relationship among the bricks more useful than those words themselves. (胡壮麟, 1996: 1) The connotation of technical and semitechnical words is not only influenced by the special field and collocation, but also by the grammatical function of the words, such as their parts of speech and the whole logics of the sentence. Scientificity and logicality of the final decision can be both achieved, which are also the ultimate pursuit of scientific translation. The grammatical discrepancy between English and Chinese must be marked.

Example 3:

ST: Steam **reforming**, for example, is a method to produce hydrogen from natural gas, which reacts with water, resulting not only in hydrogen but also in carbon dioxide.

TT 1: 以水蒸汽**变化**为例，这是一种利用天然气制取氢气的方法，在与水反应的过程中，不仅会生成氢气，还会生成二氧化碳。

TT 2: 以蒸汽**重整法**为例，这是一种利用天然气制取氢气的方法，在与水反应的过程中，不仅会生成氢气，还会生成二氧化碳。

According to the dictionary, the word “reform” means an instance of a change or improvement as a noun. And steam happens to be able to change into the solid state as ice, and liquid state as water. Each of the process involves the participation of tremendous amounts of energy, which is exactly the main topic of the source text. So, in TT 1, the translator chose the Chinese word “变化” as the target meaning. However, while reviewing the translation, some feeling of strangeness occurred to the translator. The description “水蒸汽变化” isolates itself from not only the preceding part of the text but also the sentence it is in. According to the context, the word “reforming” is actually a demonstrative noun referring to “a method to produce hydrogen from natural gas,” which makes the expression “水蒸汽变化” not so appropriate. “水蒸汽变化” means the state change from steam to ice or water, remaining some kind of physical change in which no new substance comes into existence. It is not in accordance with the requirement of the “method” because “produce hydrogen from natural gas” is definitely some kind of chemical changes. So, the translator chose “重整” as the demonstrative expression to describe the chemical reaction between hydrocarbon and steam to generate hydrogen and another hydrocarbon, which perfectly chimes in with the information in the example. By this way, the whole phrase “steam reforming” is changed into “蒸汽重整法” in TT 2. And after putting this Chinese description into local browsers, all results led to a regular method used in chemical factories to produce hydrogen, which vindicated the translator completely.

3.1.3 Judging from the Collocation

Collocation refers to the relationship among different words which often occur in the sentence at the same time and then possess relatively concrete meanings. Generally speaking, collocation usually shows itself with a manifestation of noun and noun, adjective and noun, verb and noun or verb and adverb, because they are naturally compatible with each other and conducive to the exclusion of word ambiguity. (杨先琇, 1990: 19) Even in the field of scientific translation, polysemy is rather prevalent

and able to endow the same word with various meaning with the help of the collocate. Therefore, the final determination of the word's meaning can be made in accordance with the connotation of its collocate.

Example 4:

ST: The ideal **hydrogen tank** should therefore consist of several solid container walls that float into each other at very short distances – because each solid connecting element would intensify heat conduction.

TT 1: 因此，理想的**氢箱**应该由多个固体容器壁组成，这些容器壁在很短的距离内相互浮动——因为每个固体连接元件都会令热传导效应加剧。

TT 2: 因此，理想的**储氢罐**应该由多个固体容器壁组成，这些容器壁在很短的距离内相互浮动——因为每个固体连接元件都会令热传导效应加剧。

The phrase "fuel tank" came straightaway into the translator's mind when he noticed the word "tank" at the first sight on account of its frequent use in petrol vehicles. With petrol or diesel inside, "tank" is usually translated as "油箱" in Chinese. Spontaneously, the translator hence linked the word "tank" to "箱" for meeting the common translation criterion and subconsciously ignored all other Chinese explanations. And after searching for the phrase "氢箱" through Chinese search engine, what then comes out to be large square metal boxes used in factories and rockets, much differing from the image of a long and round container attached on the source text. So, the translator had to go back to the descriptions of "tank": ①a large container for holding liquid or gas; ②a large military vehicle that moves along on metal tracks; ③ an artificial pool, lake or reservoir. Apparently ① ranks the most appropriate choice and its relevant Chinese explanations incorporate "箱," "槽," "罐," "缸," "桶," etc., from which the inequivalence between English and Chinese tells itself so effectively and clearly. As a conversion process between two languages, translation is supposed to adhere to not only the expression habits of the source text, but also of the target language. In Chinese, "箱" refers to a large box, "槽" a long square container with no lid, "罐" a cylindrical hollow container in which things can be stored, "缸" a very large cylinder without lid, and "桶" usually a basin-shape container with much higher

periphery. As for the specific “hydrogen tank” mentioned in the article, it is a cylindrical sealed hollow container in which the hydrogen can be reserved under high pressure. Also, people in China tend to entitle the container as “罐” once it is used to keep any kind of gas. Thus it can be seen that the phrase “储氢罐” is more suitable than any others considering the function of the tank, and the word meaning is limited by the its collocate “hydrogen,” leaving no other choices than the explanation “罐” in Chinese.

Example 5:

ST: Well, I don't know, with such batteries without a decent **range** and with the electricity from coal? I prefer to wait until the right technology of the future comes, the fuel cell with hydrogen!

TT 1: 呃，我也不知道，用充电电源来自煤电的没有体面**范围**的电池？我还是想等未来好的技术的到来，氢燃料电池！

TT 2: 呃，我也不知道，用充电电源来自煤电的没有良好**续航里程**的电池？我还是想等未来好的技术的到来，氢燃料电池！

Before and after this sentence, the word “range” shows itself many times in the source text and nearly all of them mean the complete group that is included between two points on a scale of measurement or quality, which is also why the translator selected “范围” as the right translation so surely in TT 1. Prior to this sentence, there was discussion about “the X-ray range of the spectrum”, which the translator interpreted into “光谱中 X 射线的范围” in Chinese and gave much confidence to determine “范围” as the final translation. Equally, following this sentence, the topic “a wide range of technical innovations worldwide” comes onto stage and the “range” in it is also explained as “范围,” which seems to add even more rationality to the choice. However, together with the word “battery,” they are pointless and continue to make the whole sentence full of nonsense, because the size or area of battery is not reasonable enough to make stark contrast with “the fuel cell with hydrogen.” Back to the starting point, “range” in Oxford Dictionaries also means the limits between which something varies and the distance over which a gun or other weapon can hit things, which the translator then extended to the longest distance a car can travel with full tank, for battery, fully

charged. In this way, the Chinese meaning of “range” is narrowed by the its collocate word “battery” to “续航里程.” Then, while inputting the phrase “电池续航里程” into the C-E dictionary for double check, the result immediately comes out as “battery range,” which makes the translator finally meet with the right answer. In addition, the meaning of the word “decent” prior to “range” is also changed into “良好的” instead of “体面的,” for corresponding to the language habits of Chinese, making the final translation turn out to be “良好的电池续航里程” in TT 2.

3.2 Appropriate Translation of Culture-loaded Words

No matter what kind of language it is, every word should be of great significance for at least three facets: form, meaning and sound. Correspondingly, there is transliteration for conversion of sound, free translation for meaning, literal translation for both form and meaning.

Words are fundamentally symbols for features of the culture. Accordingly, the cultural situation in both languages must be known in translating, and the words which designate the closest equivalence must be employed. An examination of selected problems in various aspects of culture will make it possible for one to see more clearly the precise relationship of cultural information to the semantic problems encountered in descriptive linguistics. Translation-problems, which are essentially problems of equivalence, may be conveniently treated under (1) ecology, (2) material culture, (3) social culture, (4) religious culture, and (5) linguistic culture. (Nida, 1993: 91)

3.2.1 Transliteration

By overlooking form and meaning of the word, transliteration places much more emphasis on substituting the foreign word by target language with similar features in sound, and pays no attention to its connotation. Based on the classification to the

culture-loaded words, most names of people, location and company belonging to the material culture ought to follow the transliteration rules because their indicating function outweighs any other roles. Besides, different words from the same language family may share same or at least have similar external appearance, and transliteration requires sound conversion from the source language. For example, the very common name “Michael” in English is pronounced like /ˈmaɪkəl /, which is usually used as male name, but in German is pronounced like /ˈmɪʃeˌaɪl/, usually used for female, and their Chinese version are “迈克尔” and “米歇埃尔” respectively. So, given the source text was written by German author and involves many German company names and expressions, the translator dealed with these words through G-C rules while transliterating.

Example 6:

ST: One thinks certainly first to smelly like East-German **Trabant** cars (**Trabbis**).

TT 1: 人们首先一定会想到东德的**特瑞班特**（**特瑞比斯**）之类的臭气熏天的汽车。

TT 2: 人们首先一定会想到东德的**特拉贝特**（**特拉比**）之类的臭气熏天的汽车。

In TT 1, the translator transliterated “Trabant” and “Trabbis” directly into “特瑞班特” and“特瑞比斯” to meet their English pronunciations. However, after searching for these two Chinese phrases, there was merely a few of results on the Internet and most of them had nothing to do with cars or engines. Then, the translator noticed the word “East-German” and soon realized that the above two words “Trabant” and “Trabbis” might be not originally English but German. And in fact they truly were. After typing these two words into G-C dictionaries, there were “特拉贝特” and “特拉比” on the answer list. In 1957, when Trabant car came into existence, Germany was still on separation and the East Germany was under control of the Soviet Union, who just launched the first satellite into space in human history. In German, “Trabant” means faithful servant, personal guard or satellite, which happens to be appropriate for using as the name of the newborn car to celebrate and commemorate that great day. And due to its undeveloped technology, the Trabant engine always emitted so ghastly and smelly dark smoke while operating that even after so many years the German people can still

recall the trying experiences and repelling flavor while seeing or hearing the word "Trabant" or "Trabbis." Thereupon, the translator searched for them through Chinese search engines and gets a multitude of information about cars and engines, which further corroborated the translation of "特拉贝特" and "特拉比."

Example 7:

ST: A very compact radial gas turbine, developed by **Capstone** for the generation of electricity and heat when operating with biogas or natural gas, delivers no less than 61 kW of power with incredible small dimensions of 77x196x280 centimeters!

TT 1: 顶石曾开发了一款十分紧凑型的径流式气轮机，用于通过生物气或天然气发电和热，机身尺寸十分小，为 77×196×280 公分，但输出功率却不低于 61kW。

TT 2: 卡博斯通曾开发了一款十分紧凑型的径流式气轮机，用于通过生物气或天然气生成电能和热能，机身尺寸十分小，为 77×196×280 公分，但输出功率却不低于 61kW。

In the very beginning, the translator looked up the word "Capstone" through the E-C dictionaries and acquire "顶石" and "顶点" as the result, which respectively meant one of a set of slabs on the top of a wall or building and the best and final thing that somebody achieved. So, "顶石" was selected as the translation in TT 1, for meeting the component "stone" in the word "Capstone." And after that, the translator imported the translation into the Chinese search engine for more information and double checking, but unexpectedly found that nearly all results pertained to game company or courses in university and nothing about engine or machine company. Apparently, literal translation method did not work. Then, the translator tried to keep the whole form of "Capstone" and discard its connotation. However, unlike "BMW" or "KW," which is usually used and accepted by Chinese people in their daily life, "Capstone" can just remind people of nothing in default of acquaintance. And the translation of popular science articles attaches much importance to brevity and easiness of language, which makes the omission method not so suitable. Again, the translator turned to Nida who once classified the company names as material culture-loaded words and recommended transliteration as the relevant solution. So, the translator then put his eyes on the

transliteration method. And according to different E-C sound conversion rules, there were mainly “卡普斯通” and “卡博斯通” on the list. After typing the first one into the Chinese search engine, the results were mostly relevant to commercial and trading company or biotechnology, which was evidently not the right answer. By contrast, the second one led the translator to a company which was committed to environmental protection material and new energy. Under this circumstance, the expression “卡博斯通” was chosen as the final translation.

3.2.2 Literal Translation

Nida claims that literal translation method is of great use in the translation of some material culture-loaded words. (Nida, 1993: 91) It is committed to reaching the equivalence of both form and meaning and finally achieving perfect translation, during which the interpreters can cope with the culture-loaded words appropriately. Thus, the translator applied literal translation method to the words directly conveying equivalent or similar imagery between Chinese and English.

Example 8:

ST: The only question is how to heat the water in the boiler. With wood, with coal, with heavy fuel oil, with gasoline, with gas, with **schnapps**, with an electric heated spiral?

TT 1: 唯一的问题在于，该如何加热锅炉中的水。用木头、煤、重油、汽油、煤气、杜松子酒抑或是电螺旋加热棒？

TT 2: 唯一的问题在于，该如何加热锅炉中的水。用木头、煤、重油、汽油、煤气、德国水果烈酒或螺旋式电加热棒？

On the E-C dictionary, there are mainly two kinds of Chinese descriptions for “schnapps”: “杜松子酒” and “烈酒.” The former is a strong alcoholic drink made from potatoes and the latter refers to any kind of liquor with particularly high alcohol content. In the beginning, the translator thought that “杜松子酒” was proper and chose it in TT 1. Unfortunately, after putting the Chinese descriptions into the C-E dictionaries for checking, the answers showed themselves as “gin” and “spirits,” connoting a huge

misunderstanding in the above process. The true “gin” is made from juniper berries and the so-called schnapps “杜松子酒” is actually from potatoes. “烈酒” in China usually refers to liquor with an alcoholic strength of more than 50% vol, such as Red Star Erguotou, Luzhou Lao Jiao, Wuliangye and so on, but only 30%-40% vol in Europe, implying a huge cognitive discrepancy. So the translation process reached a terrible predicament: no proper description is available. Under the circumstances, the translator had to seek help from the professional and friends living in Germany. As a result, “schnapps” turned out to be some liquor made from assorted fruits and peculiar to German. So, the translator finally decided “德国水果烈酒” to be the final translation, conveying its flavor and raw material by “水果. ”

Example 9:

ST: Whole atoms, protons, neutrons, electrons rattle like little devils at **the stake**.

TT 1: 所有的原子、质子、中子和电子就像**木桩**上的小恶魔一样吱吱作响。

TT 2: 所有的原子、质子、中子和电子就像**火刑架**上的小恶魔一样吱吱作响。

The Collins English Dictionary explains the word “stake” as “a pointed wooden post which is pushed into the ground, for example in order to support a young tree,” so the translator first converted it into “木桩” in TT 1. The whole sentence, however, did not make any sense then. Even if the author had omitted the word “stake,” the phrase “little devils” would have been enough to delineate the scene that all atoms, protons, neutrons and electrons are rampaging and screaming due to the high temperature and pressure. There is no need for little devils standing on stake, whereupon the translator tried to expand the searching range and involved the definite article “the” prior to “stake” in the target phrase. Immediately, the Chinese explanation “火刑架” leapt to my eyes. From 1480 to 1780, the whole Europe witnessed huge social and religious turbulence under the influence of the industrial revolution and the Protestant Reformation, making the medieval Europeans believe that the world was suffering from curses and ascribe all this to wizards who were apparently unreal. Then the medieval Europeans, out of fear, impaled or bound more than 10 thousand innocent “witches” and “wizards” to stakes and burned them into death. And this period was called “the Witch-hunt,” which

lasted at least 300 years. The word “stake” began to remind the Europeans of sin, blood, fire and devil and people started to use the phrase “the stake” to refer to the special stakes for burning the innocent to death as a punishment. In ancient China, there was also similar punishment tool “火刑架” binding the criminal to the wooden or copper posts and then burning them to death, which is capable of generating similar feelings and memories. So, it soon occurred to the translator that the popular science article, as a kind of technical texts, featured literariness and scientificity to a large extent too, (郭建中, 2007: 85) which strongly corroborates the translation of “火刑架” in TT 2.

3.2.3 Free Translation

The paramount target of translation is to convey both form and meaning of text in one language to another. (王克非, 1997: 45) However, in many cases it is not so realistic to deliver the external form because of the discrepancy of history and culture among various countries, which then contributes to the advent of free translation method. Though this method focuses only on the precise communication of text meaning, it happens to meet the translation requirement of most culture-loaded words according to Eugene A. Nida. Free translation method befits most of social, linguistic and religious culture-loaded words.

Example 10:

ST: The fuel cell developers can **dress warmly**!

TT 1: 燃料电池开发人员可以**穿得暖暖和和的**！

TT 2: 燃料电池开发人员仅凭这些技术就能**衣食无忧了**！

Literally speaking, “dress warmly” means putting on more thick clothes to resist the cold wind and low temperature, which makes the Chinese expression “穿得暖暖和和” appear to be much proper. Typically, that dressing warmly is a fundamental desire of all mankind leads to no other equivocal meanings, even for different countries and culture. However, apart from the sentence itself, no other relative expressions about

coldness, clothes or temperature have been mentioned ever before as well as after in the context. As the last sentence of the paragraph, its previous sentence, “Switching from one gas to another as fuel, hydrogen instead of biogas or natural gas, poses absolutely no problems,” is about changing the traditional fuel into hydrogen and has nothing to do with “dress warmly.” Yes, it is like a wild goose who strays into the chicken flock, conspicuous and suspicious. There must be something wrong. Then, the translator googled online and put the phrase “dress warmly” into the AntConc based on the Brown corpus, but unfortunately failed to find anything new. Suddenly, it occured to the translator that maybe a slang dictionary would be helpful, given all the attempts to figure the riddle out through regular dictionaries and databases were of no avail. Immediately, the slang “dress warmly and eat one’s fill” came into sight. It means putting on warm clothes and getting enough to eat in chill, connoting a satisfying living standard in virtue of a proper job and salary. In accordance with Nida’s theory, this slang belongs to the linguistic culture-loaded words and chimes in with the free translation method. Coincidently, there is a similar Chinese expression “衣食无忧” that indicates a proper living quality as a result of considerable incomes. In the circumstances, the translator at last chose “衣食无忧” as the final translation in TT 2, for meeting the equivalence of connotations among different languages.

3.3 Precise Translation of Complex Sentences

Different culture and history result in various logics and language habits. While translating English into Chinese, translators must place much emphasis on the precise conversion of connotations hidden behind the words. (王东风, 1998: 7) In the source text, there are lots of long and difficult sentences, especially compound and complicated sentences, which require different translating methods such as reverse, division and comprehensive methods etc.

3.3.1 Reverse Method

Due to the large discrepancy of historic backgrounds, the Chinese culture is always impregnated with idealist views which pay much more attention to the feeling of people, while the English tends to be imbued with materialistic thoughts which focus more on the objective facts. As a result, the Chinese language usually takes animate thing, especially people, as the subject of the sentence, and the positive voice is frequently used. (胡菊兰, 2004: 73) By contrast, the English language abounds in passive voices in the expression and inanimate subjects are quite common. So, the reverse translation method must be very helpful while translating the original popular science text into Chinese.

Example 11:

ST: The breakthrough of the fuel cells based on pure hydrogen and oxygen flows via light catalyst electrodes in alkaline-aqueous electrolytes succeeded in the fifties, driven by special requirements in power generation for aerospace applications.

TT 1: 燃料电池的突破是基于纯氢和纯氧通过碱性水电解液中的光催化电极流动的结果，50 年代时，特别需要发电以供应航空航天研究。

TT 2: 为满足航空航天应用的电力需求，50 年代，科学家通过对碱性水电解液的光催化电极的研究，最终利用纯氢和纯氧的离子运动生成了电流，燃料电池技术成功获得突破。

The popular science text popularizes itself among an astonishing number of people in different countries by virtue of brevity, novelty and easiness. (雷璇, 2020: 54) So, the difference between the two translation versions may seem to support the choice of TT 1, which comes into existence as the result of sequential translation method. However, the brevity necessitates precision and easiness as prerequisites and are not supposed to work as a barrier impeding translators to reach faithfulness and smoothness. The first clause in TT 1 consists of thirty-five Chinese characters and most of them are esoteric technical words, which contribute much to the equivocal meanings and obscurity for the target reader. And the words amount of TT 2, though, may appears to be much more in quantity, the reader can easily catch the gist without any

misunderstanding. Moreover, the original expression is full of passive voices and logics, which is quite common in English but definitely not in Chinese. So, when the translator tried to convert the above example directly into Chinese by sequential method, he had to remember the last information unit while analyzing the new one, making the whole translation process torturous, intermittent and endless. Also, the result is just of no avail. Under the circumstances, the translator turned back to the source text itself and attempted to clarify the logics and relations among different components. The "breakthrough" is actually the target or the final result of the sentence, which is usually put in the end in Chinese expression. And for the phase "pure hydrogen and oxygen flow," the word "based" declares that it is an approach to achieve the "breakthrough." As for the "special requirements," it is the fundamental driving motive, the reason to be exactly speaking, and always show itself at the beginning of the sentence. By that, the translator chose to add a category word "科学家," which does not exist in the original English example, to be the subject of the whole translation because the Chinese usually uses animate expressions. By employing the reverse method, the whole sentence is reorganized in accordance with the language habits of Chinese.

3.3.2 Division Method

As a kind of hypotactic language, there are many conjunctions, prepositions and pronouns in English, together ensuring a continuous internal logic of different components within one sentence. Therefore, the English expression can be as long as the author wishes it to be, even have no punctuation at all apart from the full stop in the end of the sentence. In contrast, Chinese, as a kind of paratactic language, features a large number of short clauses and commas, which incorporate a multitude of sense groups. (任晓霏, 2002: 33) So, the division translation method must be put into use while translating the English into Chinese if the original sentence consists of too many words without the help of punctuations.

Example 12:

ST: The combustion of hydrogen with the oxygen from the air in the combustion chamber of an engine proceeds very differently from the proton exchange of hydrogen and atmospheric oxygen along a membrane in the fuel cell – but the product is the same: water, without carbon dioxide.

TT 1: 氢气可以和空气中的氧气在发动机的燃烧室中以一种不同于膜燃料电池中氢气的质子通过交换膜后与来自空气中的氧气进行反应的方式进行燃烧——不过产物相同：水，没有二氧化碳。

TT 2: 氢气可以和空气中的氧气在发动机的燃烧室中进行燃烧。这个过程与燃料电池大不相同，膜燃料电池的原理是氢气的质子通过交换膜后与来自空气中的氧气进行反应。不过二者的产物相同：都是水，并没有二氧化碳产生。

The above English example involves totally forty-six words in which the part before the dash accounts for up to thirty-six words. With the help of the underlined prepositions and conjunctions, the native speaker can easily apprehend what the author is talking about because they get so used to this kind of expression and the length in their daily reading and writing. So, if the translator attempted to convert the source sentence directly into its Chinese counterpart (see TT 1), the result turned out to be long and full of equivocal meanings for the target reader. In fact, the whole English sentence can be divided into three parts: i. “The combustion of hydrogen with the oxygen…”; ii. “…proceeds very differently from…”; iii. “—but the product is the same…”. Each part can be translated into a simple Chinese sentence (see TT 2). In this way, the Chinese readers may comprehend it naturally.

3.3.3 Comprehensive Method

Translation is a long and complex process necessitating various methods to deal with a variety of problems, requesting translators not to be obsessive with some particular approach or theory of authoritative specialists because the translation quality is always the primary pursuit. (Lefevere, 1992: 21) Sometimes, even in the same one sentence there can be different kinds of barricades leading to disturbance of

comprehension for the target readers, which requires corresponding translation methods. In this circumstance, the comprehensive method happens to be capable of addressing such questions by suiting the remedy to the case, trying the best to efface the influence of translators' subjective intentions.

Example 13:

ST: The main disadvantage of a Wankel engine for direct drive in automobiles is the formation of a very unfavorable, gap-shaped and jagged combustion chamber, which is due to the shape of the rotary piston and chamber: without this Wankel geometry, however, compression, combustion and expansion during a rotary movement would hardly be possible.

TT 1: 直驱式汽车转子发动机的主要缺点是看起来不太顺眼的似乎缺了一块的燃烧室，其原因是旋转式活塞和腔室：不过若转子发动机不是这样的几何形态，压缩、燃烧和膨胀就不可能在旋转过程中同时发生。

TT 2: 由于转子发动机使用的是旋转式活塞和腔室，导致燃烧室中形成了不规则的空腔，看起来不太顺眼，这是直驱式汽车转子发动机的主要缺点。然而，也正是得益于特殊的几何形态，转子发动机才可以在旋转过程中同时进行压缩、燃烧和膨胀。

Logically speaking, the original English is mainly divided into two sense groups by the punctuation colon. The former part firstly elucidates the failings of Wankel engine and then provides the reason by the use of a non-restrictive attribute clause. And the latter part digresses from the previous logics to throw light on the merits of the peculiar geometry. So, the translator first applied sequential method to the conversion of the former part but unfortunately fails to make the translation smooth in Chinese expression, which features the frequent use of short clauses instead of a long sentence full of new information. As for the latter part after the colon, the translator just directly converted it into a conditional sentence in TT 1 as a comparison to the demerits. However, different from English which uses colon to be the adversative, Chinese tends to go into details after colon, similar to the usage of dash in English. Under the circumstances, the translator decided to separate the example into two sentences by

division method and made the adversative relation clearer to understand for Chinese readers. Continuously, the former part which consists of only one single clause with the help of seven prepositions and conjunctions splits into five clauses for chiming in with the language habits of Chinese. The phrase “due to” apparently makes the attribute clause in the original English example the reason, which is usually put at the beginning in the Chinese expression. And the “formation” is actually the “disadvantage” resulting from the special geometry, which often appears in the end of the Chinese sentence. So, the former part is finally translated by reverse method. As for the latter part, the translator used the Chinese phrase “然而” as the adversative word to usher the benefit of the Wankel engine as the contrast. It is clearly seen that the comprehensive method, combining division and reverse methods here, is employed in TT 2.

3.4 Re-embodiment of Cohesion and Coherence in TL

According to Halliday and Hasan, cohesion refers to smooth logics within text by virtue of lexical cohesion, conjunction, reference, or substitution, which is quite objective. By contrast, coherence refers to barrier-free comprehension of the language, which is quite subjective. Due to different history and culture, the organizations of Chinese and English differ in many aspects. The Chinese people tend to expound the background of something first and then concentrate on the gist of the text on account of their spiral thinking mode. In contrast, the English people like to put the most important thing in the beginning and then illustrate the reason and evidence because of their linear thinking mode. As a result, Chinese, as a paratactic language, lays much more emphasis on recessive relationship among various components of the text instead of having recourse to formal connection to show the connotation and logic, featuring inattentive sentence structure and flexible sequence arrangement. By contrast, English, as a hypotactic language, attaches more importance to dominant connection by virtue of conjunctions between sentences, featuring strict structure and inflexible arrangement. The internal coherence is the target of external cohesion (Kaplan, 1996: 1).

3.4.1 Conversion of Logic Relationship

Logical structures in technical texts involve coordinative, adversative, comparative, progressive, concessive, conditional and causal relations, etc. While translating, it is vital to convert the logics properly for meeting the language habits of target readers as well as avoiding translationese in the target texts. (Sommers F., 1982: 13) Under the circumstances, a raft of translation methods is supposed to apply to the conversion process between Chinese and English, such as amplification, omission, imitation and adaptation.

Example 14:

ST: The alternative option — high pressure instead of low temperature — is also used, at pressure values between 350 and 900 bar, whereby the hydrogen remains in the gaseous phase. **However**, it should be noted that the difference to the ambient pressure creates an outflow potential: The hydrogen molecule is, as mentioned before, the smallest of all elements and can therefore easily penetrate most material structures.

TT 1: 后备选项——用高压而不是低温——也被使用过，在 350—900 巴压力下，氢气仍是气态。**然而**，需要注意的是，与环境气压之间的压差会造成外泄风险：氢分子，就像之前提到的那样，是所有元素中最小的，因此可以轻易穿透大多数物质结构。

TT 2: 备选方案——用高压代替低温——也尝试过，但在 350—900 巴压力下，氢气却仍是气态。**而且**需要注意的是，与环境气压之间的压差会引起氢气外泄的潜在风险：如上文所说，氢分子是所有元素中最小的，可以轻而易举穿过大多数物质结构。

For the first sentence, TT 1 may seem to be not bad by inheriting the original logics of English expression. At first sight, it contains two constitute parts with casual relation: the use of “high pressure” leads to the unaltered “gaseous phase” of hydrogen. However, by this way, the first sentence is actually isolated from the context. Prior to the sentence, the gist of the whole paragraph is mentioned in the beginning with a question “how do you get a lot of mass into a limited volume, like in the tank of a car?” which then introduces two answers: temperature down or pressure up. So, these two solutions come

into comparison with each other and the method “temperature down” actually proves to be viable to liquidize the hydrogen even if the density is only one tenth of the gasoline. But in contrast the method “pressure up” leaves the hydrogen still in the gaseous phase and in Chinese the word “但” is usually used to usher in the relatively bad result, just like in TT 2. As for the second sentence in the example, “the smallest of all elements” and “penetrate most material structures” apparently form causal relation, which is also evident from the word “therefore.” Chinese language is rather more implicit in logics and tends to omit the unnecessary conjunction, (王佳敏, 王文斌, 2022: 36) therefore the Chinese words “因此” are deleted in TT 2. From a more macroscopic aspect, the first sentence and the second together constitute adversative relation, also obvious from the word “However” in the original English text. But the second sentence is actually a continuous explanation to the first, recounting the other negative consequence apart from “gaseous phase.” The translator then converted the logics of English to that of Chinese for making the two sentences easier to understand for the target readers.

Example 15:

ST: This looks like a sandwich: the outer halves form the walls of the cell, in the middle there is a polymer membrane instead of a sausage slice. **Another** difference to the sandwich is that there is a gap between the membrane and the two lids, which is neither filled with mayonnaise nor with mustard: hydrogen flows from a tank through the left column, air from the environment, which contains about 21% oxygen, flows through the right column.

TT 1: 这看起来就像一个三明治：外半部分是电池壁，中间是一层聚合膜而不是香肠片。另一个与三明治的差别是，聚合膜和两个盖子之间有缺口，被填充的物质既不是蛋黄酱也不是芥末酱：氢气从储氢罐中流经左边的柱形槽，环境中的空气含有 21%的氧气，流经右边的柱形槽。

TT 2: 它看起来就像三明治：外面是电池壁，中间是一层类似香肠片的聚合膜。而与三明治的差别在于，聚合膜和两个盖子之间存在空隙，里面填充的既不是蛋黄酱也不是芥末酱：氢气从储氢罐中流出，经过左边的柱形槽，含有 21%氧气的环境中的空气则流经右边的柱形槽。

The former English sentence follows a typical summary and deduction structure, firstly concluding the metaphorical object of the modern fuel cell for automobiles and then rationalizing the argument by comparing the structure of cell with a sandwich. And in Chinese there is similar logic which then is able to inherit the original structure without conversion. And in the clause "in the middle there is a polymer membrane instead of a sausage slice," the "polymer membrane" and "a sausage slice" practically go with coordinative relation from the phrase "instead of." But it cannot be translated literally as the same structure in TT 1 due to different language habits. For a more fluent expression, the translator converts the "sausage slice" in the coordinative relation into a prepositive attribute in TT 2. And according the English logics, the word "Another" actually appears on the condition of the existence of the coordinative relation in the clause one mentioned, which has vanished into the thin air as a result of conversion. So, the sequential change must ensue. After removing the negative implication in the former sentence, the latter works as a comparison by elaborating the difference between the polymer membrane and a sandwich. And the translator soon converted the progressive relation between the above two sentences into adversative. As for the latter sentence itself, the clause "which is neither filled with mayonnaise nor with mustard" in it is originally formed by passive voice. However, differing from English putting the subject at the beginning of the sentence and then leading to frequent use of passive voice, Chinese is inclined to clarify the subject in the end or even hide it the whole time, leading to a myriad of positive voice in the sentences and in many cases the subjects of them are animate or just omitted. (William, 2002: 33) Under the circumstances, the translator converts the original passive voice in English into sentence with no subject in Chinese as "里面填充的." Moreover, the last clause in the latter sentence involves two subjects: "hydrogen" and "air," which is quite unusual in English, especially in technical articles. And the word "air" is followed by two verbs, which may confuse the reader. So, the translator converts the first verb accordingly into a prepositive attribute as "含有 21%氧气的" in Chinese.

3.4.2 Rearrangement of Sentence Order

Different from the conversion method which is actually used to passively amend the inappropriate logics and structures of the original sentence and then largely retain the rest, the rearrangement method chooses to abandon all of the primary language habits in the source text and then employs more authentic expressions of the target language for catering to the local readers. By contrast, the rearrangement method finally discards all the heterogeneous factors and cultural backgrounds, ranking itself as the most domesticating translation method and making the target readers unaware of the existence of the source text and author.

Example 16:

ST: Methanol can be stored in liquid form at ambient temperature and pressure, making the tank similar to a conventional tank for liquid fuels. The working temperature range of the DMFC is 50°C to 120 °C. The problem is that as a result of the reactions in a DMFC, carbon dioxide is emitted. However, methanol from plants is recyclable.

TT 1: 在环境温度和大气压下，甲醇可以液态储存，其储存罐和常规的液体燃料储存罐很相似。DMFC 的工作温度范围在 50°C 和 120°C 之间。问题是，DMFC 中的发生的反应会释放出二氧化碳。但来自于植物的甲醇是可再生的。

TT 2: DMFC 的优点在于，原料甲醇可以从植物中获取，属于可再生资源，且在环境温度和气压下可以液态储存，因此甲醇罐与常规的液体燃料罐大同小异，而它的工作温度范围则在 50°C 和 120°C 之间。但缺点在于，其反应产物中有二氧化碳。

In TT 1, the translator applied literal translation method, making the translation weird and the target reader confused. The original English paragraph consists of fifty-eight words in total and four separate sentences, among which the longest sentence has twenty-three words. Within fifty-eight English words, the author offers with at least five topics: “liquid,” “tank,” “temperature,” “carbon dioxide” and “methanol,” baffling the readers with a multitude of information about different things. In Chinese, short sentences exist in a large quantity, but most of them are inanimate and serve the same topic, which comes into stark contrast with the above example. So, the translation of

these four sentences is much beyond the ability of literal translation as well as logical conversion, requiring the approach in a higher-level rearrangement. By overlooking all the original structures as well as qualifiers of the example and extracting the fundamental information from the sentences, nearly all elements in ST 18 come out to be advantages of DMFC, except only one thing: “carbon dioxide is emitted.” Under the circumstances, in TT 2, the translator mainly divided these elements into two parts: the merits and the demerits. After in-depth analysis, the elements in merits part can be rearranged in accordance with the sequence of obtainment, reservation, and application of methanol. So, by rearrangement, the two parts are endowed with adversative logics for applying to the Chinese expression habits and making themselves much easier to apprehend.

Chapter 4 Reflection

During the translation process, the translator encountered a substantial number of unexpected difficulties and had to put much effort into resorting to a myriad of theories, methods, and professionals. Fortunately, the translator had also benefited a lot in the process and was aware of his own limitations on translation as well as where to go in the future.

4.1 Proofreading

Once the original translation was done, the translator firstly took the initiative in reviewing both the source and target texts, ensuring no visible mistakes were made and the writing style remained invariable within the selected parts. Then, the translator input the source and target texts into Snowman, whose translation memory was established according to various bilingual parallel texts, and found no evident flaws. So the translation result was passed to the teammates for double checking the constancy of professional terms as well as writing style, during which some discrepancies showed themselves clearly. For eradicating the differences among the three translation versions of some terms, the translator worked together with his two teammates by referring to the same authoritative terms book and reached agreement upon the translation. Afterwards, the translation was submitted to the supervisor for ultimate check. Subsequently, after enlisting enormous professional supervision, the translator corrected the insidious mistakes one by one and polished the target text in accordance with his advice. Finally, along with the submission of the report to the experts, the target text underwent another inspection and acquired a number of suggestions on revision. By this way, the target text was revised once again in line with the expertise.

4.2 Gains

Prior to this translation practice, the translator has learnt a raft of relevant theories but seldom has the chance to apply them to such long and complicated texts. So, thanks to the practice, the translator comprehends better about different translation theories, the guiding translating principles / methods, through painstakingly converting the foreign language into Chinese. Those theories are like warehouses that store different series of accessories for constituting various equipment—the target texts. Under the circumstances, the translator decides to prescribe "the proper drugs to the disease," transcending the narrow perspective of employing only one specific theory for some genre and applying appropriate methods to the target translation problems, leading to fruitful results. By this way, a multitude of translation skills turn into subconscious behaviors on account of frequent uses, making the translator much more confident and thoughtful in the face of unknown materials.

As for the text itself, it gives much information about building nuclear power plants and the difference among a variety of fuel cells, so that the translator becomes more informed of the carbon neutrality and energy transition. Rome was not built in a day, and protecting the environment necessitates joint efforts of generations by all countries around the world.

4.3 Limitations

Prior to the translation of the popular science works, the translator has never learned about any specialized knowledge of the construction of power plants or structure of fuel cells and engines, which brings about many barriers to the translation process. Much effort is put on the determination of the meanings of professional words, especially on the semi-technical words and expressions for ensuring the specialty of the target text, making the whole translation tortuous for the translator. In addition to that, the lack of thorough understanding of translation theories and methods also renders the

translator all at a loss, not knowing what to do in the beginning. As for the culture-loaded words, the translator must familiarize himself with the cultural background of the source text and search for its counterpart in target language. Even though the translator succeeded in translating some culture-loaded words in the translation process, he still lacks in confidence in doing a good translation job.

4.4 Future Efforts

For a better translation, a wide range of knowledge of nearly all fields is needed, because a translator will never know what the next translation material is about. Therefore, firstly, the translator has to raise his level of understanding towards a multitude of majors, maybe not so deeply, but roughly at least, so as to enhance the comprehension and avoid mistranslation. Secondly, the translator should not only focus on the contents of those translation theories but also their proper applications, which requires a thorough comprehension and a lot of practice, for better applying theories into practice. Thirdly, with the rapid technical development of translation tools, the translator is supposed to be familiarized with the cutting-edge technology, which will certainly help improve the translation quality and accelerate the translating process.

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Appendixes

Appendix 1: Glossary

序号	英文	中文
1	acidified water	酸化水
2	AFC (Alkaline Fuel Cell)	碱性燃料电池
3	air-zinc battery	锌空气电池
4	alkaline-aqueous electrolyte	碱性水电解质
5	axial turbomachinery	轴流式涡轮机械
6	bar	巴
7	biogas	沼气
8	biosphere	生物圈
9	boiler	锅炉
10	calorific value	热值
11	catalytic converter	催化转化器
12	chlor-alkali electrolysis	氯碱电解
13	clay rock	粘土岩
14	coke gas	焦炉煤气
15	combustion chamber	燃烧室
16	combustion engine	内燃机
17	compressor	压缩机
18	cooling circuit	冷却回路
19	crankcase	曲轴箱
20	cylinder	汽缸
21	DMFC (Direct Methanol Fuel Cell)	直接甲醇燃料电池
22	electrolyte	电解质
23	electron	电子

24	energy carrier	能量载体
25	ethylene	乙烯
26	four-stroke	四冲程
27	fuel rod	燃料棒
28	fuel cell with hydrogen	氢燃料电池
29	gaseous hydrogen	气态氢
30	gas turbine	气轮机
31	granite	花岗岩
32	hard coal	硬煤
33	heat exchanger	热交换器
34	heavy fuel oil	重油
35	high-tech	高新技术
36	HT-PEMFC (High-Temperature Proton-Conducting Polymembrane Fuel Cell)	高温质子传导聚合膜燃料电池
37	injection nozzle	注射喷嘴
38	intake manifold	进气歧管
39	iodine isotopes	碘同位素
40	jet engine	喷气式引擎
41	light catalyst electrode	光催化电极
42	lithium-ion	锂离子
43	magnetic force	磁力
44	mass pairing	质量对
45	MCFC (Fuel Cells with Molten Carbonates)	熔融碳酸盐燃料电池
46	methanol	甲醇
47	mineral oil	矿物油
48	molecular mass	分子质量
49	neutron	中子
50	nuclear energy	核能
51	nuclear fission	核裂变

52	orders of magnitude	数量级
53	PEM (Proton Exchange Membrane Fuel Cell)	质子交换膜燃料电池
54	PAF (Phosphoric Acid Fuel Cell)	磷酸燃料电池
55	per unit of power	单位能量
56	phosphoric acid	磷酸
57	piston	活塞
58	platinum	铂
59	plutonium	钚
60	polybenzimidazole	聚苯并咪唑
61	polymer membrane	聚合膜
62	potassium hydroxide	氢氧化钾
63	propeller	螺旋桨
64	proton	质子
65	pulsation	脉冲
66	radial turbomachinery	径流式涡轮机械
67	radioactive radiation	放射性辐射
68	radioactive waste	放射性废料
69	range	续航里程
70	reverse electrolysis	反向电解
71	rotating piston	旋转式活塞
72	salt dome	盐丘
73	shaft	连轴
74	SOFC (Solid Oxide Fuel Cell)	固体氧化物燃料电池
75	solar energy	太阳能
76	steam reforming	蒸汽重整
77	sulfuric acid	硫酸
78	the power plant with pressurized water reactor	压水堆核电站
79	thermal conductivity	热传导性
80	torque	扭矩

81	transuranium	超铀
82	turbine	涡轮机
83	turbocharging	涡轮增压
84	uranium	铀
85	uranium oxide	氧化铀
86	water cooler	水冷器
87	wind energy	风能
88	working fluid	工作流体
89	zinc	锌
90	zirconium oxide	氧化锆

Appendix 2: Source Text and Target Text

Source Text	Target Text
12	12
The last weapon: nuclear power	最终手段：核能
Should nuclear power still be mentioned in relationship with energy for the world? Closing the eyes and turning off the mind by repudiating nuclear power as a matter of principle will not solve the problem. The so-called "nuclear power" (correct would be nuclear energy, as for photovoltaics, wind and water) brings in comparison with all other sources the incomparably largest energy amount with the lowest mass in use. Neither carbon dioxide nor other substances are emitted, you do not need much space, the costs per unit of power are more manageable than those of gigantic dams and endless basins. Admittedly, after the terrible disasters of Chernobyl and Fukushima, nuclear energy appears to be the very last weapon for securing the energy for the world.	现今，在谈到世界能源问题时，还会有人提起核能吗？但就算不看不想，遇到核能二字就本能回避，问题也不会得以解决。所谓的“核电”，其正确说法应该是“核能”，如光能、风能和水能。不同的是，核能可以用最少的质量产生最多的能量，在这一点上，其他所有方式都无法与之相比。核能不会产生二氧化碳之类的物质，也不需要太大空间，单位能量的成本更低，毕竟并不需要巨大的水坝和广阔的盆地。但必须承认的是，在经过切尔诺贝利和福岛核电站的恐怖灾难后，除非到了万不得已的地步，一般不会利用核能来确保世界能源安全。
The nuclear energy could ensure single-handedly all the world energy!	核能可凭一己之力满足全世界的能源需求！
Thesis 35: If the high-tech nations of the world no longer want to build nuclear	论点 35：即便拥有高新技术的国家不再继续建造核电厂，能源极度短缺的

power plants, this type of precision weapon would be given in the hands of desperate energy-hungry people who have only rudimentary manufacturing technologies.	国家也不会放弃，届时接手这项精密工程的将会是一群只懂原始制造技术的人。
Won't they build nuclear power plants just because we don't build them anymore?	难道我们不再建造核电厂，他们就会也跟着停止吗？
They will build them, but rickety, unsafe, dangerous. And if radioactive radiation is produced at the place of production or use?	当然不是。他们还会继续，但是会建得东倒西歪，如风中烛火，摇摇欲坠。甚至可能会在建造和使用过程中产生放射性辐射。
Is it possible to stop radiation from other countries on the border of Germany or Italy, such as people infected with the coronavirus?	就像无法阻止新冠患者的流动一样，阻止他国辐射进入德国或意大利境内的想法现实吗？
The benefits of nuclear power plants are clear. On the other hand, the hazards must be precisely measured and evaluated, and their avoidance or circumvention measures should be precisely formulated, implemented or prepared.	核电厂的好处确实显而易见。一方面，必须对风险进行精确判定和评估，制定、实行或准备详细的预防规避措施。
Tsunamis, floods, earthquakes, terrorist attacks, cyberattacks and plane crashes can also hit large dams, chemical plants, battery plants and hydrogen production plants, also with catastrophic consequences.	此外，海啸、洪水、地震、恐怖袭击、网络攻击以及飞机失事还会影响大坝、化工厂、电池厂和制氢厂，同样会造成灾难性的后果。
In 2020, 442 nuclear power plants with a total capacity of almost 400,000	2020 年，全世界核电厂的总发电量接近 40 万兆瓦，核电厂数量共 442 座，

megawatts will be in operation all over the world, 95 of them in the USA, 56 in France, 48 in China, 38 in Russia, 22 in India, 5 in Pakistan [8].	其中美国 95 座、法国 56 座、中国 48 座、俄罗斯 38 座、印度 22 座、巴基斯坦 5 座。
Thesis 36: In principle, there is no difference between a nuclear power plant and a coal-fired power plant in terms of the course of the cyclic process and of the machine modules. The only difference is the way to heat the water, as the working fluid in the system.	论点 36：从原理上讲，核电厂和火电厂在循环过程和机器模块方面并无区别。唯一不同之处在于对工作流体（此处指水）的加热方式。
The water is heated in the nuclear power plant similarly as in the coal-fired power plant, as the working fluid, in a boiler until evaporation, the steam is then relieved in a turbine that is mechanically connected to the current generator, which produces in base on the incoming mechanical work electric energy. The steam after the turbine is cooled in a heat exchanger until it becomes liquid water again; the water is brought back to the boiler with a pump and the process starts all over again.	作为工作流体，水在核电厂和水电厂中被加热的方式类似，在锅炉中变为水蒸气，然后进入涡轮机，涡轮机通过机械连接着发电机，最后由发电机将获得的机械功转变为电能。而经过涡轮机的水蒸气则在换热器中再次冷凝为液态水；水泵将水送回锅炉，然后开始新一轮的循环。
The only question is how to heat the water in the boiler. With wood, with coal, with heavy fuel oil, with gasoline, with gas, with schnapps, with an electric heated spiral? Everything is possible, everything	唯一的问题在于，该如何加热锅炉中的水。用木头、煤、重油、汽油、煤气、德国水果烈酒或螺旋式电加热棒？一切都有可能，一切都已尝试，但每每想到将水果烈酒用作发电厂，却只会觉

has already been tried, man was only with the schnapps for powerplants every time very avaricious. And, what about hydrogen? This is also possible, but we leave it for a later chapter.	得人类实在是人心不足蛇吞象。那么，氢可以吗？这个方法也有可能，不过我们留待下一章再作讨论。
What do the nuclear fuel elements in the reactor of a nuclear power plant so differently? They also only produce heat, which is used to grow warm the water in the boiler, but in a different way.	核电厂反应堆中的核燃料元件为何如此与众不同？的确，这些燃料同样只负责产生热量，然后利用该热量加热锅炉中的水，但具体方式却大相径庭。
The nuclear fuel elements are a bundle of thin fuel rods encased in water. However, in one of the common power plant embodiments, the power plant with pressurized water reactor (easier to understand as an example at this point), this is an "own water", not the water as a working fluid in the cycle of the power plant. In the fuel rods there is uranium, more precisely uranium oxide. There, a controlled nuclear fission takes place, in which the atomic nuclei are bombarded by free-running small particles, called neutrons, and broken down into splinters. The newly created splinters fly explosively apart, this is similar to chopping wood. With their enormous speed, the splinters rub themselves against the liquid in which they are	核燃料元件是一束纤细的燃料棒，周身浸在水中。不过，在常见的发电厂实施方案中，如压水堆核电站（此处作为示例更容易理解），这里的水是一种“自用水”，并不是发电厂中用作工作流体的循环水。燃料棒中的物质是铀，更确切地说，是氧化铀。这里就是可控核裂变发生的地方。一种名为中子的微小粒子在自由运动过程中轰击铀原子核，使其变为碎粒高速爆射分离，整个过程和劈木头差不多。高速运动的碎粒会与四周包裹的水发生摩擦，其过程类似于陨石砸向地面。落向地球的陨石会与大气层中的空气摩擦生热，摩擦处的温度高达数千度，导致整个陨石都燃烧起来。其后，高温液体会像电热棒一样将大部分热量传递给发电厂锅炉中的水。这就是核电厂的工作原理。

trapped. This is like the meteorites that fall on Earth, they rub against the air in the atmosphere until the temperature at the point of contact reaches thousands of degrees, with the meteorite itself burning. The hot liquid transfers a large part of the heat to the water in the boiler of the power plant, like the rods of an electric heater. And that's about a nuclear power plant.	
The energy of the utilized uranium is much greater than the calorific value of wood, coal, gas or heavy fuel oil, with which the boiler could also be heated. One kilogram of uranium has as much energy as 12,600 liters of crude oil or 18,900 kilograms of hard coal. This allows to generate 40 megawatt hours of electricity. A nuclear fuel element remains in the reactor for about three years. After that, there is a reprocessing to plutonium, which in turn also gives off a lot of energy.	虽然木头、煤炭、煤气和重油也都可以对锅炉进行加热，但其热值却根本无法与使用铀所产生的能量相提并论。1千克铀所蕴含的能量相当于 12600 升原油或 18900 千克硬煤，可以发电 40 兆瓦时。一组核燃料元件可以在反应堆中使用三年。之后，可将其再加工成钚，也可以产生大量能量。
And then? Of all the world's nuclear power plants currently in use, about 12,000 tons of radioactive waste are generated each year, which also contains plutonium [9].	再然后呢？全世界当前正在运行的核电厂每年要产生12000吨放射性废料，其中同样含有钚。
In addition to the problem of reactor safety during its function, there is also the	除了反应堆运行时的安全问题，放射性废料的处理和最后存放也是个麻烦

disposal and the final storage of radioactive wasted components, such as fission products, and incubated transuranium like plutonium. These components are still active, even if not with the same intensity as in the reactor. However, they radiate the energy generated during further cleavage to wavelengths in the X-ray range of the spectrum, which can be carcinogenic as far as lethal for humans and animals. These post-reactions last a very long time, between a few months and a few thousand years, with iodine isotopes it is even millions of years. Reprocessing would theoretically be possible, but it would "only" reduce the activity of such fractions to a few hundred years.	事，里面不仅有核裂产物，也有钚等使用过的超铀。这些废料依旧很活跃，只是程度不像在反应堆中那么强烈罢了。然而，废料在后续分裂过程中所释放出的能量的波长属于光谱中 X 射线的范围，对人类和动物来说，轻则致癌，重则致命。这些后续反应能持续很长时间，短则几个月，长则几千年，碘同位素甚至能达几百万年。从理论上来说，确实能对这些废料进行再处理，但最多只能把这部分的反应时间降至几百年。
The final storage of such "nuclear waste" remains a problem that has not yet really been solved worldwide. Storage materials are not able to permanently bind or insulate such substances. They are often melted into glass, incorporated into ceramics, poured into concrete and stored in mines, whereby the mountain rock must ensure the safe confinement of radioactive materials. Catastrophic would be the penetration of water into such	时至今日，这类“核废料”的最终存放问题在全世界范围内依然无解。储存材料并无法永久控制或隔离此类物质。因此，常用的方法是将这些物质熔融为玻璃，随后用陶瓷进行包裹，再倒入混凝土中，最后存放在矿井里，利用山石来确保放射性物质受到安全管控。不过储藏地一旦有水渗入，就会导致一系列危险的化学反应，引发灾难性的后果。因此，目前也正在研究其他可靠的储藏地，如盐丘、花岗岩、粘土

repository because it could lead to several types of dangerous chemical reactions. Salt domes, granite and clay rock are currently being discussed as final repositories. The storage of radioactive material in the open air is of course strictly prohibited by law in Western Europe. However, the "export" of such nuclear waste to Siberia or Kyrgyzstan, where the barrels may be parked in parking lots and other areas under the open sky, is not prohibited. In 2009, the wreck of a large freighter with 120 barrels of nuclear waste on board was discovered in the Mediterranean. According to the subsequent investigation, at least another 32 ships with similar cargo were lowered in the Mediterranean.	岩。西欧虽然明令禁止放射性物质的露天存放，但却可以将核废料“出口”至西伯利亚或吉尔吉斯斯坦等不禁止的地方，存放在那里的停车场和其他露天场所。2009 年，地中海发现了一艘装有 120 桶核废料的大型货轮。根据后续调查，至少还有另外 32 艘载有类似货物的船只沉没在地中海里。
Scenarios for the final storage of all the world's nuclear waste under the Antarctic ice sheet are also being developed. It doesn't get any more stupid!	目前，还有人提议把全世界的核废料都存放在南极洲的冰川之下，这简直是愚蠢到不能再愚蠢的想法！
Or is it?	不过或许有更愚蠢的？
Storage in space is the new booze idea of "experts" from science, business and politics! Simply store on asteroids and on other planets – perhaps also in parking lots there, as in Siberia. But the most foolhardy idea is to shoot the nuclear	一些科学界、商界和政界的“砖家”喝多了就开始说胡话，竟然提出要把核废料发射到太空！把废料随意存放在小行星和其他星球——或许就像在西伯利亚那样，放在外星球的停车场就行。不过，最愚不可及的想法是将核废

waste directly into the sun, so it would actually be away from our biosphere! What we then get from our beloved sun as a receipt for our biosphere and for our flora and fauna, so far the spinners had not come!	料直接发射向太阳，以为这样就能令其远离我们的生物圈！但是有没有想过，后续太阳会对我们的生物圈和地球上的动植物造成什么样的影响？幸好目前这个想法并未实施！
13	13
The energetic water cycle: nature – electrolysis – machine – nature	水能量循环：自然—电解—机器—自然
13.1 Hydrogen production and storage	13.1 氢的制备与储存
It is fascinating! The water will quench all the energy hunger of this world, or rather, the thirst for energy! Hydrogen can be obtained from the water. If you just say or think hydrogen, it already smells of the future, on the horizon everything turns blue, all people become happy! If you ask your friend in Germany: "Fritz, would you buy an electric car now, with all the so great premiums from the German government and from the dealers as well?", he will surely answer: "Well, I don't know, with such batteries without a decent range and with the electricity from coal? I prefer to wait until the right technology of the future comes, the fuel cell with hydrogen!"	太好了！水能满足全世界对能源的需求或对能源的渴望！氢可以从水中获得。单单提及或想到氢，似乎就能畅想出未来的场景。那时，目之所及皆是一片湛蓝，所有人都洋溢着幸福之色！你如果问你的德国朋友：“弗里茨，德国政府和经销商现在对电动汽车有大量补贴，你会考虑买电车吗？”，他肯定会回答：“呃，我也不知道，用充电电源来自煤电的没有良好续航里程的电池？我还是想等未来好的技术的到来，氢燃料电池！”。
Fritz doesn't know exactly what that is, but one thing is clear: water can be split	弗里茨并不知道那具体是什么，不过可以确定的是：可以通过分解水来制

to obtain hydrogen, which is then pulled through such a fuel cell from space technology and after all it becomes water again, non-toxic, odorless, noise-free.	氢，然后利用空间技术使氢经过燃料电池，最后再变回水，全程无毒无味无噪音。
The first cars with fuel cell technology using hydrogen are already on the road, or rather on the road again. "The Japanese are fooling us, the German engineers have overslept a bit again!" is Fritz's opinion, according to the opinion of the people par excellence. No, the German engineers have only slowed down the huge lead time they had 10 20 years ago in the field of fuel cells with hydrogen for automobiles (the examples will not be missing in this chapter). We will talk about the reasons in a moment.	第一批使用氢燃料电池技术的汽车已经上路了，或者说又上路了。弗里茨觉得："日本人愚弄了我们，德国工程师又有点睡过头了！"，精英人士们也对这样的观点表示认同。但事实却并非如此，德国工程师只是在一二十年前放缓了脚步，毕竟那时德国在汽车氢燃料电池领域有着巨大的领先优势（本章会举例说明）。不过让我们待会儿再讨论其原因。
Hydrogen is truly the subject of most ideal scenarios as the energy carrier of the future:	氢确实是未来能量载体的最理想方案：
—The hydrogen production is theoretically possible on the basis of solar energy by water electrolysis, whereby no harmful byproducts are generated.	氢的制取—理论上来说，可以通过太阳能电解水来获得氢气，过程中也不会产生有害副产物。
—The use of hydrogen—either by combustion in a heat engine to generate work and/or heat or by proton exchange in a fuel cell to generate electrical energy—leads back to the original water.	氢的应用—可以通过在热机中燃烧来做功和/或产热，也可以通过在燃料电池中进行质子交换来产生电能——最后再变回最初的水。

However, this future is still a long way off: The production of hydrogen is currently hardly carried out according to this ideal, clean scenario with electrolysis, for which one would need electrical energy again – here we are again with photovoltaics, wind, water and nuclear energy!	然而，未来还有很长一段路要走：要想用电解这种清洁的理想方式来制取氢，目前来说依旧难以进行，因为电解首先需要的是电——这就又回到了如何用光能、风能和核能来发电的老问题！
Currently, only less than 2% of hydrogen worldwide is produced by electrolysis. The most part, this means over 98% – is obtained from fossil fuels. This kind of hydrogen production has as result carbon dioxide or carbon:	当前，世界上只有不到 2%的氢是靠电解获得的。这就意味着，超过 98%的绝大部分氢——依旧要靠化石燃料来制取。这种制氢方式则会产生二氧化碳和碳：
—Steam reforming, for example, is a method to produce hydrogen from natural gas, which reacts with water, resulting not only in hydrogen but also in carbon dioxide. In order to produce one kilogram of hydrogen in this way, 2 kg of natural gas and 4.5 kg of water are required. The result is then not only the expected 1 kilogram of hydrogen but also 5.5 kg of carbon dioxide.	——以蒸汽重整为例，这是一种利用天然气制取氢气的方法，在与水反应的过程中，不仅会生成氢气，还会生成二氧化碳。用这种方法制取一千克氢需要 2 千克天然气和 4.5 千克水，产物不仅有 1 千克目标产物氢气，还有 5.5 千克二氧化碳。
—By cracking natural gas, without further reactants, 1 kg of hydrogen is produced from 4 kg of natural gas, but also 3 kg of carbon fall off.	——而天然气裂解制氢法虽不需要额外反应，但制取 1 千克氢气却需要 4 千克天然气，同时生成 3 千克碳。
The production of the 500 billion norm	全世界每年要制取 5000 亿标准立方米

cubic meters of hydrogen generated worldwide annually is based on the energy carriers listed in Tab. 2:	氢气，其能量载体来源如表 2 所示：
<table><tr><th>Energy sources</th><th>Percentage</th></tr><tr><td>natural gas:</td><td>38 %</td></tr><tr><td>heavy oil:</td><td>24 %</td></tr><tr><td>gasoline:</td><td>18 %</td></tr><tr><td>ethylene:</td><td>6,6 %</td></tr><tr><td>other products of the chemical industry:</td><td>1,4 %</td></tr><tr><td>Chlor-alkali electrolysis:</td><td>2 %</td></tr><tr><td>Coal (coke gas):</td><td>10 %</td></tr></table>	<table><tr><th>能量来源</th><th>百分比</th></tr><tr><td>天然气:</td><td>38 %</td></tr><tr><td>重油:</td><td>24 %</td></tr><tr><td>汽油:</td><td>18 %</td></tr><tr><td>乙烯:</td><td>6.6 %</td></tr><tr><td>其它化工产品:</td><td>1.4 %</td></tr><tr><td>氯碱电解:</td><td>2 %</td></tr><tr><td>碳（焦炉煤气）:</td><td>10 %</td></tr></table>
Tab. 2 Energy carriers for current hydrogen production in the world	表 2 现今世界制氢所用能量载体
The hydrogen obtained in this form has been used for decades in the industry for the production of fertilizers, paints, solvents and plastics, as well as in the mineral oil industry to improve the fuel structure.	用这种方法制取的氢气已经在工厂中应用了几十年，广泛应用于生产肥料、颜料、溶剂、塑料以及在矿物油产业中改善燃料结构。
Thesis 37: An energetic water cycle via machines that should supply electricity, heat and work requires hydrogen production by electrolysis using photovoltaic systems, wind turbines and micro-hydropower plants, which can also work decentrally and discontinuously.	论点 37：能量水循环通过机器可以产生电力、热能和功，但前提是光伏系统、风力涡轮机和微型水力发电厂能够通过电解生产氢气，这些设备可以分散和也可以不连续地工作。
However, the promising use of hydrogen, for example in automobiles of the future whether with fuel cells or with a combustion engine first has the problem	氢能的应用固然有着光明前景，但以未来在汽车中的应用为例——无论是燃料电池也好，内燃机也罢——其首要问题就是要解决车载储氢，以实现

of its storage on board, for mobile use. Hydrogen is the element with the lowest molecular mass, so its density, as mass in a given volume, is accordingly the lowest of all elements. Simply comparing it with air is revealing: at the same temperature and pressure in the atmosphere, air is 15 times denser than hydrogen.	移动使用。在所有元素中，氢气有着最小的分子质量和给定体积下最低的密度。将氢气与空气做一下简单对比就能发现：在同温同压环境下，空气的密度是氢气的 15 倍。
How do you get a lot of mass into a limited volume, like in the tank of a car? Pressure up or temperature down until the gas even becomes liquid. But even in the liquid phase, at a temperature of minus 253 ° Celsius, hydrogen has only one tenth of the gasoline density [10]. The liquefaction itself requires one third of the energy stored in the respective amount of hydrogen. The alternative option — high pressure instead of low temperature — is also used, at pressure values between 350 and 900 bar, whereby the hydrogen remains in the gaseous phase. However, it should be noted that the difference to the ambient pressure creates an outflow potential: The hydrogen molecule is, as mentioned before, the smallest of all elements and can therefore easily penetrate most material structures. Preventing this	怎样才能在诸如汽车油箱之类的有限空间中放入大量的气体？答案是通过高压和低温的方式将气体液化。然而，即便是在 – 253°C 的液体状态下，氢的密度依然只有汽油的十分之一，且液化过程本身所需的能量就占氢气所含能量的三分之一。备选方案——用高压代替低温——也尝试过，但在 350—900 巴压力下，氢气却仍是气态。而且需要注意的是，与环境气压之间的压差会引起氢气外泄的潜在风险：如上文所说，氢分子是所有元素中最小的，可以轻而易举穿过大多数物质结构。要防止泄漏就需一种多层复杂设计的氢箱，使其在高压下依然能保持相当强度。然而，氢气透过箱体外溢根本无法避免。当前的研究报告显示，外溢速度约为每天 1%。这个数量虽然看起来不多，却隐藏着另一个隐患：逃逸的氢气会以常压的状态存在于封闭空间中，例如车体——圆材、圆柱、内外包

leakage requires a multi-layered, complex design of a hydrogen tank, which also has the appropriate strength at the high pressure. Nevertheless, hydrogen loss through the tank walls is unavoidable. Currently, about 1% loss per day is reported. Even if this amount does not seem large, it hides another danger: the escaping hydrogen then remains unpressurized in closed spaces, for example in an automotive body – spars, columns, spaces between exterior and interior cladding. Within the very wide ignitability, of 4 % Vol. up to 77 % Vol. hydrogen concentration in the air, at a comparatively high speed of the flame front during hydrogen combustion (whereby the flame is also invisible) it can lead to dangerous detonations. The proved absorption of these hydrogen accumulations in the body of a vehicle by pumps increases the technical complexity. The low storage density is partly compensated by the high calorific value of the hydrogen, but the range of a hydrogen car remains far below that achieved with gasoline with the same tank volume.	层间的空隙中。氢气具有极高的可燃性，从 4%到 77%之间的体积浓度都是其可燃范围，再加上氢气燃烧时的火焰峰具有极快的速度（因此肉眼对其不可见），甚至会引发危险的爆炸。事实证明，用泵吸收车体中的氢气会增加技术复杂性。虽然氢气的高热值可以稍微弥补低储存密度的缺陷，但氢能车的续航里程仍比同等油箱体积的汽油车低得多。
The storage of hydrogen in liquid form,	将液态氢气储存在－253°C 的低温储

in cryogenic tanks, at minus 253 °C requires particularly effective insulation: Gases or vacuum have the lowest thermal conductivity as insulators. However, insulation by means of a gas requires such a thin gas layer that no gas movement occurs in the layer: This would convert the heat conduction into convection, whereby the resulting heat flow would increase by orders of magnitude [1]. The ideal hydrogen tank should therefore consist of several solid container walls that float into each other at very short distances – because each solid connecting element would intensify heat conduction. In some versions, the floating of the tank layers into each other is realized by magnetic forces.	罐中对隔离材料的性能有着极高的要求：气体或真空正好像隔热材料一样有着极差的热传导性。然而，气体隔离法需要气体层非常薄，以确保其中没有气体流动：这就会将热传导转化为对流，从而导致热流以数量级的方式增加[1]。因此，理想的储氢罐应该由多个固体容器壁组成，这些容器壁在很短的距离内相互浮动——因为每个固体连接元件都会令热传导效应加剧。在某些版本中，氢气罐各层之间的相互浮动是通过磁力实现的。
In a newly developed hydrogen tank for automobiles two tank layers are separated from a gas layer, the gaseous hydrogen is accumulated, whereas the cryogenic storage requires a cooling circuit with a corresponding heat exchanger.	在新开发的汽车氢气罐中，两层罐体与气层分离，气态氢被积聚，而低温储存则需要一个带有相应换热器的冷却回路。
13.2 Fuel cell with hydrogen	13.2 氢燃料电池
Despite a wide range of technical innovations worldwide, the batteries for automobiles remain large and heavy:	尽管世界范围内的技术革新层出不穷，但汽车电池仍然又大又重：
A lithium-ion Tesla battery, for example,	例如，特斯拉锂离子电池的重量相当

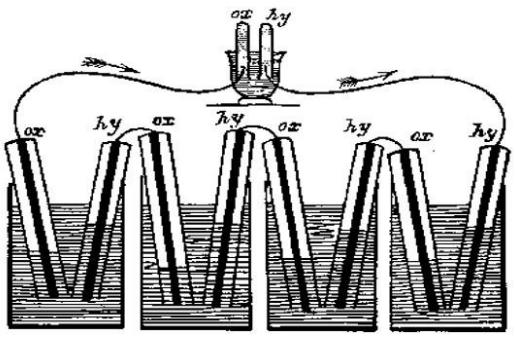
is just as heavy as an entire Renault Twingo with a gasoline engine and full tank, which has the same range as the Tesla.	于一整台加满油的雷诺 Twingo 汽油车，且二者的续航里程相同。
Let's see what fuel cells can do differently: Their operating principle was successfully tested as early as 1839 by the British physicist Sir William Robert Grove as "reverse electrolysis". The electrodes of this original hybrid between battery and fuel cell consisted of platinum strips, which were originally in acidified water and were surrounded by hydrogen or oxygen, as can be seen in Fig. 17.	燃料电池的不同之处：早在 1839 年，英国物理学家威廉姆 •罗伯特 •格鲁夫爵士就成功研究出了燃料电池的运行原理，即“反向电解”。如图 17 所示，这种最初的电池和燃料电池混合体的电极由铂条组成，铂条最初浸泡在酸化水中，周围环绕着氢气或氧气。
And what was the electrolysis that Sir Grove turned upside down? Through two electrodes, an electrical direct current is passed through a conductive liquid (electrolyte). Electrolysis produces reaction products from substances of the electrolyte at the electrodes. From water, as an electrolyte, hydrogen is produced at one electrode and oxygen at the other.	那么，格鲁夫爵士所颠倒的电解过程是什么样的？在两个电极的作用下，直流电通过导电液（电解质）。电解质由于电解反应在电极上生成反应产物。若电解质是水，则两个电极上会分别生成氢和氧。
	ox: 氧 hy: 氢

Fig. 17 Functioning of the first fuel cell (1839)	图 17 第一台燃料电池的功能（1839 年）
In a further version, Grove used sulfuric acid as an electrolyte, the hydrogen supply was realized by the reaction of the acid to zinc and the oxygen was supplied by means of an air flow.	在改进版本中，格鲁夫用硫酸作电解液，通过锌酸反应提供氢，通过空气流动提供氧。
The resulting analogy with the most modern air-zinc batteries on the one hand and with the forward-looking fuel cells on the other shows a development path that characterizes the technology in many cases:	再后来，就有了最新的锌空气电池和前景广阔的燃料电池，而这样的发展轨迹也正体现了许多领域中的技术发展特点：
Thesis 38: The latest technical concepts very often have physically proven ancestors. Moreover, a technical development is rather continuous than erratic and revolutionary, albeit a new quality is achieved as a result.	论点 38：最新的技术概念往往都有先贤的影子。此外，技术发展更多是循序渐进的过程，突如其来的发现和革命性的进展往往很少见，不过二者确实也推动了技术的进步。
In this last context, the zinc-air battery is a functional link between batteries – with pure storage of components – and fuel cells – with continuous component feed as mass flows. The breakthrough of the fuel cells based on pure hydrogen and oxygen flows via light catalyst electrodes in alkaline-aqueous electrolytes succeeded in the fifties, driven by special requirements in power generation for	紧接上文，锌空气电池是蓄电电池——依靠构成成分进行单纯储存——和燃料电池——依靠构成成分提供源源不断的质量流——的功能链接。为满足航空航天应用的电力需求，50 年代，科学家通过对碱性水电解液的光催化电极的研究，最终利用纯氢和纯氧的离子运动生成了电流，燃料电池技术成功获得突破。对火箭来说，并不需要笨重的电池就作压舱石。另一方面，火

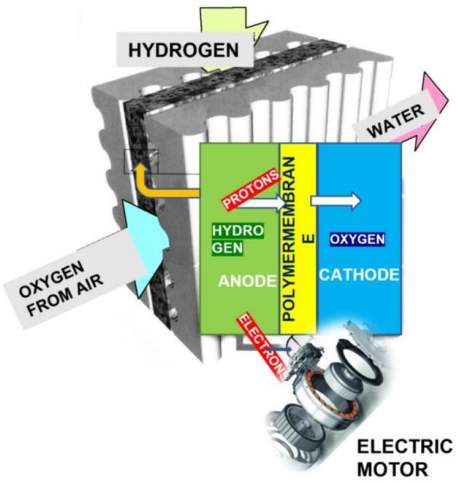
aerospace applications. Heavy batteries are a ballast that no-one need in a rocket. On the other hand, hydrogen and oxygen were available on board of rockets, even for propulsion. Thus, the aeronautical engineers have had the idea of digging up Sir Grove's reverse electrolysis and producing the electricity on board of rockets with hydrogen and oxygen instead of getting it from batteries. This makes real sense for such an application and for the already existing reaction partners, needed for combustion in the heat engine which ensures the rocket propulsion. The functional principle of a modern fuel cell for automobiles is shown in Fig. 18.	箭上可以使用氢和氧，甚至可以用于推进。因此，航空工程师们想要改进格鲁夫爵士的反向电解技术，用火箭上的氢和氧代替电池提供电能。这项技术不仅对航空应用来说意义非凡，同时也极大影响了现存的反应物，而热能发动机中的燃烧过程则正需要此类反应物来确保火箭的推进。当前的汽车燃料电池功能原理如图 18 所示。
	HYDROGEN：氢 WATER：水 OXYGEN FROM AIR：空气中的氧 ELECTRIC MOTOR：电动机 PROTONS：质子 ANODE：阳极 EXLECTRON：电子 POLYMERMEMBRANE：聚合膜 CATHODE：阴极

Fig. 18 Functional principle of a modern fuel cell for automobiles	图 18 当前汽车燃料电池的功能原理
This looks like a sandwich: the outer halves form the walls of the cell, in the middle there is a polymer membrane instead of a sausage slice. Another difference to the sandwich is that there is a gap between the membrane and the two lids, which is neither filled with mayonnaise nor with mustard: hydrogen flows from the left column, air from the environment, which contains about 21% oxygen, flows through the right column.	它看起来就像一个三明治：外面是电池壁，中间是一层类似香肠片的聚合膜。而与三明治的差别在于，聚合膜和两个盖子之间存在空隙，里面填充的既不是蛋黄酱也不是芥末酱：氢气从储氢罐中流出，经过左边的柱形沟槽，含有 21%氧气的空气则流经右边的柱形沟槽。
Hydrogen and oxygen naturally attract magically each other, what else could you expect? After all, they are always intimately connected in nature, as water. However, the polymer membrane does not allow the hydrogen atoms to pass through to the oxygen atoms. This causes every hydrogen atom to despair, it bursts in its components. Amazingly, however, the heavy proton from the atomic nucleus passes through the membrane, the light electron, which has only 0.5 thousandths of the mass of a proton, remains.	氢气和氧气天然便对彼此有着玄而又玄的吸引力，现在金风玉露一相逢，会发生什么还用多说吗？最终，它们往往紧密结合在一起，形成了水。不过，氢原子并不能通过聚合膜与氧原子相遇。这令氢原子悲痛欲绝，崩溃至分离。然而不可思议的是，原子核中较重的质子可以通过聚合膜，而重量只有质子两千分之一的较轻的电子却留了下来。
But remains is not the right word: the electron tries to reach its proton via detours by flowing through an electric	不过“留”字似乎不太贴切：电子会尝试绕一下远路，也许是个电动机，也许是个电灯泡，无论如何都要找到它的

motor or a light bulb. The electric motor spins with joy, the light bulb shines with joy. Then, if the electron is already further, it leaves room for the next one and goes to its proton on the oxygen side. But the oxygen itself also wants to play along, and so it comes to the wedding, from which a water molecule is born and immediately evaporates out.	质子。于是，电动机愉快地旋转，电灯泡开心地发光。之后，如果电子已经离开去到氧气的一边寻找它的质子，那么空出来的空间将继续迎来下一位旅客。而另一边，氧气自己也想见证这场寻爱之旅，于是参加了婚礼，然后就生成了水分子并立即蒸发掉。
Scientifically, such a sandwich is called low-temperature proton-conducting polymer membrane fuel cell PEM (Proton Exchange Membrane Fuel Cell). PEM fuel cells have the advantage of a very high power density at working temperatures of 20 °C to 120 °C. Their flexible operating behavior and the possibility of obtaining oxygen from an air flow are very advantageous premises for the utilization of PEM fuel cells in a vehicle.	科学上将这种三明治结构称为低温质子传导聚合膜燃料电池，即 PEM（质子交换膜燃料电池）。PEM 燃料电池的优点在于能量密度特别高，工作温度在 20°C 和 120°C 之间。该燃料电池具有灵活的工作性态，可以从空气中获取氧，这些特点是 PEM 燃料电池应用于交通工具十分有利的前提。
However, there are also other types of fuel cells used for domestic energy supply or for central and decentralized power generation or for co-generation of electricity and heat.	此外，还有许多其他类型的燃料电池，广泛应用于家庭能源供应、集中和分散式的发电系统或电热共生。
Tab. 3 Other types of fuel cells other than PEM and their applications	表 3 除 PEM 外的其他类型燃料电池及其应用
—Alkaline fuel cells – AFC use	——碱性燃料电池 (AFC) ——对比所

potassium hydroxide solution as electrolyte and have the advantage of the highest efficiency of all embodiments. Due to the potassium hydroxide, only operation with pure hydrogen and oxygen is possible, which justifies its preferred use in aerospace technology.	有燃料电池，使用氢氧化钾溶液作为电解液的 AFC 具有最高的效率。也正由于电解液是氢氧化钾，只有提供纯氢和纯氧才可以运行，因此常用于航空航天技术。
—Direct methanol fuel cells – DMFC have a proton-conducting membrane similar to PEM, but they can be operated directly with methanol. Methanol can be stored in liquid form at ambient temperature and pressure, making the tank similar to a conventional tank for liquid fuels. The working temperature range of the DMFC is 50°C to 120 °C. The problem is that as a result of the reactions in a DMFC, carbon dioxide is emitted. However, methanol from plants is recyclable.	——直接甲醇燃料电池 (DMFC) ——DMFC 有着与 PEM 类似的质子传导膜，只需甲醇就能直接运行。DMFC 的优点在于，原料甲醇可以从植物中获取，属于可再生资源，且在环境温度和气压下可以液态储存，因此甲醇罐与常规的液体燃料罐大同小异，而它的工作温度范围则在 50°C 和 120°C 之间。但缺点在于，其反应产物中有二氧化碳。
—High-temperature proton-conducting polymembrane fuel cells – HT-PEMFC can be operated without additional water in the fuel cell. The newly developed polybenzimidazole membrane allows the direct use of phosphoric acid as a charge carrier, which ensures proton exchange.	——高温质子传导聚合膜燃料电池 (HT-PEMFC) ——HT-PEMFC 燃料电池运行时不需要额外加水。新开发的聚苯并咪唑膜可直接将磷酸用作电荷载体，确保质子的顺利交换。
—Phosphoric acid fuel cells – PAF operate at higher temperatures than the	——磷酸燃料电池 (PAF) ——与 AFC 和 PEM 相比，PAF 的运行温度更高，

AFC and PEM versions (180 °C to 220 °C) with a rather limited efficiency and are partly corrosion-prone. They are mainly used in decentralized electricity-heat co-generation systems in the power range around 200 kW.	为 180°C 至 220°C，效率有限，容易腐蚀，因此主要应用于 200kW 功率范围内的分离式电热共生系统。
—Fuel cells with molten carbonates – MCFC operate at comparatively high temperatures, around 650 °C and, despite the complex process control and the corrosion sensitivity, are being intensively developed for the decentralized energy supply due to their suitability for working with coal gas.	——熔融碳酸盐燃料电池（MCFC）——MCFC 的运行温度相对较高，约为 650°C，过程操纵较为复杂，极易腐蚀，适合与煤气一同使用，广泛开发应用于分散式能量供应。
—Solid Oxide Fuel Cells – SOFC operate at the highest temperatures among all types of fuel cells (850 °C to 1000 °C) based on a solid electrolyte consisting of zirconium oxide. The expected high efficiency in the production of electrical energy directly from natural gas or biogas justifies their rapid development for central and decentralized electricity-heat co-generation plants.	——固体氧化物燃料电池（SOFC）——在所有类型的燃料电池中，SOFC 的运行温度最高，为 850°C 至 1000°C，电解质是固态氧化锆，可以直接利用天然气或沼气高效发电，在集中式和分散式电热共生发电厂中得以快速发展。
For a satisfactory performance of the fuel cell, the exchange surface between hydrogen and oxygen at the membrane must be large enough. To keep the dimensions of the whole fuel cell within	为了实现燃料电池的高效运行，要保证氢气和氧气与中间的交换膜有足够大的接触面积。但整个燃料电池的尺寸要保持在合理范围内，因此整个三明治结构就会像一个巨无霸汉堡，中

limits, the sandwich will be a Big Mac, with several slices of sausage in the middle, between which neither cheese nor mayonnaise, but hydrogen and oxygen flow. But that's not enough, labyrinths are also being built, which also bring more space. In the end, the whole thing looks like the water cooler in the car, has anyone ever sawed one apart?	间是几片香肠片，香肠片之间既不是起司也不是蛋黄酱，而是氢气流和氧气流。不过这还不够，要把通道设计得像迷宫一样才能带来更多空间。最后，整个电池看起来就像汽车的水冷器一样，有人见过里面是什么样吗？
The only problem is that column, pulsations and local bubble formation. Moreover, rapid acceleration or deceleration of the flows – in accordance with the power currently required by the driving motor – impairs this flow sequence considerably more. A fuel cell is therefore particularly advantageous for steady operation, with relatively low power or when large dimensions are allowed.	唯一的问题在于，迷宫中长时间的回流会导致紊流和脉冲，并在局部生成气泡。此外，在当前驱动电机的功率要求下，流速的快速上升和下降不可避免，对流序有很大影响。因此，燃料电池如果可以相对降低功率或加大尺寸，会十分有利于稳定运行。
The function groups are built in a modular design on one platform. The air pressure of 2 to 3 bar required for the air flow is provided by means of a compressor.	模块化设计的功能组处于同一平台上。压缩机提供 2 至 3 巴的气压促使空气流动。
Meanwhile, Toyota and Hyundai offer series-production automobiles with electric motor drive and electric energy on board from a fuel cell with hydrogen.	与此同时，丰田和现代都已经实现了氢燃料电池电动驱动汽车的量产。

Fig. 19 Series-production automobile with electric motor drive and electric energy on board from a hydrogen-powered fuel cell (Source: Toyota)	图 19 使用电动机驱动和氢燃料电池电能的批量生产汽车（资料来源：丰田公司）
And where are the German engineers?	那么德国工程师们又干了什么呢？
Fig. 20 shows some of Daimler's versions, beginning in 1994, representing a variety of realized automobiles with fuel cells. The achieved performance, the range, the hydrogen storage technology have been throughout improved, a production-ready technology has been developed. At the end of the twentieth century, Daimler was the undisputed world champion in the field of fuel cells for vehicles.	图 20 展示了戴姆勒从 1994 年就开始设计的一些版本，是许多已成功生产的燃料电池汽车的标杆，其实际性能、续航里程、氢储技术都得到了全面提升，相关技术也已经进入可生产阶段。在二十世纪末，戴姆勒在汽车燃料电池领域是无可争议的世界第一。
Fig. 20 Versions of Daimler vehicles with fuel cells based on methanol and hydrogen for the electric drive of vehicles (Source: Daimler)	图 20 戴姆勒汽车采用甲醇燃料电池和氢燃料电池驱动汽车（资料来源：戴姆勒）。
In 2011, several Mercedes B-Class vehicles with hydrogen fuel cells drove around the world to demonstrate the concept's suitability for series production.	2011 年，梅赛德斯的几辆氢燃料电池 B 级车上路环游了世界，向大家宣告氢能汽车也适合量产。
They crossed Europe, then North America, even Australia and finally reached China. The tour lasted 125 days. In addition to the fuel cell, the cars also had a lithium-ion battery on board as an	这些车穿越了欧洲、北美、甚至澳大利亚，最终抵达中国。整个旅程持续了 125 天。除了燃料电池外，这些车上还配备了锂离子电池以提供缓冲电能。电动机的功率为 100kW，相当于一个

electric energy buffer. The drive electric motor had 100 kW and reacted like a two-liter gasoline engine.	两升的汽油发动机。
Up to 400 kilometers could be driven non-stop because the lithium-ion battery was constantly replenished by the fuel cell. The four kilograms of hydrogen were in the tank under a pressure of 700 bar. To refuel hydrogen, you do not have to wait 8 hours, as with the battery, but only 20 minutes. The problem was another, namely the tanker truck full of hydrogen that drove behind, because in the world there are still very rare hydrogen filling stations, in China there were none at that time.	这些车可以连续跑 400 公里，过程中燃料电池也一直在给锂离子电池充电。氢罐中的氢有四千克，气压值达到了 700 巴。充氢只需 20 分钟，并不像蓄电池那样要等 8 小时。真正的问题在于，过程中需要一辆满载氢气的氢罐车提供后勤，毕竟加氢站在世界上还很少见，甚至当时在中国一个都没有。
Thesis 39: It is not enough to ensure the hydrogen infrastructure in the world for fuel cell cars: over that, it is essential to produce the hydrogen on a large-scale CO2-neutral, and not as a by-product of the chemical industry.	观点 39：对于氢燃料电池车来说，仅仅保证世界范围内有足够的氢能基础设施还不够：比之更重要的是要实现二氧化碳中和式的大规模制氢，不能仅靠化工厂的那点副产物。
Toyota and Hyundai are now on the market with fuel cells, Mercedes are not. why? Daimler? The reason is certainly not only the high price of this technology.	目前，丰田和现代都有燃料电池产品上市，梅赛德斯却没有。这是为什么呢？戴姆勒？原因肯定不仅仅是因为这项技术的价格很高吧。
13.3 Internal combustion engine with hydrogen	13.3 氢气内燃机
The combustion of hydrogen with the	氢气可以和空气中的氧气在发动机的

oxygen from the air in the combustion chamber of an engine proceeds very differently from the proton exchange of hydrogen and atmospheric oxygen along a membrane in the fuel cell – but the product is the same: water, without carbon dioxide.	燃烧室中进行燃烧。这个过程与燃料电池大不相同，膜燃料电池的原理是氢气的质子通过交换膜后与来自空气中的氧气进行反应。不过二者的产物相同：都是水，并没有二氧化碳产生。
The temperature of a flame during combustion in an engine often reaches 2000° Celsius, this is much more than the process temperature around 100° C in a fuel cell. A temperature in the range of 2000°C is a sign that the particles involved in the hydrogen and in the air molecules are almost bursting apart from energy.	发动机中的燃烧温度常常高达 2000° C，比燃料电池大约 100°C 的运行温度高很多。2000°C 的高温意味着氢气粒子和空气分子粒子正在发生近乎爆燃的高能反应。
Whole atoms, protons, neutrons, electrons rattle like little devils at the stake. In addition, there is no longer a membrane wall between the hydrogen and the air. Fractures of atoms from both camps fall into each other's arms. Millions of pairs found together spin in millions of vortices, faster and faster, directed as a devil's waltz by the maestro himself. No other way to provide so much contact surface between hydrogen and oxygen, no kind of membrane can ensure it, be it as large or labyrinth-rich. The hot	所有的原子、质子、中子和电子就像火刑架上的小恶魔一样吱吱作响。此外，氢气和空气之间也没有了隔墙一样的聚合膜。二者的原子发生裂解，又彼此结合起来。百万对粒子一起旋转，越来越快，形成了百万个漩涡，像是一场大师亲自指挥的恶魔华尔兹。这种方法可以让氢气和氧气充分反应，接触面积比任何类型的膜都要大，行进通道比任何形状的迷宫槽都要多。双方粒子彼此交融结合，产生了大量质量对。

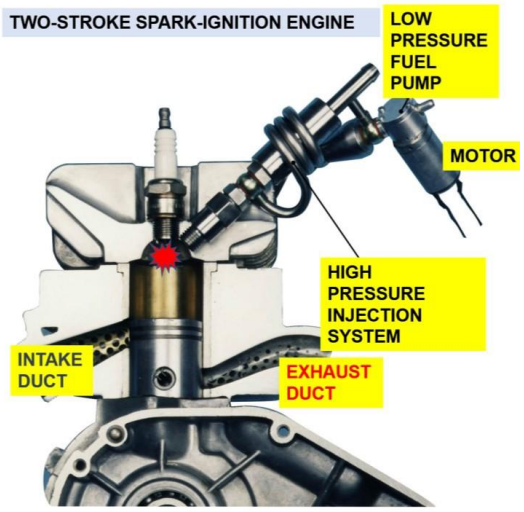
pairs melt together, resulting in a huge mass pairing.	
Fig. 21 shows a comparison of the reactions in a fuel cell and in a combustion engine [10].	图21展示了燃料电池和内燃机中的反应对比。
Fig. 21 Comparison of reactions in a fuel cell and in a combustion engine [10]	图 21 燃料电池和内燃机中反应的比较 [10]
Mercedes sent the hydrogen into the fuel cell, BMW couldn't just leave it at that, and sent the hydrogen into the combustion engine.	梅赛德斯将氢气送入了燃料电池，宝马也不甘示弱，将氢气送去了内燃机。
Mercedes had the hydrogen in the tank below 700 bar pressure, BMW preferred to make it cold: In the cryogenic hydrogen storage at minus 253 ° C, the entire tank and the hydrogen injection system, from the tank via lines to the injection nozzles, must be thermally insulated to avoid a phase change from liquid to gas.	梅赛德斯选择利用 700 巴的高压将氢气储存在氢罐中。宝马则更偏向于对氢气进行－253°C 的低温储存，从氢罐、输送管到注射喷嘴，整个氢罐和注氢系统都要进行隔热处理，防止氢气由液态变为气态。
The hydrogen was simultaneously injected into the intake manifold and into the head of the engine. These two injectors were needed because the injection time for the required hydrogen volume was always so short: At 6000 engine revolutions per minute, a single revolution simply takes 10 thousandths of a second, the fuel supply directly into the	氢气被同时注入进气歧管和发动机缸盖中。之所以需要两个喷嘴，是因为要注入足够量的氢所能用的时间往往十分短暂：发动机转速是每分钟6000转，每一转只需百分之一秒，燃料直供缸盖约需千分之一秒，在进气歧管中时间会稍微长一些，但也不会长太多，因此建议双管齐下。不过，氢从喷嘴中出来后会立刻气化占据大量空间，甚至

head remains about a thousandth of a second, in the intake manifold is a little more, but not much more time, so it was recommendable to use both. However, the hydrogen immediately becomes gaseous after escaping from the nozzles and suddenly takes up a lot of space, space that until then belonged to the air. By that, the air is simply partially displaced, but, unfortunately, the hydrogen needs itself the air for combustion. And so a vicious circle is created. Therefore, the torque of the engine is not as spectacular as one might expect from hydrogen.	会占据一部分空气的空间。因此，一些空气只能白白浪费，但不幸的是，氢气燃烧却需要足够的空气。如此一来就形成了恶性循环。因此，氢内燃机的扭矩并没有预期中的那么可观。
There are currently around 600 hydrogen-powered automobiles in use worldwide. The first hydrogen car ran at BMW as early as 1979, with a 4-cylinder engine that achieved an output of 60 kW (82 hp). For on-board power generation, BMW has developed a compact fuel cell with 5 KW / 42 volts, which had as fuel the same hydrogen as the combustion engine.	目前，世界上约有 600 辆氢动力汽车。早在 1979 年，宝马就生产出了第一辆氢动力汽车，配备了一台四缸发动机，输出功率达到了 60kW（82hp）。在车载发电方面，宝马研制出了一款紧凑型的燃料电池，参数为 5KW/42V，与氢内燃机同样使用氢气作为燃料。
Such a car with hydrogen combustion in the piston engine is neither in terms of performance nor driving behavior among the current standard fuel cell cars powered by electric motors. The witness	与当下标准的燃料电池电动汽车相比，这种利用活塞发动机的氢内燃机汽车不仅性能差劲，驾驶感受也不好。本书作者作为见证者，对这两种流派的车都有过亲身体验。

is the author of this book himself, who has driven vehicles from both genres.	
What will prevail depends on the overall efficiency in the chain between tank and power on the wheel, on the technical complexity of the respective system, on the price and, last but not least, on the acceptance by customers.	究竟哪种流派更胜一筹，取决于将氢能传递至车轮转变为机械能的总体效率、取决于各自系统的技术复杂性、取决于价格，最后但同样重要的是，取决于消费者对其的接受度。
Fig. 22 Automobile with hydrogen piston engine for propulsion and hydrogen fuel cell for power supply on board (Source: BMW)	图 22 采用氢活塞发动机推进和氢燃料电池供电的汽车（资料来源：宝马公司）
Thesis 40: There is no need to be afraid of the combustion engine in the automobile, it is not the polluter of the world per se. Fed with hydrogen, it also emits only water, like the fuel cell.	论点 40：没必要担忧汽车内燃机，它本身并不是世界的污染源。若燃料是氢，内燃机其实和燃料电池一样，排出的只有水。
13.4 Internal combustion engine with hydrogen in the role of the fuel cell	13.4 氢内燃机扮演燃料电池的角色
In a fuel cell, hydrogen can react with oxygen through a membrane, in order to produce electricity, even though nothing burns in this cell.	在燃料电池中，氢和氧通过聚合膜发生反应产生电能，过程中不需要燃烧任何东西。
But hydrogen can be also burned with oxygen, with a really hot flame, so that a pressure is created in the burned mixture with which you can push anything: a piston running back and forth, a rotating piston or the blades of a turbine. In all	不过氢和氧也可以进行燃烧反应产生高温火焰，二者混合燃烧所产生的压力可以推动任何东西：往返式活塞、旋转式活塞或叶片式涡轮。在所有情况下，都可以通过连轴将强力的旋转运动传递至发电机。

these cases, the powerful rotative movement of a shaft is transmitted, which can turn a current generator.	
Now we are exactly where we arrived with the fuel cell: The electricity can be sent to an electric motor to drive any machine, air taxi propellers or car wheels. In some cases, this current can also be stored in a connected battery if the electric motor occasionally has to work less. And from here on, a significant difference arises from the combustion engine with hydrogen described above, which served as a direct drive in a car like BMW. Direct drive means frequent change from idle to full load, from 1000 to 6000 revolutions per minute. It is difficult to adapt an engine to such speed and load jumps, we all know the good and the worse areas of work of an automobile engine.	现在我们来到了和燃料电池一样的起跑线：电能可以传送至电动机驱动任何类型的机器，如小型飞机的螺旋桨或汽车车轮。一些情况下，如果电动机偶尔需要降低功率，可以将部分电力储存在相连的电池中。从这里开始，出现了一个巨大的差异，之前提到的氢内燃机并没有配备电池，而是直接驱动，如宝马。直接驱动意味着要在怠速状态和满负载状态——即每分钟 1000 转和 6000 转之间频繁切换。想要让发动机适应这样的速度差和功率差十分困难，毕竟汽车发动机做功的优点和缺点是众所周知的。
The now meant internal combustion machine (at this point deliberately not called "combustion engine" to avoid a direct association with "four-stroke piston engine") should only rotate a current generator, always at constant speed and with constant load. You really don't need a high-tech four-stroke piston	这就意味着内燃机（此处有意没有将其称为“燃烧机”，以避免和“四冲程活塞发动机”产生直接联系）应该只带动发电机，这样就能一直保持不变的速度和输出功率。如此一来，你其实并不需要每个气缸有四个阀门和双涡轮增压的高科技四冲程活塞发动机！也不需要每分钟转 6000 转。带动发电机

engine with four valves per cylinder and double turbocharging for that! And also not 6000 revolutions per minute. This task requires nothing else as a simple machine that can send the pressure from a combustion to a shaft in the easiest way, in order to turn on an electric generator.	所需的机器很简单，只要能用最简单的方式把燃烧产生的压力传递给连轴即可。
The first approach is a two-stroke engine: it not only has fewer components than a four-stroke engine, but also a double number of working cycles, work in every one revolution, not in every second revolution, as with the four-stroke engine. With the same power, this makes the two-stroke engine much smaller and lighter[10]. One thinks certainly first to smelly like East-German Trabant cars (Trabbis). Using this type of stationary working engine with hydrogen, however, the processes are different: In the Trabbi, air was thrown into the cylinder together with fuel and lubricating oil through the inlet slots, at low speeds part of this charge was lost through the still open outlet slot. In the two-stroke engine as a generator, there is essentially a single working speed, for which the air supply ca be exactly tuned. The hydrogen is injected separately from the air, directly	第一种方式是二冲程发动机：它的零件虽然比四冲程发动机少，但同样能进行双工作循环，就像四冲程发动机一样，每一转都可以做功，而不是每个循环的第二转才做功。虽然动力相同，但二冲程发动机体积更小，重量更轻。看到这里，人们首先一定会想到东德的特拉贝特（特拉比）之类的臭气熏天的汽车。但这种使用氢能的固定式发动机却大不相同：在特拉比发动机中，空气、燃料和润滑油一起通过输送槽进入气缸，低速情况下一部分燃料会从没来得及关闭的输送槽溢出。而使用二冲程发动机作为发电机的重点则在于它的工作速度是单一不变的，空气供应也十分协调。氢气和空气分开注入，直入缸盖，此时所有输送槽都已关闭，在燃烧反应发生前不会有燃料损耗。润滑油是单独分开的，在曲轴箱里。这种紧凑型的燃料直入式二冲程发动机由茨维考技术研究中心发明，在实际应用中体现出了较高价值。图

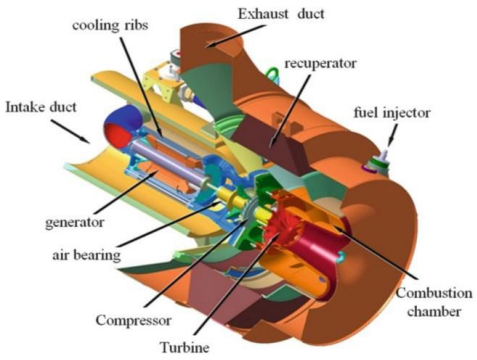
into the engine head, after all slots are closed, so there is no lose of fuel before combustion. Lubrication is carried out separately, in the crankcase. Such compact two-stroke power generators with fuel direct injection, which were developed at the Zwickau Research and Technology Center, have proven themselves in practice [10]. Fig. 23 shows such a two-stroke engine with fuel direct injection.	23 展示了这种燃料直入式二冲程发动机。
The fresh air compressed by the piston, which is passed from the inlet channel (right) via the crankcase into the cylinder, can escape partly via the outlet channel (left), but what you lose is only a little amount of fresh air. The fuel is only injected later, in a 0.3 thousandth of a second, from the nozzle in the head.	空气经过曲轴箱从进气口（右）进入气缸，活塞再对新进来的空气进行压缩，过程中会有一部分空气借由排气口（左）排出，不过你损失的只不过是少量的新鲜空气。燃料只会在万分之三秒后从缸盖的喷嘴注入。
	TWO-STROKE SPARK-IGNITION ENGINE：二冲程火花点火式发动机 INTAKE DUCT：进气口 EXHAUST DUST：出气口 HIGH PRESSURE INJECTION SYSTEM：高压喷射系统 MOTOR：马达 LOW PRESSURE FUEL PUMP：低压燃油泵
Fig. 23 Two-stroke engine with fuel	图 23 作为发电设备的燃油直喷二冲

direct injection as a power generator (Source: FTZ Zwickau)	程发动机（资料来源：茨维考外贸区）
Fig. 24 Wankel engine with rotary piston as power generator (Source: Mazda)	图 24 采用旋转活塞作为发电机的转子发动机（资料来源：马自达公司）
Like the two-stroke engine, a compact Wankel engine can be used as a power generator as well. The main advantage of a Wankel engine over a piston machine is the rotational movement during the work phases, which allows the work to be transmitted directly to the current generator via a shaft. In piston machines, the back and forth of the piston must first be converted into rotation using a crankshaft.	和二冲程发动机一样，紧凑型的转子发动机同样可以用于发电机。转子发动机对比活塞机的主要优势在于，转子发动机进行的是旋转运动，可以通过转轴将功直接传递给发电机。而在活塞机中，活塞进行的是往返运动，必须先利用曲轴箱将其转变为旋转运动。
The main disadvantage of a Wankel engine for direct drive in automobiles is the formation of a very unfavorable, gap-shaped and jagged combustion chamber, which is due to the shape of the rotary piston and chamber: without this Wankel geometry, however, compression, combustion and expansion during a rotary movement would hardly be possible. Mazda has shown in an excellent manner, that such engines work in cars and have a good torque curve, but with the pollutant emissions it was not so famous: The sickle-shaped combustion	由于转子发动机使用的是旋转式活塞和腔室，导致燃烧室中形成了不规则的空腔，看起来不太顺眼，这是直驱式汽车转子发动机的主要缺点。然而，也正是得益于特殊的几何形态，转子发动机才可以在旋转过程中同时进行压缩、燃烧和膨胀。马自达极好地展示了这种发动机在汽车上的应用表现，扭矩曲线十分优秀，但由于污染排放问题，这种车并没有那么出名：转子发动机镰形燃烧室的自身面积太大，可用容积太小，导致汽油之类的液体燃料会附着在室壁上无法完全燃烧，生成碳氢化合物和一氧化碳，这对催化转

chamber has to much surface for hers volume. Therefore, a liquid fuel such as gasoline lays there on every wall, making the combustion incomplete, and so hydrocarbons and carbon monoxide are spit out, the catalytic converter has a hard task.	化器来说是个巨大的考验。
But when injecting hydrogen, which immediately becomes gaseous, this problem does not exist at all! For this purpose, the engine works as a current generator at a constant and not too high speed, as with the two-stroke engine in the previous example. Similarly, air intake, compression, exhaust gas expansion and discharge can be exactly tuned.	然而，如果注入的燃料是氢，就完全不会出现这种问题，因为氢进入燃烧室后会立刻气化！为了这个目的，转子发动机类似于上例的二冲程发动机，以恒定的不太高的速度运行，就像发电机一样。相似的是，整个进气、压缩、废气膨胀和排放过程也十分协调。
Mazda presented such a configuration in 2010: the Wankel engine of the RX8 car type ran in stationary mode with hydrogen, which was injected in the compression phase and thus completely evaporated in the combustion chamber and then mixed with air. This is a configuration with a lot of potential for power generation when using hydrogen as an energy carrier!	2010 年，马自达发布了这种配置：在静止状态下，RX8 型汽车的转子发动机靠氢气运转了起来。在压缩阶段将氢气注入燃烧室，然后完全气化，最后与空气混合在一起。这种配置利用氢气作为能量载体，发电能力强，前景十分广阔！
But there is more potential of combustion machines powering current generators,	不过，用气轮机驱动发电机的应用前景更广阔！

offered by the gas turbines!	
Similarly to the Wankel engine, a gas turbine has the advantage of a pure rotational movement in comparison with piston engines. But, in the case of a gas turbine, without the eccentricity of a Wankel rotary piston. Moreover, a gas turbine has a fundamental functional advantage: All state changes of the working fluid – compression, combustion, expansion, scavenging – take place simultaneously (as far as with the Wankel engine), but each state change takes place in a specially developed and optimized functional module: compressor, combustion chamber, turbine, intake diffuser and exhaust duct.	与转子发动机类似，对比活塞发动机来说，气轮机的优点在于只会进行单纯的旋转运动。不同之处在于，气轮机并没有转子发动机那样古怪的旋转式活塞。此外，气轮机有一个基本的功能优势：工作流体的所有状态变化——压缩、燃烧、膨胀、排放——同时发生（与转子发动机相同），每一个状态变化过程都对应着一个经过特别开发和优化的功能模组：压缩机、燃烧室、涡轮机、进口扩压器和排气管。
A piston-cylinder unit of a piston engine acts differently, once as a compressor, then as a combustion chamber, as an expansion module and as a scavenging system and serious compromises are in this case inevitable.	活塞发动机的活塞缸单元则有不同的运行方式，一会儿是压缩机、一会儿是燃烧室、一会儿是膨胀模组、一会儿是排气系统，在这种情况不免要做出重大妥协。
The axial turbomachinery (casually referred to as "gas turbines", although they also have components other than the turbine) are generally used in aircraft construction (jet engines).	轴流式涡轮机械（通常指“气轮机”，不过除了涡轮机外还有其他组件）常用于飞机构件（喷气式引擎）。
The radial turbomachinery having radial	径流式涡轮机械有径向压缩机和径流

compressors and radial turbines have a lot of potential as powering machines for current generators with hydrogen or other fuels due to their already wide application as turbochargers for piston engines: Basically, for such function, the turbocharger of a diesel engine for automobiles can be quite completed with a combustion chamber.	涡轮机，作为发电机的动力机，可以使用氢气或其他燃料，潜能巨大，在活塞发动机的涡轮增压器方面已有广泛应用：总的来说，有了这个功能，汽车柴油发动机就能在燃烧室中实现涡轮增压。
As a result of the continuous mass flows of air and fuel, the injection nozzle of an axial or radial gas turbine is always open and is designed in a swirl shape to better distribute the fuel. In contrast to piston or Wankel engines, there are no limits to a design of the combustion chamber that is favorable for combustion.	由于空气和燃料的质量流动连续不断，轴流式或径流式气轮机的注射喷嘴是恒开状态，而且螺旋形的喷嘴也有利于分配燃料。与活塞或转子发动机相比，气轮机燃烧室没有设计限制，更有利于燃烧。
The exhaust gas is relieved to the ambient pressure more efficiently than from piston engines. Gas turbines do not operate at 3000 – 6000 revolutions per minute, like piston engines, but at 96,000 -100,000 revolutions per minute. This makes the mass flows faster and the machine much more compact: A very compact radial gas turbine, developed by Capstone for the generation of electricity and heat when operating with biogas or natural gas, delivers no less than 61 kW	废气在环境气压下进行排放，比活塞发动机效率更高。气轮机的运行速度为每分钟 96000—100000 转，并不像活塞发动机那样每分钟只有 3000—6000 转。在此情况下，质量流动速度更快，机器体积大大缩小：卡博斯通曾开发了一款十分紧凑型的径流式气轮机，用于通过生物气或天然气生成电能和热能，机身尺寸十分小，为 77×196×280 公分，但输出功率却不低于 61kW。

of power with incredible small dimensions of 77x196x280 centimeters!	
Switching from one gas to another as fuel, hydrogen instead of biogas or natural gas, poses absolutely no problems. The fuel cell developers can dress warmly!	若把燃料从一种气体换成另一种气体，把生物气或天然气换成氢气，运行起来也绝对没问题。燃料电池开发人员仅凭这些技术就能衣食无忧了！
	Exhaust duct:排气管道 Recuperator:回热器 Fuel injector:喷油嘴 Combustion chamber:燃烧室 Turbine:涡轮 Compressor:压缩机 Air bearing:气浮轴承 Generator:发电机 Intake duct:进气管道 Cooling ribs:散热片
Fig. 25 Radial gas turbine as a power generator (Source: Capstone)	图 25 作为发电机的径向燃气轮机（资料来源：卡博斯通）

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