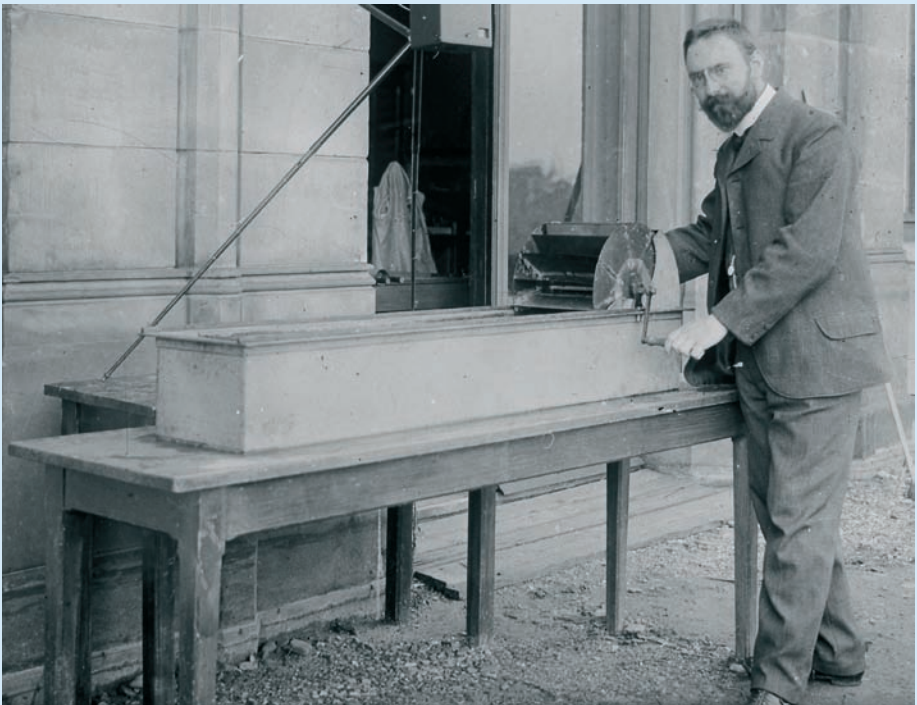


Göttinger Klassiker der Strömungsmechanik Bd. 9
herausgegeben von Andreas Dillmann

Johanna Vogel-Prandtl

Ludwig Prandtl

A Personal Biography Drawn from Memories
and Correspondence



Universitätsverlag Göttingen

Johanna Vogel-Prandtl
Ludwig Prandtl

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Johanna Vogel-Prandtl

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A Personal Biography Drawn from
Memories and Correspondence

Translated into English by
David A. Tigwell



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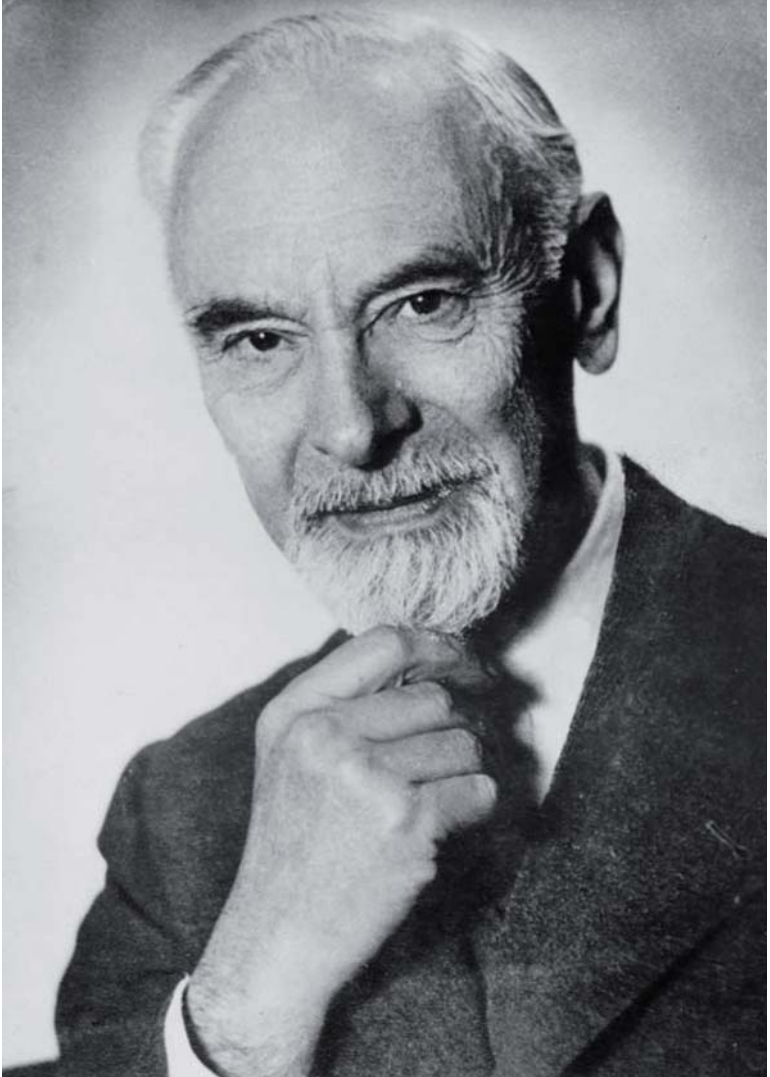
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Titelabbildung: Ludwig Prandtl an einem Wasserkanal.
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Ludwig Prandtl

4.2.1875 - 15.8.1953

Preface

With his seminal contributions to applied mechanics, hydro-, aero- and gas dynamics, Ludwig Prandtl decisively advanced developments in these fields in the first half of this century. With the publication of his collected works, in three volumes, which took place a few years after his death, his papers became accessible to subsequent generations. This written legacy is, however, only a part of his lifework which science has to thank this genial scholar for. Through his encouragement, he also contributed to the work of numerous students and research associates, as well as many colleagues throughout the world.

The portrait of Ludwig Prandtl the researcher would be incomplete if reference were not made, in addition to his scientific works, to his qualities as a person. Some of his former co-workers have, on the occasion of remembrance, described their experiences stemming from encounters with their teacher and so have tried to keep alive the memory of his radiant and exemplary character. As the essays and treatises with recollections are widely scattered, there is a danger that, in the course of time, they will fall into oblivion. So, there has also been the fear that a biography of Ludwig Prandtl would never be written. This gap is filled by the book presented here which was written by his daughter Johanna Vogel-Prandtl. With her memories and other material, she wished, above all, to bring the reader closer to the “man” Ludwig Prandtl.

In 1904, Prandtl was appointed to a position at Göttingen University, where his research career began which gained admiration and recognition throughout the world. As the younger generation may no longer be aware of his achievements, these will be recounted in the following synopsis.

Prandtl proposed the boundary layer theory and the airfoil theory, he had ground-breaking ideas regarding the flow of compressible media and the motion of turbulent fluids, and he applied flow physics to meteorology. But, I should also mention his contributions to the problems of elasticity, plasticity and rheology at this point.

He established two important research institutes in Göttingen: in 1907 the *Aerodynamische Versuchsanstalt* (initially named the *Modellversuchsanstalt*) and, in 1925, the *Kaiser-Wilhelm-Institut für Strömungsforschung*. In the

latter institute, freed from the constraints of external demands, he was able to carry out intensive basic research. He was particularly successful in linking theory and experiment: in addition to the theories referred to above (both bear his name), he developed wind tunnels and measurement equipment for his experiments (e.g. the Prandtl tube and the Prandtl manometer) and so proved himself to be an all-embracing scholar.

Eighty-three dissertations were written under his supervision as a university lecturer. He belonged to the active cofounders of two well-respected societies, the *Wissenschaftliche Gesellschaft für Luftfahrt* (now called the *Deutsche Gesellschaft für Luft- und Raumfahrt*) and the *Gesellschaft für Angewandte Mathematik und Mechanik* (GAMM), founded in 1922, whose president he was from the year of the society's founding until 1945.

Ludwig Prandtl was showered with honours and awards. Amongst his honorary doctorates were those awarded by the TH Danzig, TH Zurich, TH Prag, TH Trondheim, University of Cambridge (England), University of Bucharest, and the University of Istanbul. Some twenty academies or other scientific institutions made him a member or honorary member. Moreover, a large number of medals and other awards were presented to him, most recently the *Großes Verdienstkreuz der Bundesrepublik Deutschland*.

At the end of 1946, Prandtl resigned from being the director of the *Kaiser-Wilhelm-Institut für Strömungsforschung* and he became an emeritus of the university. In 1953, he died at the age of 78 years. He left behind a fulfilled working life and one that was rich in honours.

Ernst-August Müller

Universitätsprofessor für Angewandte Mechanik
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Foreword

In the past few years, it has become an ever more urgent concern of mine to create a portrait of my father, Ludwig Prandtl, in the form of a biography. As his daughter, it should be possible for me to produce a biographical portrait, based on many personal memories that would do justice to the many sides of his character. This account should also not leave aside the scenes which took place in the close circle of his family, which shed light on his personality and which I wish to record now, as the last of his offspring, at least for my children and for those who knew Ludwig Prandtl personally or by name.

I should also note at this point that my uncle, Professor Ludwig Föppl, repeatedly brought up the subject, in conversation with his brother-in-law, that it would be important for him then, having reached old age, to write his memoirs, just as his father August Föppl had done. Prandtl always turned down this request with a smile, “Perhaps sometime in the future: at the moment, I have too many other things to do”. But, I knew him well enough from this kind of reply to realise that he obviously did not intend to reflect on his own life and give an account of it - not even at a later date.

When my father died in 1953 my uncle Ludwig Föppl turned to me with the words, “Now, you should write about him!”

This was certainly the first impulse I had to think about how such an enterprise could be undertaken. Of course, as a layperson, it has not been possible for me to give a specialist interpretation of his scientific work. For this reason, I have only given a general account of my father’s research. His scientific achievements are, however, comprehensively described in his collected papers [50]¹, which are easily accessible to the reader. In addition, numerous references to the literature are given, in order to help the interested reader to study the works of Ludwig Prandtl.

As I started the task of putting together the papers and to write about his life and career, I found that I was able to draw on many publications and

¹ The numbers in brackets refer to the bibliography at the end of this book.

other similar resources to be found in newspapers, articles and letters, which I have cited in this book as extracts. It may be that those readers specialising in the fields of aerodynamics and natural sciences feel that my account of the work of Ludwig Prandtl is insufficient. But, nonetheless, I have at least tried to include in this biography those things which, for him, certainly constituted the core of his life.

It has been my task to give an account of Ludwig Prandtl the person. In carrying out this task, I am grateful for having been able to refer to his own letters and articles, as well as letters written by his students, so that my text has benefited from an authentic record of events in my father's life.

Finally, I would like to thank my husband for the final reading and correction of the book.

A special word of thanks is also due to Dr. Julius Rotta, whose committed assistance enabled me to incorporate valuable additions. He provided scientific articles and checked many quotations for their authenticity. A special contribution of his was to prepare the comprehensive bibliography of the writings of Ludwig Prandtl. I would also like to thank him for proof-reading the book.

I would also like to express my gratitude to Dr. Walter Tillmann, the administrator of the archives of the Max Planck Institute (MPI), for his cooperation and his readiness to help, as well as for his competent assistance in the printing of the book.

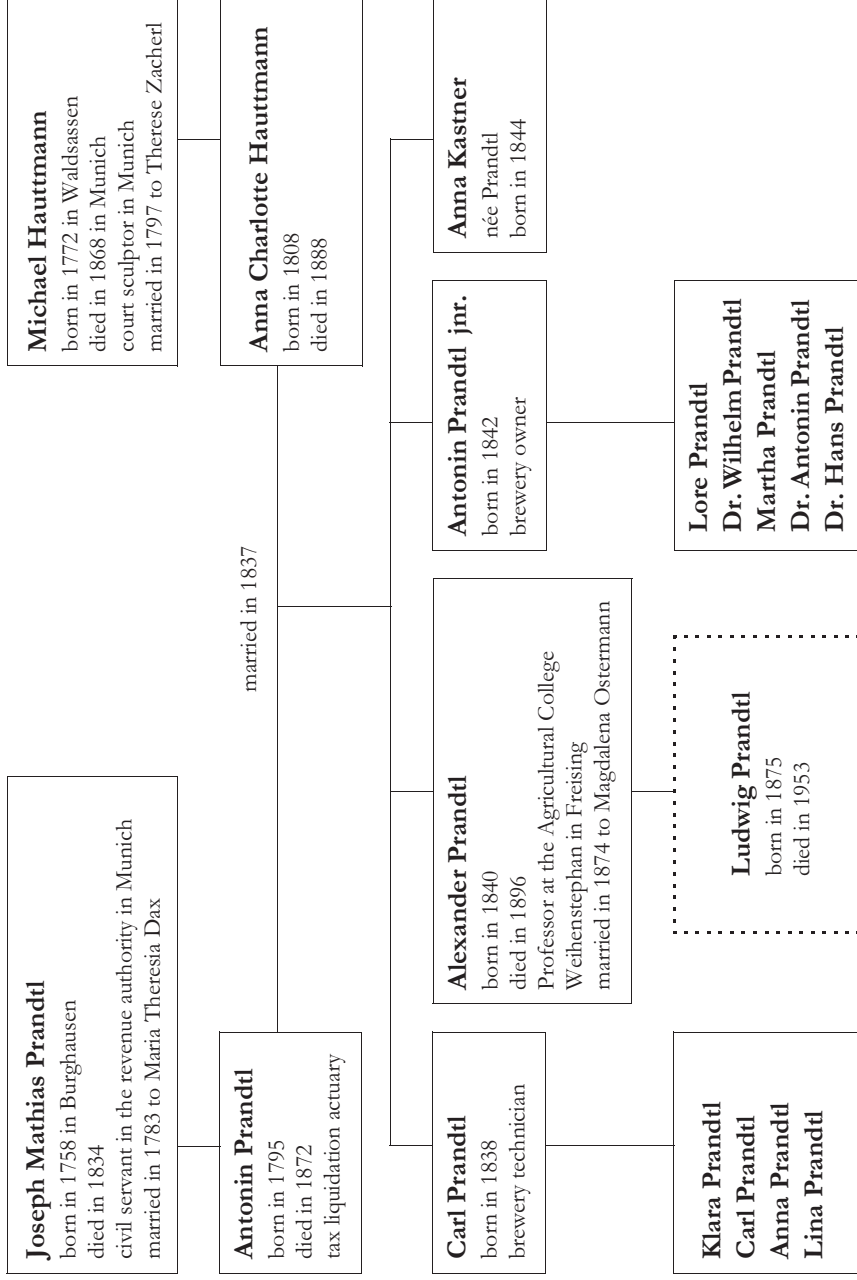
1. Introduction

Which impressions of my father remain foremost in my memory? I think it is his good nature and his inner harmony which first spring to mind. I also remember his calm, thoughtful manner, undisturbed by the impatient fervour often prevailing in the world around him. I have a picture in my mind of a man who tried to cope with things in a caring manner. If, for instance, he wound up the wall clock, whose timing he always kept meticulously regulated, he would not only carefully raise the weight, which had reached its lowest position, with the support of his hand, but also listen attentively for a moment to the steady swing of the pendulum, before he gently closed the glass case.

He had a very strong sense of keeping and preserving things. The simple and unassuming lifestyle prevailing in our house remained unchanged over the years. Greater attention was placed on the material usefulness of objects than making modern improvements. Habit determined the almost unchanging continuity of the existing state of things. I honestly cannot remember my father ever having expressed a wish of a purely material nature. Indeed, I think it was his exceptional modesty and lack of pretension which made it possible for him, in the lean years following the Second World War, to be grateful for even the smallest of gifts.

I know that he would have been surprised or even astonished if he had become aware of my efforts to write this biography. He would certainly have claimed that his life, about which I now wish to share my recollections with you in this book, was not of such great importance to warrant the effort.

Prandtl Family Tree



2. Ludwig Prandtl's Childhood

In attempting to write about my father's childhood I can only give an account that is incomplete and full of gaps since there is no-one who can help me to completely raise the treasure of memories. I will therefore draw on details of his childhood which partly rely on the notes made by my grandfather which faithfully, even if sketchily, record the development of his only son and, in addition, I will recount some of the stories my father told us from memory. Some facts about the family history are recorded in documents collected while researching the history of the Prandtl family, which were compiled and preserved by two cousins of my father, Professor Wilhelm Prandtl and *Ministerialrat* (ministerial council member) Carl Prandtl.

Ludwig, the first child of Alexander Prandtl, a professor in Weihenstephan zu Freising and his wife Magdalena, née Ostermann, was born on Thursday the 4th February 1875 at a quarter to seven in the evening, on the third floor of his grandmother's house, the widow Maria Ostermann, who had been married to a businessman.

The house at Hauptstraße 64 had been in the possession of the Ostermann family for more than a hundred years. The progenitor Ludwig Ostermann emigrated from Austria to Germany in 1760. Together with his brother Franz, who worked as a glass painter, he left his hometown of Kranebitten near Kiefersfelden in order to start a new existence in Freising. The colonial goods business which was then founded bordered a city gate, "Veitstor", which was, however, demolished in 1875, because it was in a dilapidated state. At the same time, modifications had to be made to the merchant's house. In the west part of the house, there were horse stables and low cottages which belonged to a guesthouse. The windows at the rear of the house provided a view to gabled buildings dating back to the Middle Ages and small houses at the back.

In the merchant's house in Hauptstraße, Alexander Prandtl rented a room from the widow Maria Ostermann as, at the age of 29, he started to work as a university teacher at the central agricultural school in Weihenstephan in Freising. He came from Munich, where he had been to school and then studied. After attending the polytechnic school, he gained the qualification

of cultural engineer and obtained an appointment in this capacity with the federal state in Lower Bavaria. He subsequently received an appointment as professor of applied mathematics and amelioration². In Weihenstephan, the following subjects were also taught: agricultural chemistry, agricultural equipment drawing and botanical drawing, the anatomy and physiology of domestic animals, forestry, meteorology, as well as other subjects. A brewery for study purposes was attached to the institution. Alexander carried out scientific work in the laboratory of the dairy research station. In the period between 1870 and 1875, he mostly worked on the construction of a continuously operating milk centrifuge. The idea of studying the separation of cream from milk using centrifugal force came from his brother Antonin, who had published a work on this subject eleven years previously in the polytechnic journal. He initially approached the practical task of making it possible to concentrate milk using his knowledge of chemistry. Alexander was successful in adding some significant improvements to his brother's discovery and, in 1875, he demonstrated his cream separator at the World's Fair in Frankfurt am Main, Germany. This machine, which was the first continuously operating milk centrifuge in the world, attracted great attention and provided the impulse for further developments. The same model was later exhibited in the *Deutsches Museum* (German Museum), in the Department of Dairy Farming. In the next few years, he developed a new piece of equipment: a milk separator that could be used to produce milk in parts without it creaming. In addition, Alexander published a number of scientific papers in the Weihenstephan Milk Journal, whose themes I would like to mention here for reasons of completeness. In 1877 the article "On the theoretically expected effect of creaming caused by centrifugal forces" and, in 1879, "The effect of currents caused by heating or cooling milk" were published.

The Prandtl family, which earlier had the family name of Präntl, had been resident over a number of generations in Munich since the beginning of the 18th century. Tracing the family history further back reveals that their forefathers were to be found in the Tegernsee region. It was here that the carpenter Bartholomäus Präntl lived, whose eldest daughter Maria is mentioned in a chronicle in Egern, as she was the founder of the Marian Association in her hometown. She died, having led a pious life, on the 19th

² The science of soil improvement

January 1770 and the following words were entered in the Egern register of the deceased:

“Huius nomen, benigne lector, non leviter praetereas, illius Mariae nomen est, quae plurimas, et verbo et exemplo, animas docuit imitari quoad possibilitatem nostram in castitate Virginem Beatissimam. Fundatrix enim seu auctrix pacti ut vocant Mariani in Egern, haec erat immo et benefactrix, quod suo labore sudore re sibi lucrata fuerat, Deo, pauperibus et Beatissimae Virgini consecraverat. Conclude bone lector, qua morte mortua fuerit, quae tam pie vixit. A Daemone quidem obsessa fuit, sed crede non ad suam, sed ad maiorem daemonis torturam, daemonis inquam utpote tot excellentes virtutum actus, quos illa quotidie exercuerat, aegre certe ferentis, quia videntis. 19. Jan. ad hoc invisio hospite et simul a carcere carnis liberata est cum Christo aeternum regnatura in coelis, quem unice amavit in terris et ante abitum ex hoc mundo saepius in Domino devotissime suscepit Altaris sacramento.”

“Dear Reader, please do not pass casually over her name, for it is the same Maria who taught numerous souls through her words and her example to emulate the most holy virgin in the virtue of chastity, in so far as this is possible for us. She was, namely, the founder and patroness of the so-called Marian Association in Egern and a true benefactor who, in the sweat of thy face, devoted herself to God, the poor and the most holy virgin. Please infer from this, dear reader, what a death one who had led such a pious life must have had. She was indeed possessed by an evil spirit, but please believe it was not hers but the demon’s greatest anguish, who was surely vexed when he had to observe the many outstanding deeds of piety which she performed every day. On the 19th January, she was freed from this unbidden guest and, at the same time, from the fetters of the flesh, in order to be for eternity in heaven with Christ, whom she solely loved on earth and whom, before departing from this world, deeply devoted to God, she frequently received in the holy Sacrament of the Altar.”

Maria’s brother Wolfgang Pränzl, also a carpenter like his father, was the first one to emigrate to Munich, where he found employment in the Anger monastery. It would provide the reader with too much detail if I were to list all the members of the family, over many generations, and therefore I will jump to the grandfather of Ludwig Prandtl, Antonin Prandtl, who was

born in 1795. As a young man he was a regular soldier before he chose the career of a civil servant, which later led him to become an actuary and tax liquidator. At the age of forty and with a good position, he married Anna Charlotte Hauttmann, the daughter of an electoral court sculptor. His father-in-law, Michael Hauttmann, born in 1772 at Waldsassen, descended from a well-known family of artists, who were referred to in Franz Bienbach's book *Geschichte des Cisterzienserstiftes Waldsassen*, whose various family members created woodcarvings for the monastery church in Waldsassen. The court sculptor Michael produced works for the burnt-out chambers of King Maximilian I, in the old residence, as well as the decorations for the royal box in the court theatre. He later devoted himself to carving in ivory, alabaster and mother-of-pearl. Items from this ivory cabinet can be found in the Bavarian state museum. A few small pieces of work from his creative period at the beginning of the 19th century are still in our hands: very fine carvings which are also worthy of a place in a museum. He died in 1868, in Munich, at the age of 97.

Antonin Prandtl and his wife acquired a garden plot in Untergiesing and established a small coffee business there. Their guests were exclusively young people; mostly artists who were attracted to the "foreign" suburb. The liberal, free lifestyle there, with guests providing much excitement and stimulus, gave great pleasure to Antonin's growing children - three boys and a girl - and, at the same time, very much advanced their intellectual development. The parents enabled them to gain a secondary education and then a good training for a career. Carl attended lectures in chemistry given by Justus Liebig. He then changed to fermentation chemistry and subsequently devoted himself exclusively to the brewing business. He was an assistant for chemistry and technology at the Central Agricultural School in Weihenstephan. He produced some scientific works and articles, and also invented the Prandtl filter press and the Prandtl yeast press. He became the general representative for these brewery machines. There was already much talk about the intellectual achievements of Antonin the younger at this time. When he was not given the privilege of transforming his ideas about dairying into practice himself, he changed to the brewery business. He was a master brewer in Switzerland, for many years in Hamburg, and then returned to Munich in 1884 and, together with his brother Carl, acquired the Giesing brewery. A decade later, as electrification was being introduced into breweries, it was no longer

possible for him to adapt the small business and it went into insolvency. As experts, they were able to continue to work, thanks to their good scientific knowledge. The youngest of the sisters, Anna, married a district judge. Alexander, the father of Ludwig Prandtl, has already been mentioned above.

The circumstances in the Ostermann house in Freising in which he found lodgings were much more modest and confined than those of the Prandtl family in Untergiesing. Of course, in this suburb of Munich, which was even connected with the capital of the federal state by a horse tram, life was more exciting and freer than in the small town on the left-hand bank of the Isar where the Mosach flowed in. The resident population of Mosachstadt (the town of Mosach), as it was sometimes called, amounted to 7,000 souls at the time when Alexander resided there. The towers of four old churches rose up between the old houses. There was a basilica with adjacent monastery buildings in which there was a seminary for Roman Catholic priests, visible from a long way away on a hill, the so-called Domberg. The widow Maria Ostermann, née Döbl, was the daughter of a master baker in Freising. The tradesman Ludwig Ostermann - as he was referred to in the Freising church register - was 22 years older than his wife. He died when the children were still very young and so Maria Ostermann had to carry the burden of and responsibility for raising them alone. The four children, Magdalena, Ludwig, Leopold and Maria were brought up in a strictly catholic manner, for reasons of living under the influence of this spiritual centre or because of traditional constraints. She saw to it that they attended the convent school and regularly attended church as she had absolute faith in the authority of the church, which she believed would give her help in the fulfilment of her difficult tasks. When Alexander later got to know his future wife, she was still a schoolgirl and just 14 years old at the time. But, already at this early stage, he had formed a liking for this small, delicate girl who, with touching conscientiousness, took upon herself domestic and school duties. A number of school books belonging to Magdalena, which are filled with many pious words and maxims and written in delicately sweeping, perfect handwriting, still survive. Also, my father Ludwig Prandtl kept some book prizes in safe-keeping, which contain a dedication such as the following example, "1st prize for general progress throughout the year to Magdalena Ostermann,

pupil of the higher secondary school for girls³ Freising”. All of these gift books were for receiving the first prize. Alexander increasingly took the image of this earnest, very shy girl to his heart. On the 18th September 1872, he celebrated his engagement with Leni. He married his eighteen-year-old fiancée on the 19th March 1874 in the parish church of Freising. The couple were both Catholics, but Alexander was not, however, so firmly committed to the church. In a letter to his future wife, Ludwig Prandtl wrote in 1909, “Up until not a very long time ago, I was strictly Catholic — a fact which can certainly be attributed to my pious mother”. He asked Gertrud Föppl about her religious beliefs and then continued, “If two people wish to live in harmony, the religious attitudes of the partner constitute a very important element. Much to my sorrow, I have observed that my parents, although they were good people, did not harmonise very well in certain aspects, whether it be in questions of religious belief, the upbringing of children or other matters. My parents’ marriage was, apart from the later strains brought about by unfortunate illnesses, a model marriage, which was concluded as a result of mutual love but, as a result of a lack of understanding between the couple, later was not a happy one for them both.”

When Ludwig Prandtl was born in 1875, his mother was just 19 and his father 35 years old. I would like to quote a few notes from the latter’s diary at that time. “On the 11th February, his baptism took place. On the 4th May, we went to the shooting range, so that we could plant 12 conifers in memory of the birth of Ludwig. On the 16th December, Ludwig fell out of his pram without injuring himself seriously.” The child’s weight and height were measured precisely every birthday. 4th February 1879, “Ludwig can count up to 10 objects and perfectly repeat tones”.

In the meantime the young family had moved into their own accommodation, which was also located in Hauptstraße at number 41. 30th April ‘79, “Ludwig is able to take a message to his grandmother”. On his way, he independently made his own observations. Full of curiosity, he looked into the holes to the drains opened up by the road-men and arrived

³ Translator's note: in the original text, the expression ‘höhere Töchterschule’ is used. This is not used in modern German. Basically, it means a secondary school for girls at which modern languages are emphasised in the curriculum

home late. He told me the following about a quite early recollection: the lonely, dreamy child played, as he frequently did, on the street in front of the house as a dark cloud suddenly opened its flood-gates and it started to rain. Instead of running immediately into the house, the young Ludwig stayed in the rain. For him, it was so fascinating to observe the way in which the gutters filled more and more with water, and leaves and scraps of paper floated away in the stream. A woman hurried past him with her garment gathered up. The end of her broad dress had blown up like a hood over her head. The little Ludwig made an unexpected discovery: under women's dresses, legs were concealed that were constituted like those of a man. The fashion for dresses going right down to the feet and the prudish attitude typical of the time had kept this fact hidden from him. Another little story, which happened later, took place at the railway station. Ludwig accompanied his father to meet some relatives travelling by train. The expected encounter occurred, the relatives greeted each other warmly and then they all tried to make their way to the ticket barrier amid the stream of people. But, Ludwig's father then noticed that his son was no longer beside him and was nowhere to be seen. Somewhat worried, he walked down the platform. There was Ludwig lying with his stomach on the kerbstone directly in front of the train, observing it attentively from below. Ludwig's father was not sparing in his harsh words as he led his son away. When my father told me his story, he assured me that he was not really conscious of being guilty although, understandably, he was bored by the exchange of words and so had pursued his own interests.

Another memory, relating to Easter, can be recounted here. In Germany, at Easter time, it is customary to hide coloured eggs in the garden for the children to find. Ludwig systematically searched the garden and placed the treasure he had found in a small basket which his mother had provided for him. It really took a long time before all had been gathered. But, there was an expression of disappointment on the boy's face as he was allowed to take the basket. He saw at a glance that not all of the eggs which he had collected earlier from their hiding places were still in the small basket. So he started to check and count them and, to the astonishment of his parents, he had remembered exactly how many eggs of each kind he had collected and this number did not precisely correspond with the number now to be found in the basket. The reason was that his father had secretly re-hidden the eggs which Ludwig had found, in order that the game would

go on longer, thinking that he could play a little game with such a young boy. However, now, in order not to be accused of deception and being fond of sweet things himself, he had to admit the whole truth about his actions to his son.

1880: “Ludwig started to read printed material.” 1881: “Although Ludwig is thin, he looks healthy. He wants to be a gymnastics teacher.” In the autumn of 1881 he started going to school. 1882: “Ludwig came first amongst 82 pupils!” He remained the best at elementary school. In September 1885 he was enrolled to attend the grammar school which was at the Freising Domberg. On the 4th April 1886, Ludwig attended Holy Communion for the first time and, on the 15th May, his confirmation was celebrated.

Circumstances at home had become very difficult indeed at this time, as a result of his mother being frequently ill. Serious reversals of fortune had adversely affected her delicate health, which ruined her both physically and mentally. She brought another boy into the world in April 1877, but he died unexpectedly after only one week. In January 1879, a third child, a little girl, was born who had jaundice and subsequently died from this illness two weeks later. Magdalena Prandtl went alone to Altötting in the summer, in order to find comfort in prayer. In 1881, the stillbirth of a six-month-old baby followed. In 1883, the same misfortune occurred once more. She had two further miscarriages, after which her strength had become completely sapped. On the basis of modern medical knowledge, it appears likely that the “rhesus negative factor” was responsible for her misfortunes. She was naturally unable to take preventive measures, since the cause of the problem was unknown at that time.

Magdalena Prandtl suffered quite often from spasms of the heart (stenocardia). In 1888, her mental upset developed into a nervous disorder and she was unable to remain at home. The doctor advised her husband to take her to a psychiatric clinic in Munich. When she returned home six months later, she was still bedridden. As her condition did not improve, after a while, she was taken to a nursing home in Neufriedheim.

His mother’s illness cast a dark shadow over Ludwig’s childhood, even though his father took even greater care of him, because of this. The

unmarried sister of Magdalena, Marie, took charge of the household for her brother-in-law during those difficult times and she occupied herself a great deal with her nephew. She played the piano with Ludwig, four-handed, and she sang folksongs and other songs with him. Nevertheless, Alexander's personality was very much at the centre of Ludwig's experiences during his childhood, while the influence of his mother increasingly declined as a result of her illness. Ludwig's father promoted his interest in physics, which developed at an early age, and he gave him his books and explained to him the functioning of machines and instruments illustrated in them. He encouraged him to observe nature; particularly during their walks together in the local mountainous countryside. The wide range of his father's knowledge about natural history was able to satisfy the intellectual demands of the young Ludwig, who frequently expressed his interest by asking questions. In order to enrich his private instruction in natural history, one day his father brought a box with two white mice into the house, as a visual aid, which was placed on the balcony. Soon after, the first baby mice appeared in the nest which required both care and attention. At the same time, they provided amusing occupation for the young boy. However, after only a few months the mouse family had grown so alarmingly in size that it was decided to bring an end to this successful breeding programme.

From time to time, Alexander was very much occupied with questions of bringing up the boy. He was very annoyed when Ludwig daydreamed or lagged behind when he should have been doing his homework, which happened quite frequently. This stretched his patience to the limit, so that he sometimes took strict action in order to correct his failings. In this way, he moulded and guided the young boy, whose well-being and development were a matter of great concern to him. He made detailed notes in a diary about Ludwig's development, including school reports, illnesses, trips and holidays. Alexander's siblings, Carl and Anna, often made visits, as well as, of course, Carl's children who were of the same age as Ludwig. Meetings also frequently took place in Munich, the old home town. Particularly fond memories remained in my father's mind of the days and weeks during which he visited his aunt Anna, his father's sister, in Dingolfing. She herself did not have any children and invited a number of her nieces and nephews to her home, whose cheerful playing in the house and garden never proved too much for her. With this aunt, the wife of the senior judge

at the Amtsgericht⁴, Ludwig felt himself to be especially affectionately accepted and, in the circle of his cousins, he forgot about the sorrows and troubles of his own sad circumstances.

Those relatives of his who were of the same age were the best playmates and they were able to fulfil the role of substitutes for the siblings which he did not have. Throughout his whole life, Ludwig showed his affection towards them. A cousin wrote the following to Ludwig in 1944, “I remember how you, already as a pupil, thought about the problems of balance and statics. Do you remember the experiments you carried out after dinner with bottles, plates, forks and knives, which reached an alarming height?”

At that time the grandmother, Anna Charlotte Prandtl, was still living with her daughter in the Dingolfing area and she was pleased to be able to often have her adolescent grandsons by her.

The trips during the holidays which Ludwig undertook together with his father were also an experience which he remembered with fondness later. These holiday trips, recorded in Alexander’s diary, were either to the lake area in the vicinity of Munich or, via Innsbruck, to the various mountain valleys in Austria, sometimes even as far as to South Tyrol, to Bozen and Meran. If occasionally the excursion lasted longer, Ludwig would use the time to sketch the landscape in great detail. His home-town of Freising was also the object of his artistic enthusiasm on many occasions. The loving manner in which he drew details reflected a well-developed talent for a child of his age and, at the same time, the mark of a patient, creative power.

Alexander attached a high value to the development of the musical ability of his son. At the age of nine, Ludwig had his first piano lessons with Professor Durmayer. The father himself liked playing the piano very much and was in the habit of organising musical evening entertainment with a teacher from Freising. In addition, he had achieved a certain virtuosity in playing the horn, just like his brother Carl. Alexander and Carl once gave a public concert of horn duets together, with a wide-ranging programme lasting over two hours. The musical activity was in keeping with an inner

⁴ Amtsgericht = lower district court having jurisdiction over minor civil and criminal cases

need of Alexander, who found no refreshment in religion. His attitude to the church became one of increasing rejection. He could not reconcile the dogmatic beliefs of the catholic religion with his scientific, critical way of thinking. In particular, the dogma of the infallibility of the Pope, which was proclaimed in 1870, appeared to him in retrospect to be unacceptable. Perhaps he was also influenced by the group of professors from Munich who together protested against the dogma (old-catholics). Alexander finally left the church around 1886.

The influence of his father on Ludwig's life in relation to religious matters, as well, cannot be disregarded. The task which fell to Alexander, as a result of his wife's illness, of caring and looking after his child was one which he could only accomplish with great difficulty, because of a lack of time, as he was often away from home in the course of his work. Therefore, in the autumn of 1888, he decided to enrol Ludwig in the Royal Educational Institute, the Ludwig Grammar School in Munich, whose director was Willy von Coulon. He was given accommodation in a dormitory, the Hollandeum, and only went home during the holidays. He had a bad experience of communal living with other pupils, since there was a lot of teasing and he was put down by the ingenious, stronger pupils. He could not muster up the strength from within to defend himself against all of this loutishness. He suffered his misfortunes in silence. As the school year came to an end, his father took him back to Freising as, in the meantime, his mother's state of health had improved. But, as has already been mentioned, this was only a temporary improvement. Her illness soon became worse again. Ludwig now attended grammar school in Freising for two years. As his mother then had to withdraw completely from family life, the young Ludwig was once more sent to the grammar school in Munich. This time, however, he knew a little better how to assert himself in relation to his fellow classmates and he also made friends. Oskar Winsauer wrote the following account of this time spent together at boarding school and day school. In 1940, he became the town priest at the Heilig-Kreuz (Holy Cross) church in the Forstenried district of Munich.

“6th April 1941. Dear fellow student,
I have finally got around to writing to you! There were many times when I intended to sit down to write to my dear fellow pupil from Hollandeum

and to congratulate you, particularly on the appearance of your picture in the '*Neuen Münchner Tageblatt*' newspaper, together with the report that a high public honour had been bestowed on you⁵. But, one thought kept me back from doing this. What would the famous scientist care about a simple priest? But, however, in the meantime I have met Klotz and Reiter, who have told me that you have kindly given them a sign of life. So, in turn, I also want to give you a sign of life and present you with a document from the previous century which I enclose herewith. Poor companion in misfortune! But, why did you also have to stain your copybook? By the way, that would hardly have been the only detention which we received. I amassed at least 60 per year of them altogether, because I allowed myself the liberty 'to write with ink in a book' or 'because of loud sneezing' and other such things — but, mostly because of a lack of attention. If you come to Munich again during your holidays, I would kindly ask you to phone me.”

Ludwig's achievements in the fields of natural science were, throughout all that time, well above the average and, as a result of this intellectual superiority, he was able to gain the respect of his classmates.

In 1894, he was able to start studying and indeed he remained in Munich. He was a student at the Technical University for four years.

In the meantime, the household in Freising was completely dispersed. Alexander, who suffered from myocardial insufficiency, retired at the age of 52 years and moved to his sister Anna in Dingolfing. The burden of his fate weighed on him. He died there on the 17th March 1896. His wife was relieved from the many illnesses she had suffered from when she died in 1898. Ludwig was now left on his own. He became completely engrossed in his research which, already after only a few years, put him on the road to success. This prompts me to say that it was particularly sad for him that his parents were not able to share in his joy.

⁵ Author's note: what is probably being referred to here is the Free State of Bavaria, Golden Ring of Honour with the Bavarian federal state coat of arms, 7.05.1926

3. Ludwig Prandtl the Apprentice, Student, Engineer and Professor

Since Ludwig Prandtl had a keen interest in physics and technical matters, the choice of a subject to study at university was not a very difficult one for him to make. He decided he would like to become a mechanical engineer. In keeping with the advice given to him by his caring father, he began a three month period of practical training in a workshop in August 1894, immediately after finishing school in July. This period of practical training, which he needed to undertake before starting to study, took him to Nuremberg, where he had applied to the *Maschinenbaugesellschaft* MAN (United Machine Works Augsburg and Nuremberg MAN). There, he worked in the foundry, as well as in the pattern-making joiner's workshop. In the autumn of 1894, he started studying at the *Königlich Technische Hochschule* (Royal Technical University) in Munich.

At the Royal Technical University, he was able to attend lectures given by, amongst others, August Föppl, Professor of Mechanics, S. Finsterwalder, Professor of Mathematics, L. Sohnke, Professor of Physics, and M. Schröter, Professor of Theoretical Mechanical Engineering.

Prandtl also used the time available to him during the holidays to extend his practical experience, some of which was acquired once again in Nuremberg. In 1898, he concluded his training at the Royal Technical University by qualifying as a mechanical engineer.

Certainly, the time Prandtl spent in Munich as a student broadened his horizons significantly. He became a member of a students' fraternity and the Munich Choral Society which brought together mostly musically-active students. My father had a beautiful bass voice and he very much enjoyed singing in a polyphonic choir. Just like his father before him he took up playing a brass instrument. His chosen instrument was the French horn. A fellow member of the student society - Hermann Peckert - who contacted Prandtl after an interval of 40 years, referred to this in a letter dated the 5th May 1939, "I assume you still remember me, even if

not with such clarity as I still remember Prandtl the trumpeter, with his full black beard and his contented disposition; a man who was always free from strong emotions. I am sure you have not changed since then. Perhaps, however, you gave up playing the trumpet after you had studied the air vortex produced by that instrument in sufficient detail". Prandtl's favourite instrument was and remained the piano. After six years of practising, he had made good progress in playing this instrument. He played sonatas by Beethoven, Haydn and Mozart. He also sang lieder by Schubert and accompanied himself on the piano.

His affinity to music and his love of the piano also found expression in other ways. He would sometimes join students for excursions in the local surroundings. In some of the small village churches he visited while out walking, he would climb the stairs to the organ, check the bellows and then play preludes for a while, changing register in succession. He had a particular liking for this versatile instrument.

It therefore comes as no surprise to learn that, when his institute in Göttingen was to be extended, he had toyed with the idea of installing an organ in one of the halls.

There were also some social occasions which gave him great pleasure. My father told me about a party which took place around the time of *Fasching* (the German word for costume parties during carnival time taking place, above all, in southern Germany) and was staged with a great deal of fantasy. Many of the female partygoers, who were dressed as Dutch women, brought linen baskets with them. Everywhere in the room washing lines had been hung up and everyone had the opportunity of hanging up their own linen. Of course, true propriety was observed - no "unmentionables" were permitted! However, handkerchiefs, serviettes and pillow cases were soon to be seen in colourful arrays hung up on the washing lines. In these surroundings, which resembled a large drying loft, the assembled party-goers laughed and danced.

My father was a frequent guest of his uncle, Carl Prandtl, who lived in Munich at that time. When visiting him, he made preparations with his cousin Carl for excursions together in the mountains, or accompanied his cousin Clara on walks along the Isar or in the park at Nymphenburg castle.

On completing his studies, in 1898, which he passed with the overall grade of “very good”, he received an offer of a post as an assistant from Professor Föppl, which he accepted with pleasure. The position, which was intended for a would-be PhD student, was only granted for one year. In principle, on completion of his studies, Prandtl would have now had to fulfil his obligation to do military service. Therefore, August Föppl wrote to the commander of the Royal Pioneer Detachment on the 8th July 1898 with the following request,

“With the start of the new academic year this winter, practical classes have been arranged in the mechanical-technical laboratory of the Royal Technical University, under my direction, for which an additional assistant has to be appointed. Mr. Ludwig Prandtl is particularly well suited for this post, but he will be leaving the technical university at the end of the semester and will then be liable to be called up for military service. Because of the reorganisation of this subject area it is very important indeed to have an engineer with a good academic background to fill the aforementioned position. If this is permitted, an ideal solution would be to defer his military service by one year. I would therefore like to ask the commander of the Royal Pioneer Detachment to kindly grant the deferment of Mr. Prandtl’s military service by one year. In this way, you will be doing a great service to teaching at the Royal Technical University. In the hope of your granting my request, I remain, with the greatest respect for the Commander of the Royal Pioneer Detachment,
Yours faithfully,
Dr. A. Föppl, Royal Professor”

The request was granted and the time spent by Prandtl working for August Föppl in the mechanical-technical laboratory can be stated precisely: from 1.10.1898 to 30.11.1899. He not only assisted in classes, but also participated in a number of experiments and theoretical projects concerned with stability and elasticity. One of these was later to become the subject matter of his doctoral thesis.

At that time, it was also common for an assistant to be invited to the home of his professor from time to time. It was customary to give young people help and guidance in learning the art of social interaction. Of course, the invitation would follow the rules of social protocol. The

young man would drive up on a Sunday in a hackney carriage. Before meeting his host, he would present his visiting card to the housemaid and then slip off his white gloves, before being greeted by his professor and his wife in the drawing-room. The Föppl family was not particularly rigid in matters of etiquette, so Prandtl felt at home in the company of his professor and family. On visiting the family for the first time, he also had the opportunity of getting to know the children. My mother, the oldest daughter of the family, was 16 years old at the time. She was a shy, fair-haired girl. There were also two younger brothers, who were still at grammar school, and a little sister who was six years old. As my grandmother heard that the new assistant had recently lost both of his parents, she quite often invited him to meals with the family.

One of the two sons, Professor Ludwig Föppl, who later became a brother-in-law of Prandtl, sent me a short private communication with the title "Recollections of Ludwig Prandtl". His description of the personality and effectiveness of his brother-in-law in many ways provides a fortunate complement to my account. His text begins already with his recollections of this time.

"My first encounter with Ludwig Prandtl which I still remember was in 1898. The twenty-three-year-old assistant to my father, August Föppl, was invited by my parents from time to time to Sunday dinner. He also gladly stayed after dinner to drink a cup of coffee, particularly since he received motherly affection on the part of my mother. This practical woman with a warm-hearted disposition took the young Prandtl, who was so alone and abandoned to the world without female support, under her wings from time to time. She gave him practical suggestions, which certainly provided him with valuable advice for coping with the problems of everyday life. Once, on one of his visits, she noticed that the hanger on his coat had become detached and as Prandtl took his leave, it came as a surprise to him to discover that, during his visit, the 'fairies' had carried out a repair. During one of Prandtl's visits at Christmas time, when I was 11 years old my father suggested, after dinner, that I play a Christmas carol on my violin. I followed his suggestion with hesitation and I must admit my playing was only of a modest standard. In no way could I claim that I had such a fine sensitivity for music as Prandtl clearly had and, when I recollect the

occasion today, I am sure that listening to me playing the violin was not something that Prandtl enjoyed that day. After I had finished playing he politely said that the violin was a little out of tune. However, I was aware that he made his criticism with much tact, so as not to hurt me.

Prandtl wrote his doctoral thesis during the time he held the post of assistant to my father. The thesis was on tilting phenomena in relation to bars subjected to a load, a subject which he chose himself.

As this was his first project, which he also carried out independently, reflecting the true hallmark of Prandtl's character, I want to devote a little space at this point to the problem he was investigating and his approach to finding a solution. Imagine, for example, a T-square placed horizontally with one end, where the cross-piece of the T-square is located, fixed in position while the other end (with the T-square placed on end) is subjected to a load created by an increasing weight. A relatively small weight will already produce a lateral displacement of the end of the T-square subjected to the load.

Prandtl introduced the term 'tilting' to refer to this phenomenon which has subsequently been adopted to refer to such processes occurring in supports, in general, and which is of great practical significance for building constructions.

Although an attempt had already been made to find an explanation for the lateral displacement phenomenon, it was left to the young Prandtl to find a comprehensive one. If one traces the train of thought which led Prandtl to the solution of the problem, as elaborated in his thesis, one becomes aware that a close dependence of the mathematical approach to the observed geometrical process during lateral displacement of the support is particularly characteristic. Prandtl's great ability to describe the observation of a process in its essentials, while at the same time leaving aside all secondary phenomena, using an appropriate mathematical-physical approach, was already evident in his first piece of scientific work.

As Prandtl was unable to receive his doctorate from the Technical University in Munich on the basis of his thesis, which was completed in 1899, because this university was first granted the right to confer the PhD degree in 1900, he was required to submit the thesis to Munich University for approval. The philosophy faculty of Munich University appointed the well-known mathematician Ferdinand Lindemann to evaluate the thesis. The examiner in the main subject was Prof. Leo Graetz. The oral examination took place on 29.01.1900. As, in the

dissertation, a decisive differential equation for lateral displacement was found in the form of a Bessel equation, and the numerical evaluation of the Bessel function of a particular order resulted for the first time from the dissertation, the work was of great interest to the mathematician and Prandtl was awarded his doctorate with a good grade.” (So much for Ludwig Föppl’s account.)

The title of the doctoral thesis was, “Lateral displacement phenomena, a case of unstable elastic equilibrium”. Publication was delayed somewhat and finally took place in Nuremberg in 1901 [28].

Of course, the printed thesis was immediately sent to August Föppl. On receiving the thesis, he wrote the following to Prandtl on 21st February 1901,

“Dear Mr. Prandtl,

I was very pleased with the fine piece of work which you kindly sent to me and which I immediately read from cover to cover. I was especially surprised by the detailed and circumspect discussion of all the various cases related to tilting phenomena. Before reading your dissertation, I was not aware that your study would encompass such a large range of phenomena. It is the first time that one of my students has carried out such a proficient piece of work and this gives me all the more pleasure.”

Prandtl had now completed his studies in Munich and the time had come for him to start his career. He wrote a letter to the senior government building officer Anton Rieppel (well-known as the builder of the Müngsten bridge, the highest railway bridge in Germany) in Nuremberg (MAN), as a reply to his letter, “Regarding your worthy proposal, I would be pleased to take on the task of establishing a laboratory and I could start on the 1st January. If everything is then on course in the laboratory, perhaps it would be indeed possible for me to cross to your gas motor or steam machine office. But, this is a matter for the future and now is not the right time to deliberate about this.

I have taken the liberty of enclosing a copy of the reference given to me by Prof. Föppl on completion of my work.

I look forward to receiving your valued decision and would welcome the opportunity of visiting you in Nuremberg, should you so wish, at a time which is convenient to you.”

He therefore joined the works of the *Maschinenbauengesellschaft* in Nuremberg on the 1st January 1900 which, at that time, was amalgamated with the Augsburg machine-building works to MAN. He was first of all employed at the well-known factory in Nuremberg as a member of staff in a design office. A new works building was planned and the machine installation was to be presented as drawings. It was the young engineer's task, amongst others, to improve a deficient installation for pneumatically drawing off wood shavings in the new wagon department. This was urgently needed, since the work in the joiner's workshop was hampered by the accumulation of a large quantity of wood shavings. Indeed, it had been established that the workers in the joinery workshop at the company suffered greatly from the dust and fine wood shavings which were produced by the wood-processing machines and that some had developed lung disorders, as a result of breathing in the contaminated air. The plan was to have a suction system extending over a number of wooden huts. This was the first time that Prandtl became involved in questions related to fluid flow. His subsequent reading of the available literature about this problem soon revealed that very little indeed had been written on the subject. He therefore decided that he himself would have to shed some light by making his own measurements and carrying out his own investigations, initially using relatively crude methodology, to resolve a range of questions which had been unanswered up until then. On the basis of these studies, the wood shavings suction installation was completely rebuilt. With the aid of the construction of a separator, which was provided with a cyclone, a solution was found to the problem. It was soon demonstrated that it would be possible to manage with about a third of the operating power used up until then, by making use of a suitable design and dimensions of the pipe lines while, at the same time, maintaining uninterrupted operation. The company then decided to include Prandtl's wood shaving suction equipment in their programme and soon many orders were received.

When Prandtl had time away from work, he always travelled to his relatives in Dingolfing or Munich. He never failed to visit his teacher at

the technical university, August Föppl, on these occasions and Föppl maintained a constant interest in his career.

In 1901, a professorship in mechanics became available in Hanover. On being asked for suggestions for a successor, August Föppl proposed, amongst others, the young engineer from Nuremberg, whose doctoral thesis had indicated great ability. Prandtl received a letter from the Prussian Ministry of Culture, Education and Church Affairs in Berlin at the beginning of August 1901 informing him that he had been proposed as a candidate, amongst others, for the post of Professor of Mechanics in Hanover. The letter included an invitation to an interview in Berlin, if he were interested in considering the appointment, should it be offered to him. A few weeks later, he was informed that he had been selected for the post. It is reasonable to suppose that Prof. Carl Runge, who had held a professorship in mathematics at the Technical University in Hanover since 1886, had played a decisive role in Prandtl being offered the post. The document confirming the appointment was signed on the 21st August 1901,

“I, Wilhelm, by the grace of God, King of Prussia give notice and hereby make it known that I have most graciously deigned that the former engineer Dr. Ludwig Prandtl from Nuremberg be appointed to the remunerated position of Professor at the Technical University in Hanover.”

Prandtl gave up his post as an engineer in Nuremberg on the 30th September and moved to Hanover as a Prussian civil servant to be, at the same time, the youngest professor in Prussia. He was 26 years old at the time. He held lectures in mechanics in the Department of Mechanical Engineering, as well as practical classes in graphic statics. He also had the task of examining students throughout the semester; one which made quite a demand on his time. But, he still managed to find the time to carry out research into flow processes. The experience he had acquired in investigating the laws of airflow had left many questions unanswered. For example, the question of why airflow in a tapered, extended pipe does not follow the walls of the pipe, but instead flows virtually as a free stream through the middle of the tube.

Prandtl told his relatives in Bavaria about his impressions following his move to Hanover in letters. The letters, which he frequently wrote, took the form of a circular letter and were sent to his father's siblings, both of whom now lived in Munich, and the Ostermann family in Freising.

Here is an example of an extract from one of Prandtl's letters, dated 26.10.1901

"I left my furniture, for the time being, with my house companions in Nuremberg. While I am on the subject of Nuremberg, I would also like to mention how things were when I moved from there. Of course, I said my various farewells in different ways. For example, at the Nuremberg Philistine Society, I had the opportunity of pouring out free beer. Then, in the company of the male-voice choir there were speeches and speeches in reply. The farewell song was 'God be with you!' as a horn solo (played by Prandtl himself). The next day, at seven o'clock in the morning, I disappeared into the mist. At the university in Hanover, virtually all regions of Germany are represented: there are people from Bavaria, Swabia, Baden, Kurhessen, Austria and, of course, hords of Prussians. (I have not yet sworn the oath of office, so I may still consider myself to be a non-Prussian).

I would like to mention something else about my move. I received 60 replies to my advertisement for accommodation, although the offer I finally accepted was not amongst these: it came from a colleague. I was very pleased with the decision to take this flat." (Prandtl moved into Nienburgerstraße No. 12.) "The location is similar to Königinstraße in Munich, except for the fact that here I see, hear and feel the rumbling by of trams, which provides a better diversion. Apart from this, the location is very attractive. There is a park opposite my accommodation and sometimes I can watch sunset over the park, if the view is not obscured by mist."

Letter dated 03.01.1902

"By the way, I wanted to tell you about the hustle and bustle in Hanover. Let me first of all say something about the language. The view is generally held that, in Hanover, the people speak the purist and best form of German; namely, that of the people. But, listen a moment. My first discovery was that I could only understand the waiter in the hotel with some difficulty. The same applies to business people. However,

after a short, time I made the amazing discovery that the local dialect can be traced back to the German language by making use of just a few rules of pronunciation. (It is not so simple to grasp the classical dialect, don't you think). The keystone is to pronounce the phoneme 'ei' as you pronounce 'a' in the word 'Kas'. Once you have become familiar with this pronunciation rule you quickly appreciate that the people here speak quite standard German.

Hanover also has something very distinctive: battery-driven trams (there are no overhead wires in the inner city). The tram system is the second largest in Germany, after Berlin. The railway also runs from every corner out into the Lüneburger Heide, just as if the railway in Munich formed a network to Freising, Dachau, Starnberg, Wolfratshausen, Sauerlich and Grafing.

I was assured that Hanover lies on seven hills. I have not yet been able to verify this myself, since I have not seen them all. I can, however, confirm the existence of one of them - 'Schneiderberg' - which I discovered myself, without any help. I pass over this hill everyday on my way to the university. It is indeed so high that, indeed, not even the tallest man could look over its peak (that is the way the local people describe it). The weather here alternates between mist, damp and windy; sometimes for a change it is also damp and misty, or damp and windy. Perhaps this climate is the reason why all the windows here are constructed to open outwards, so consequently there is no room for winter windows in front of them.

I must admit, one thing I miss here is the home-made bread, with little salt and no herbs. In Hanover bread is always eaten with only butter (even beggars reject it otherwise)."

Letter dated 1st July 1902

"On one of the first days of May, I took part in a geological expedition to the Harz, where we were able to view the beauty of the highlands and learn about the geology of the area. Despite the bad weather, it was very beautiful. The Harz region is quite a fine highland region and one which the Bavarian forest cannot be compared with, at least as I picture it in my imagination. The parklands at Herrenhausen are now very splendid: the lilac is in bloom, the nightingales sing and frogs can be heard croaking. Even at the technical university, May has not passed without a trace: A colleague of mine, with whom I often have dinner, has become

engaged. Amongst the younger members of the academic staff, I think I am now the only one who is not yet engaged. Nevertheless, I think the young ladies of Hanover do not have good prospects of hooking me at present. I still believe the one who will become my wife will have to be able to cook *Knödel* (German dumplings) and *Nockerln* (small dumplings made from semolina, typical in Bavaria and Austria) and not be overcome by a desire to put raisins in with the spinach.”

His ties with his Bavarian homeland sometimes made it difficult, in some respects, for Prandtl to get used to the lifestyle in Hanover.

In his new environment, Prandtl also experienced a different attitude to social manners. Formality was emphasised in every respect. Once, my father was asked to take part in a small performance. This was to take the form of a group of Bavarian singers who were to appear in *Lederhosen* (leather breeches, part of the folk costume of men in Bavaria). When the young academic staff appeared at the dress rehearsal for the event dressed in good Bavarian *Tracht* (Bavarian folk costume), they were handed out skin-coloured leg tricots to be worn underneath the Lederhosen because it was considered indelicate for men to appear in front of ladies with their knees uncovered.

This general regard for decorum was not a characteristic feature of the warm human relationship which developed between Professor Carl Runge, a native of Bremen, and Ludwig Prandtl who was 19 years younger than his mentor. My father admired the witty, urbane colleague, in whose home in Kirchrode he had the opportunity of enjoying many happy hours. In her reflections on Carl Runge's life, his daughter Iris wrote [44], “At that time, Runge frequently brought a young friend with him, Ludwig Prandtl, to whose appointment my father made a contribution and with whom he very much liked to converse on scientific matters. It quickly became known that this new friend had a good sensitivity for music and also had a good bass voice”. (In the Runge family they tried to perform the St. Mathew Passion.) “With Prandtl's sonorous bass voice, Runge taking the tenor part and the daughters singing the soprano and alto parts, it was possible to create full harmony, though these unpractised voices first achieved success only after many attempts.”

Letter to Prandtl's relatives dated 30.01.1904

“I spent Christmas Eve⁶ this year in the company of my colleague and fellow student of philistinism Runge (4 girls and 2 boys, and therefore very lively company). I now visit them frequently anyway, since we have many scientific interests in common, and to have the opportunity of regularly playing music (in a mixed quartet).”

There were some other colleagues who were soon to become friends of Prandtl. One of these was the *Privatdozent* (a member of university teaching staff with a PhD and a licence to teach without supervision) for literature, Dr. von Hanstein, who frequently invited my father to his house. Also, by chance, Prandtl moved into an apartment diagonally opposite Hanstein's home in 1903, so that they became close neighbours.

Letter dated 03.01.1903, at which time he had moved to Militärstraße

“In the last quarter of this year, I had a lot of work to do. In fact, I had so much work that I hope this will never be repeated. The principal reason why I had so much work was the fact that I had begun to hand out autographed sheets during all my lectures in which the most important facts were summarised for the students. I was forced to prepare the material with such a degree of care that they could be used for a number of years. Regarding my research I am pleased to say that I have made good progress.”

He had constructed a small research installation with a water channel. The water, which was moved by a mechanical blade wheel, was first mixed with small shiny flakes (micaceous iron ore), in order to make the flow movements visible when produced under various experimental paradigms. The fortuitous circumstances under which he had the idea of using micaceous iron ore was once recounted by Prandtl to one of his students, Dr. W. Tillmann: When Prandtl was working for MAN in Nuremberg, construction workers came to see him. They wanted to

⁶ Translator's note: In Germany, Christmas Eve is the main time of celebration at Christmas. It is, above all, a family occasion on which presents are also opened after they have appeared under the Christmas tree where they have been placed, unobserved by anyone, by the Christkind (Christ-child).

show him some red-coloured clumps which they had found during excavation and which indicated to them that they had reached a stratum containing copper. On suspending the material in water, he noticed minute, flaky particles. These particles allowed the flow of fluids to be followed. The reason for this is that, if they are subjected to a shearing force, the suspended particles adopt a preferential orientation. The reflected light from these particles then produces an image of the flow. The chemical involved in making the image visible is iron oxide which, in this case, was present in the form of micaceous iron ore. By suspending the material which had been collected in a number of folded cardboard trays, he was able to collect a large quantity of the material for use, in order to make the flow visible. Since then, no-one has found a more suitable material for this purpose. His supply of micaceous iron ore migrated with him on his appointments to Hanover and Göttingen. Thrifty use of the available material meant that his supply was sufficient for use over a fifty year period, until it was replaced by a synthetic, shiny bead pigment.

In his search for laws underlying physical phenomena, Prandtl would often work late at night making sketches and carrying out calculations. As a result of the experience that excessive eagerness to work can result in over-strain, he consciously drew a lesson for the future to moderate his workload, despite pressing problems.

Letter dated 23rd January 1903

“Quite unexpectedly, in February, I had had enough of constantly working to excess, and I became aware that I was lagging behind in my work, as a result of quickly becoming tired from working. For the sake of gaining some distraction from my work, I have taken up photography.”

His daily hours of work were and continued to be well above a normal workload. It is therefore reasonable to assume that, at that time, he frequently worked through the night. He now lived a somewhat secluded life and, at Whitsun, he went on a long excursion to the Weser highlands, which provided him with a period of relaxation. He supplemented his description of this journey with small drawings, to illustrate the route he took when walking and his impressions of the landscape.

Letter dated 23rd June 1903

“I travelled by train to Coppenbrügge, then I went walking at the Ith⁷. I had a mid-morning snack at Lauenstein, then my journey continued on the ridge. I took a rest on the Hammerslust range, and in the evening I went to Eschershausen. In the morning, the journey continued via Homburg (there is the ruin of a castle on the high peaks) to Stadtoldendorf, and from there I went on the Ebersnacken and to Königszinnen. At Bodenwerder, I travelled by boat on the River Weser to Hameln. I visited the town and swam in the River Weser. The next day, I went to Ohrberg (which has a beautiful park), swam in the River Weser once more and, in the evening, I went home. The highest peak I saw was 495 metres high!”

Letter dated 30th January

“I will start my letter with an account of my departure from Bavaria last September. As you already know, I went to the Natural Scientists and Physicians Meeting in Kassel. I have no regrets about participating in the meeting. I made a number of valuable acquaintances there; particularly mathematicians and physicists. It was unfortunate that my own talks were both scheduled for the afternoon of the last day of the meeting. I myself was quite weary. One talk was received with applause, but the other (about vectors) provoked a large measure of difference of opinion, as I had already expected. At the end of the conference, a number of mathematicians and physicists took up an invitation to go to Göttingen, where there was an extraordinary number of interesting things and people. The hospitality there was quite excellent. I stayed overnight at the home of the astronomer Schwarzschild and had lunch with Professor Nernst, the chemist, and two places away from me was the English chemist Mr. Ramsy. When I arrived back in Hanover, there was soon other business to be dealt with: examining in the morning and again in the afternoon, and so it continued for a period of 4 weeks. In the meantime, lectures had begun, then there were examinations again, in addition to the lectures, and so it continued until Christmas. Lectures have taken place again since the 5th January. There was quite a lot of work in addition: extended publications of my lectures, other publications in preparation and then the commissions, so that there was never a moment when I had no

⁷ The Ith is a ridge along the Weser in the vicinity of the town of Hameln

work to do. But, despite this, on the Kaiser's birthday, I allowed myself to take a whole day off from work and went skating and walking."

Then it was time to start working again on the many tasks which had been given to him.

In spring, Prandtl received an inquiry from the privy councillor Felix Klein from Göttingen about whether he would like to take over the Institute for Technical Physics, which had, up until that time, been headed by Prof. H. Lorenz. This institute, to which an associate professorship was assigned, was established on the initiative of Felix Klein, the creative mathematician and organiser of the mathematical-physical-technical educational system, when the *Göttinger Vereinigung zur Förderung der Angewandten Physik und Mathematik* (Göttingen Association for the Promotion of Applied Physics and Mathematics, also known as *Göttinger Vereinigung*/Göttingen Association) under the chairmanship of Henry Th. Böttinger and Felix Klein made the money available. Prandtl's former boss at MAN, senior government building officer Rieppel, commented on the possible appointment in a letter to Klein in the following way, "7th March: I think your idea of Dr. Prandtl being given first consideration is a fortunate one. Prandtl is an exceptionally talented and at the same time, exceptionally hard-working person. With his good-natured character I am sure that the prerequisites for a pleasant collaboration will be fulfilled ..."

However, Runge in Hanover, expressed the following opinion, "I have a very high opinion of his ability and will do everything in my power to keep him at the Technical University in Hanover."

Karl Schwarzschild, referring to this matter in correspondence dated 22nd April addressed to Klein wrote, "I have received a letter from Runge concerning Prandtl. The prospects are bleak!"

On May 4th, Prandtl wrote a provisional reply to the offer.

“Letter dated 4th May, Hanover

To Prof. Felix Klein

Dear Colleague,

as promised, I am sending you my reply concerning my reflections about the professorship in mechanical engineering in Göttingen. On the one hand, I was attracted by the idea of having my own laboratory and a large measure of freedom regarding the allocation of my time; not least, however, because of the excellent scientific environment in Göttingen. On the other hand, my work in Hanover, which has now been less than three years following my arrival, is very rewarding for me. I would have to exchange my large sphere of activity here for very much less. I place less value on the fact that, in Göttingen, I would, as an associate professor, have no chair in the faculty, whereas I am a regular member of the department here. My most serious reservation arises from the fact that I feel that I belong to the field of technology. It has been a real wish of mine for some time now to contribute, to the best of my ability, to the raising of the scientific character of lectures at technical universities. From this perspective, the transfer to the university can only be justified if it were not to be my last position and it would offer me an exceptional opportunity to increase my own scientific status and prepare myself for future tasks and, on the other hand, would provide the opportunity of exchanging ideas with theoreticians and allow me to have their assistance in the search for solutions to practical questions.”

The salary requirement of 6,500 German marks annually was equivalent to that at the Technical University in Hanover.

The matter was to be decided in the ministry in Berlin. Klein had sent his suggestions with a personal letter which included the following comments about Prandtl, “Prandtl’s work stands out due to the combination of his specialist knowledge and his grasp of mathematics, a marked intuitive ability and the originality of his thought. At the same time, he also has a great interest in education.”

As the ministry did not agree to the salary claim, Henry von Böttinger (business manager of the paint factory, formerly the company Bayer in Elberfeld) wanted to underwrite the difference between the salary offered and the 6,500 German marks from private resources. Consequently, the invitation to go to Göttingen was something to be considered. Prandtl travelled to Berlin for negotiations and asked for time to consider his decision.

In a letter to Professor Klein dated 25th June 1904, it was apparent that everything was still unsettled.

“Hanover, 25th June 1904

Dear privy councillor,

The decision has not yet been communicated to me and I also do not have the written offer. The delay has arisen from the fact that my colleagues in Hanover in the ministry have made efforts to keep me here. I would also like to use this opportunity to inform you that recently I have had to fight hard with myself, as it would mean cutting all the ties which keep me here. Indeed, every effort has been made to keep me here. Some members of the civil engineering department even offered me the use of a very suitable laboratory for investigating strength and stability, which is nearing completion, for my use etc.! I weighed up the pros and cons in my mind and finally the scales tipped in favour of a decision to go to Göttingen.”

The decision to go to Göttingen was made on the 1st July.

The negotiations with the ministry were, however, not yet over. But, on the 1st July 1904, they had reached a stage at which Prandtl was able to give his final decision. He wrote a postcard to Klein, “Dear privy councillor! Having just received a letter from Mr. Naumann (member of the ministerial committee), I have decided to accept the appointment in Göttingen.”

Although he made what was essentially an unusual step backwards in his academic career, by giving up the position of a full professor in return for an associate professorship, Prandtl anticipated the possibility of now being able to really devote himself to research. The supervisor for his

PhD, August Föppl, had seriously advised him against accepting such an offer. It would have been contrary to common sense to wish to accept a demotion. But, Prandtl's creative mind propelled him in the direction of accepting the possibility of more time for his research, even if it meant a lowering of academic status. What attracted him was the prospect of having substantially greater freedom in the pursuit of solutions to problems and the development of his ideas at his new working place. In addition, he was convinced that there would be an opportunity, in the future, of once again obtaining a full professorship.

Prandtl had great admiration for the mathematician Klein, to whom he was also personally attracted and under whose patronage he expected a good working environment.

Klein had particular objectives for lectures in the area of mathematics and natural science. He wanted to provide the students, who frequently later pursued a practical career rather than continuing in academia - working in a factory or teaching in a school - with a training matched to their goals. At that time, the universities in Germany had few links with engineering and industry. Thanks to Felix Klein, the links between university scientists and technology were once again established. American universities served as a model for this. He was an excellent organizer and his actions left an impression over a wide area. It was the result of his initiative that a number of professorships and institutes were established that were intended to serve the practical application of science. In Prandtl, he had found someone who, as a teacher, could truly develop his knowledge from the practical perspective. For Prandtl, Felix Klein became a great friend who contributed to his plans and who supported him at all times in his specialist area through discussions.

On 12th August 1904, before he moved to Göttingen, he travelled to a congress in Heidelberg to attend the 3rd International Congress on Mathematics. He gave a talk on his new scientific theory which came to be known as the boundary layer theory [35]. It was the result of his experimental and theoretical work which has already been referred to. This lecture was received with great attention from the mathematicians present at the meeting, who listened with great interest to his ideas about flow processes. A fundamental step in increasing knowledge was

achieved; one which would soon be of importance for aviation. He had now gained recognition amongst the circle of scientists.

We can gain an impression of the importance of Prandtl's boundary layer theory from the comments made by Professor Ludwig Föppl at the time,

“I would like to describe the essential significance of this work by drawing attention to its essential elements. Up until that point in time, it had not been possible to explain the resistance of a body in a flowing liquid or in the wind; equally, there was no explanation available for describing the lift of an aeroplane. Classical mechanics either assumed friction-free flow, or it took into account the friction, but the mathematical complexity was so great that no practical solution could be found. The liberating idea of Prandtl, which resulted in an escape from this bottleneck, was to assume friction-free flow in the whole area - with the exception of flow along solid boundaries. Prandtl showed that friction in a thin layer along solid boundaries, however small, has to be taken into account. Since that time this layer has been referred to as Prandtl's boundary layer. With this simplifying assumption the mathematical difficulties referred to above, which show up in the classical mechanics of fluids with friction, can be overcome in many practical cases. Prandtl was able to demonstrate, both theoretically and practically, that the boundary layer can separate at certain positions from the surface of a body around which the liquid flows, in order to unroll and leave the body as an individual vortex.

Sommerfeld heard Felix Klein say to Prandtl at the mathematicians' congress in Heidelberg, 'Your lecture was the best of the whole congress'. It is typical of the wealth of brilliant ideas with which Prandtl's mind was filled that in addition to the boundary layer theory just referred to, at the same conference, he presented another piece of work related to the field of elasticity theory. The lecture was on a subject which has subsequently been referred to as Prandtl's soap membrane comparison. This is a comparison, known to every elasticity theoretician, between the torsion of a prismatic rod with that of the surface curvature of a soap film which is formed over the cross-section of a rod as a hole when there is excess pressure on one side. The comparison has, since then, been used many times in the solution of questions concerning torsion using experimental technical approaches.” Two articles have been published on the latter problem [24, 40].

The letter of appointment for Prandtl's position as a professor in Göttingen had already been received by Prandtl at the time of the congress. It read as follows:

“From the Minister for Philosophical Studies and Medical Matters, Berlin, 31st July.

Following the negotiations which have taken place with you on my behalf, I appoint you with the supreme authority of his majesty the Kaiser and King, from the 1st September of this year to the position of associate professor in the philosophical faculty of the University of Göttingen and grant you the associate professorship made vacant on the departure of Professor Lorenz, with the duty of taking responsibility for lectures and practical exercises in physics and agricultural mechanical engineering. At the same time, I entrust you with the task of heading the Department of Technical Physics, which belongs to the Physics Institute. I request you to take up your office in due time before the start of the new semester and to immediately send the curriculum for the latter lectures to be announced to the Dean of the Faculty.

In place of the income you have received up until now in the position you have held I shall grant you as of the 1st September of this year a salary of

4,000 M annually

in addition to the annual housing subsidy of

540 M,

as per tariff ...”

Prandtl arranged to be deputised for the month of September, starting his work at Göttingen University on the 1st October. In the same winter semester of 1904, Felix Klein had also successfully arranged the appointment of Carl Runge to Göttingen who, just like Prandtl, looked forward to the move with much pleasure. At an interview in Berlin regarding his potential appointment all the requests Runge made were granted, much to his delight. This new appointment was converted into a full professorship with a corresponding increase in remuneration. Runge had indeed received other offers of professorships from Marburg, Danzig and Aachen but none of these universities could fulfil his salary requirements. His professorship, which was designated as Professor of Applied Mathematics, was the first full professorship in this subject area in Germany. Prandtl received the title of Professor of Applied Mechanics.

Both moved into an old, venerable institute building in the Prinzenstraße, in the so-called Michaelishaus in which Karl Friedrich Gauss and Wilhelm Eduard Weber undertook the first experimental investigations of electromagnetic telegraphy.

An impression of the building is given in the following account of Iris Runge [44],

“The very small rooms, full of nooks and corners, and the well-trodden flooring and stairs made me aware of the age of the building, which was constructed in the 18th century. But, everything appeared bright and new even if somewhat simple and functional.

When Runge came to Göttingen, he and Prandtl were immediately invited to a joint seminar on questions concerning electro-technology.

On enrolment, a syllabus was given to students of natural science, which had been prepared by Klein, in order to introduce the young people to the most important assignments without taking a roundabout route. The title of this preparatory text was, ‘Suggestions and explanations for students of mathematics and physics’. Certainly, during this period of time, there was a unique collaboration between all of those who were involved in lecturing and establishing natural science. From the representatives of practical application amongst whom Prandtl with his machine laboratory could be counted - some of his colleagues referred to his department as the *Fakultät Schmieröl* (Faculty of Lubricating Grease)! - up to the guardians of the rarefied atmosphere of mathematical theory, all fellow scientists were united.”

The most famous of the mathematicians was Professor David Hilbert. Klein had succeeded in his efforts to attract him to Göttingen, where he stayed until his death, and indeed he even declined an invitation of an appointment in Berlin in 1902. The expansion of the natural sciences sphere of the philosophical faculty was very much one of Hilbert’s goals and it provided a broad base for students from all over the world.

Runge and Prandtl had a particularly close relationship; a friendship which had already been firmly established during the time in Hanover. In Göttingen, they were brought even closer together, both in terms of space and academic discipline, which was indeed a fortunate set of circumstances. But, it was the possibility of freedom in carrying out his

work that resulted in the true fruition of Prandtl's mathematical-technical originality. The union of Prandtl's and Runge's institutes gave a frequent opportunity for stimulating discussions, which promoted the creation and development of new ideas.

Prandtl, who continued to look for new knowledge in his special area of research into the theory of flow, now concentrated his research on the motion of flowing gases. He obtained good working conditions in his new institute. In 1898, Klein had already established, together with interested industrialists and some Göttingen professors, the *Göttinger Vereinigung zur Förderung der Angewandten Physik und Mathematik* (Göttingen Association for the Promotion of Applied Physics and Mathematics). As a result of substantial donations from industrialists, it was possible to initiate new projects at the institute; for example, in 1905, the physics institute in Bunsenstraße. As a result of this, more room became available in the old physics institute in Prinzenstraße for new lecturers, and Prandtl was able to supplement the existing facilities with a water circulation channel for visualising flow processes.

At this point in my account, I would like to emphasise that Prandtl, as I have mentioned already, continued his research into the theory of flow as a purely scientific study. After he had solved the practical task for MAN, he now continued to carry out research in the new area for the pursuit of scientific knowledge. He was not aware at this early stage that his research would be so full of promise for the future.

In turn with the involvement of ministerial director Althoff, a new society was founded in 1906: the *Motorluftschiff-Studiengesellschaft* (Motorised Airship Study Society), whose main aim was to support the development of the Parseval airship. Prandtl was voted onto the technical committee. In order to achieve the best conditions for the test and preliminary investigations, Klein suggested preparing a project for the setting up of a model research testing facility. He gave this task to Prandtl. So, one can say that, to some extent, the initiative came from outside for a development that was particularly in line with his possibilities and wishes. The plans were soon presented and, at the beginning of 1907, the preliminary work was commenced. I should mention in passing that Prandtl received an offer in 1907 to transfer to the Technical University

in Stuttgart. In a letter to the ministerial director Althoff, he described the situation at the university and informed him of his position regarding the offer.

“30th March 1907

To his excellence, ministerial director

Dr. Althoff, Berlin, Ministry of Culture, Education and Church Affairs

Your excellence, I have the honour of informing you that yesterday I received a letter from the Württemberg Ministry of Culture, Education and Church Affairs dated 26th March in which the post of a full professor of technical mechanics at the Technical University Stuttgart was offered to me.

Although this offer contains much to tempt me to consider the post, please allow me to mention some of the reasons which nevertheless cause me, taking all factors into consideration, to stay in Göttingen. Of course, I am not exactly free from having wishes. I am quite content with my institute, despite the much too tight budget, whose increase has not yet been achieved but, nevertheless, thanks to the assistance of the ‘Göttingen Association’ which has kept the institute above water up until now, I am not unduly concerned about this.

I am less content with my current teaching responsibilities, because it has not been possible, despite my best efforts, to interest a wider circle of students. This is partly due to the fact that the subject is ignored as being an unnecessary subsidiary subject, as it is only represented by an associate professor and constitutes a small or only minor part of the examinations. The means of increasing the status of the subject which I represent is the main concern of my wishes.

It is a wish which I would like to direct to you, your excellence, to convert my academic position into one of a full professorship and, if that were not possible, might it be possible to grant me a personal full professorship? My personal position regarding the matter remains the same as that of 3 years ago. I have willingly foregone the position of a full professor in Hanover and even now have no desire for a position and voice in the faculty. But, for the sake of the standing of my professorship, I think that it would be appropriate to grant my request.

A second step in achieving my goals, that of being appointed to the board of examiners for applied mathematics (first state examination for the teaching profession) is already under consideration, and a third goal, which relates to changing the regulations for conferring doctorates, is one which I am considering presenting to the faculty in Göttingen.

In addition to these matters, there is one more thing which is very important for me. In Göttingen, I am obliged to carry out a very diverse range of tasks. Agricultural mechanical engineering is far removed from my scientific interests. If this area of teaching could be transferred to a suitably qualified lecturer - a suggestion which I have already brought to the attention of the minister - this would release me from the agricultural department while, at the same time, greatly benefiting my research.

As the Württemberg ministry has declared this matter to be one of urgency, I would kindly ask that the request is met with a reply at your earliest convenience.

Yours faithfully, L. Prandtl”

Prandtl therefore declined the offer of a professorship in Stuttgart, as his requests regarding his needs in Göttingen were granted and his professorship was converted into a personal full professorship. The planned research facility kept him firmly in Göttingen. According to Prandtl’s account, in autumn of 1907, an enclosed wind tunnel with a cross-section of two by two metres and a strong fan for the generation of wind was set up to the east of the Leine canal in the Hildebrandstraße, which was later copied abroad as the “Göttingen Design”. Independently, at about the same time, the engineer Alexandre Gustave Eiffel constructed an open wind tunnel. This construction was also further developed. His experimental equipment was constructed for a specific purpose; namely, to investigate the wind pressure on the Eiffel Tower, which was his construction.

Professor Ludwig Föppl wrote, “At about the same time as the construction of the German wind tunnel in Göttingen, the designer of the Eiffel Tower in Paris built a similar wind tunnel and carried out wind resistance measurements there. The opportunity therefore arose of being able to compare the Göttingen results with those obtained in Paris. A close correspondence was found for most model bodies. In contrast, there were substantial differences for others. Although the measurements

were repeated with great care, both in Göttingen and in Paris, the differences in drag coefficients remained.”

After various speculations about the physical reasons for the lack of correspondence in the results had been put forward, Prandtl was successful in finding an explanation in a surprisingly simple manner, making use of his boundary layer theory. The cause of the discrepancies was the different wind flows in the Göttingen and Parisian wind tunnels. In the Göttingen wind tunnel, a low turbulence wind flow was created following the installation of a contraction nozzle which was used in the measurements. In contrast, in the construction used in Paris, the air was much more turbulent in the wind tunnel. By using carefully planned flow experiments with spheres in which, in one case, he created artificial vortices in the air flow using a mesh net and, in another experimental series, he disrupted the smooth flow by means of soldering a wire ring on the surface of the sphere, he was able to account for the discrepancies and so prove that his ideas were correct [22].

“Prandtl was awarded the Benett Prize for his impressive clarification of the contentious question.”

The diversity of tasks which Prandtl set himself threw up one surprise after another. At that time, he was also occupied with the construction of a hang glider, with the agreement of the *Motorluftschiff-Studiengesellschaft*. His research using a wind tunnel also produced results which could be used for the development of flying objects, since it was possible to make statements about how one could substantially reduce the great loss of energy associated with flying at that time. Measurements were made on model airplanes, models of dirigible airships, as well airfoil profiles, which were hung in the wind tunnel, and air resistance was measured at different wind strengths. From the scientific evaluation of these precise measurements, streamlined designs were developed.

Those living in the vicinity of the wind tunnel could not fail to be aware of its presence. The switching on of the fan could be heard by the neighbours and it was impossible to conceal the fact that something quite extraordinary was going on in the Hildebrand Straße: the new “wind home” was now one of the most modern experimental facilities in

Göttingen. If one takes just a moment to reflect on the fact that, in 1891, Otto Lilienthal was the first man to fly using a gliding device that mimicked the flight of birds, which he had constructed himself, and, that in 1903 the American Wright brothers ventured to make the first powered flight with their biplane, whose flight properties had hardly really been tested, then one can realise that the science of flight research, which we take for granted nowadays, was at that time quite novel and was the object of much public interest.

Flying with airships also attracted great attention and recognition, since the fact that an aircraft that is lighter than air would have to stand the test of flying was quite obvious.

When, on the 2nd July 1900, Graf Zeppelin succeeded in crossing the Bodensee on the maiden voyage of his dirigible airship, the reporter Eugen Wolf commented in an enthusiastic article for the newspaper *Die Woche*, “Christopher Columbus could not have been filled with more blissful, greater emotion on hearing the cry of ‘land’ than the feeling which overcame the soul of the dashing cavalry general Graf Zeppelin as now, at last, the majestic, slender ‘vehicle of the skies’, which conveyed the feeling of safety over every centimetre of its fuselage, rose calmly and without making any noise from its resting site, responding to the commands of its pilot with a light lifting pressure and immediately appeared above the ground as it took its course through the sky.”

In contrast, the very first attempts at all of the Wright brothers to overcome gravity with motor power can be better compared less with the weightless flight of a bird of passage than with the fluttering up of a chicken. For the first time, a powered aircraft glided for 12 seconds above the ground until its skids once more touched down after traversing 50 metres. The spectators who assembled for this performance did not view the spectacle from the air; instead they lay flat on the ground in order to experience the flight of a motorised aircraft as witnesses. The reason for this was that it was only in this way that they could judge whether the aircraft had really raised itself above the ground. Following repeated and persistent experiments, the two airplane technicians were successful in achieving additional, higher flights. In 1908, Orville and Wilbur Wright displayed their new machines, which in the meantime had become ever

better, in France, Germany and England with much success. So, air space had been conquered. The task of those working in aerodynamics was now that of achieving the required stability and airworthiness of the flying objects. Scientific collaborators soon came together at the research testing facility. Some of their names are known to me. First, I would like to mention Th. von Kármán. His studies brought him to Göttingen already in 1906. In 1907, Dipl.-Ing. Georg Fuhrman was appointed and participated in the setting up of the research facility. In 1909, Dipl.-Ing. Otto Föppl joined the institute and, in 1912 two additional assistants were appointed. These were Dipl.-Ing. A. Betz and Dr.-Ing. C. Wieselsberger.

The Hungarian mechanical engineer Theodore von Kármán asked Prandtl in writing whether he could work with him as a PhD student in the field of mechanics.

“Budapest, 8th September 1906

Dear Professor Prandtl!

In accordance with the request of the local Technical University, I intend to spend the next semester at the University of Göttingen and, during this time, to devote myself mainly to the task of studying technical mechanics and thermodynamics. My assignment will be, namely, to obtain greater insight into that field of applied mathematics that will serve directly as a preparation and a basis for lectures on technology and especially in the education of mechanical engineers with reference to purely technical disciplines. ...

I am convinced that I will best be able to fulfil my task if I were to entrust myself to your guidance ...

Yours faithfully, Theodor Kármán”

Kármán, who was a very successful student of Prandtl and had gained his doctorate under his supervision in 1908, became a professor at the Technical University in Aachen in 1913. Under his direction a wind tunnel was set up there at the beginning of 1914, with the one in Göttingen serving as a model. In 1929, he accepted an offer from America to work as the director of a research laboratory for aeronautics in Pasadena. He was anxious about the political developments in Germany and thought he could anticipate where the ideas underlying National Socialism were going to lead and which would have

consequences particularly for him as a Jew. In America, he found the best conditions for working. Thanks to his active inventive spirit, he helped American aeronautical research, for whose support substantial financial resources were made available, to make substantial progress.

Kármán did not allow the ties with his former Göttingen teacher to be broken, at least as long as he was still resident in Germany. Both scientists carried out research on turbulent flow and informed each other of their results.

In his biography “The Wind and Beyond” Kármán [15] wrote: “In my opinion Prandtl unraveled the puzzle of some natural phenomena of tremendous basic importance and was deserving of a Nobel prize.”

Prandtl felt very much at home in Göttingen. With a bright group of young lecturers gathered around him, who were also bachelors, he had convivial companions at the dining table. Amongst these were Karl Schwarzschild, the astronomer, Professor Max Pohlenz, classical philologist, as well as the philologist Jakob Wackernagel. The intellectual discourse and exchange of ideas was diverse. A relationship of friendship soon developed between Prandtl and his contemporary Karl Schwarzschild, who was just two years older than him and a very amiable person. His observatory was often the social meeting point for many of his friends, amongst whom was Carl Runge. His almost playful approach to mathematics inspired him to entertain his guests with delightful experiments.

Schwarzschild was equally impressed as Prandtl by the prospect of a balloon trip. The Lower Saxony Aeronautical Society was founded, which enabled its members to take off in a balloon from Göttingen. The balloon was made in a balloon factory in Augsburg and was constructed from double-layered percale sheets. The balloon had a diameter of 14 metres when filled with gas. It was called *Segler* (The Yachtsman).

The balloon was anchored in a meadow near a gasworks and filled with gas until it had taken on a rounded shape and was ready for ascent. Later, I was myself able to experience such a moment as a child. We had to wait some time before the event took place, but the time passed pleasantly and

the tension increased until the anchoring was released and the balloon rose, floating away into the sky, followed by our eyes.

The managing committee of the society had laid down very precise rules for those who wanted to gain the right to be in charge of a balloon. The club became a member of the *Deutsche Luftschifferverband* (German Airship Association) and was guided by the agreed conditions laid down in a leaflet. For example, these included proof of the ability to read instruments and to assess weather conditions (weather situation, solar radiation and cloud formation). An additional regulation was, “The managing committee of the society will allow the testing of the candidate by a specially appointed committee, to assess whether he is able to make the balloon ready and fill it without the aid of an expert providing assistance, and that he personally knows how to carry out any necessary technical procedures”. The payment conditions for passengers were also agreed.

Prandtl himself took a ride in a balloon as a passenger, as the following account, which appeared in the *Göttinger Tageblatt* (the local newspaper for the town of Göttingen) dated 10th January 1908, reveals,

“Travelling in a balloon from Göttingen to Berlin

As we reported, four academics from Göttingen University - Professor Prandtl, as well as Drs. Linke, Pütter and Bestelmeyer - recently flew to Berlin in a balloon. They ascended in the balloon named *Segler* (Yachtsman) at nine o'clock in the morning and, after a pleasant journey lasting seven hours, they arrived at 4 p.m. on the shore of Lake Müggel not far from Rahnsdorf. The airship was commanded by Dr. Linke. The balloon, the *Segler*, has a capacity of 1,400 m³ of gas. The *Verein für Luftschiffahrt* (Airship Association) held its general meeting in Berlin on the same day. As the men ascended the wind direction led one to believe the possibility of the balloon still arriving on time in Berlin, so that the four men themselves would be able to participate in the meeting. But, as they were flying in a conventional balloon and not a dirigible one, this assumption was based on unsure footing. The four scholarly gentlemen were therefore all the more proud that they were able to reach the meeting on time.”

Once Prandtl had made a few practice flights under instruction he received a licence to fly a balloon independently. He wrote to his wife Gertrud on 15.08.1909, “You can now congratulate a freshly baked balloon pilot - yesterday I passed the test!”

Ludwig Prandtl made a number of trips as a balloonist, which gave him great pleasure. It was a unique experience for him to have the opportunity of observing natural wind flow and to experience it as an elementary force. The chance of also observing cloud formation and the expanded landscape beneath him was a special pleasure. Meanwhile, Schwarzschild carried out astronomical position-finding using a surveyor’s sextant during his flights in a balloon. The creative fantasy of the scientists was stimulated again and again during these ventures.

In 1909, Schwarzschild received an offer to go to Potsdam where he became the director of the astrophysical observatory. He left the familiar surroundings of Göttingen with all his good friends.

Prandtl’s constant advancement, in contrast, was firmly established in the locality of Göttingen.

On the 11th January 1909, he received a ministerial instruction from Berlin, “I entrust your honour, from the next semester on, supplementing the teaching assignment given to you by decree, with taking responsibility for the whole area of scientific aeronautics in both lectures and practical courses. ...”

In response to this, a newspaper reported, “The Minister of Culture, Education and Church Affairs has given Dr. Prandtl a teaching assignment for aerodynamics in Göttingen. If we are correctly informed this may be the first professorship for airship navigation.”

His course of lectures was subdivided into six sections:

1. Aerostatics: on the subject of the state of equilibrium of the sea of air and an outline of dynamic meteorology
2. Aerodynamics: general laws of fluid flows
3. The equilibrium of hang gliders and gliders
4. The propulsion of air-screws

5. The stability of balloon bodies and flying machines
6. On the subject of navigation - terrestrial and astronomical determination of position. Operating range under the influence of the wind

The newspaper the *Berliner Illustrierte Zeitung* dated 15.04.1909 addressed the following request to Prandtl,

“Dear Prof. Prandtl!

We have read in the newspapers that you will shortly be giving the first course of lectures on airship navigation at the University of Göttingen and that your presentations will be combined with practical demonstrations. We would be very pleased if you would allow one of our artists to make a drawing of such a lecture during which experiments with models are used.”

The French press also reported on the new professorship and, in the English newspaper “The Times”, dated the 7th April 1909, the specialist in aerodynamics F. W. Lanchester published an article about the problems of airship navigation from which the following extract is taken,

“In Germany, a chair of aerodynamics has been founded at Göttingen, appropriately filled by a very able physicist, Professor Prandtl, whose work is well-known and who continues to hold the chair of applied mechanics at Göttingen University, in addition to his more recent appointment.

The aerodynamic laboratory in Göttingen had already been built and equipped by private enterprise before the new chair was established, and it is probably the best one of its kind in the world.”

4. Engagement and Marriage

Throughout the years, Ludwig Prandtl kept alive the contact with the Föppl family. They met during the holidays, as Prandtl did not fail to visit his respected teacher on those occasions when he was in Munich. Certainly, an additional not so transparent motive also lay behind these visits: the prospect of seeing Gertrud, the daughter of Föppl, who was now grown up. Gertrud, of course, modestly withdrew as soon as her father monopolised Prandtl.

The exchange of thoughts and opinions between the older Föppl and the much younger colleague was always stimulating. They discussed scientific subjects which could always be reconsidered and, in so doing, not only did they come closer intellectually, but the degree of trust between them also grew. Even questions regarding personnel and new appointments at the technical university were ones that came under discussion. In many of the letters written by August Föppl one can read, in addition to news about the family, suggestions regarding appointments as well as scientific discussions, but which I am unable to include in my account. I would, however, like to give reader the opportunity of reading a few extracts related to personal communications here.

From the letters of August Föppl

19th November 1903

“We are all well. My daughter” (Gertrud) “recently went to Hanover for a few weeks for a visit and saw you from a distance, from a gallery, at a students’ ceremonial beer banquet.”

1st January 1906

“My wife and I would be pleased to invite you to dinner on Thursday the 4th January at 12.45p.m. (it will be a family occasion, so please come in travelling clothes). On the 3rd January, I will begin to lecture again, so I would ask you to also meet me on the 3rd, 4th and 5th January at 10a.m. after the lectures in the laboratory.”

In 1908, August Föppl addressed Prandtl about a personal matter:

22nd July 1908

“My younger son Ludwig has been studying for two years to be a mechanical engineer and has now reached the stage of preliminary examinations. He will certainly pass these with the best grades. But, now it has emerged that my son, although very talented in mathematical subjects and someone who also enjoys this academic discipline, has increasingly lost interest in mechanical engineering. I have the intention of letting him study mathematics for one year, in the first instance, in Göttingen. After that year, he may then decide whether to continue his technical studies or to transfer to studying mathematics.

I would therefore like to ask you to prepare a study plan for my son. Certainly you will know which lectures in Göttingen are to be especially recommended to a hardworking and talented young man such as him. I would like to thank you in advance for any assistance you may be able to give (assuming that you do not communicate this by word of mouth in the meantime, which I would prefer).

Yours very truly, August Föppl.”

Föppl and Prandtl met again in the summer, which Prandtl always spent in southern Germany. As the Föppl family had owned a holiday home at the Starnberger See since 1894, their guests were able to visit them there, in the countryside, at the best time of the year. Prandtl, who made an excursion starting from Munich, as he had often done, to the Starnberger See, met the family in Ammerland and, on this occasion, had the opportunity of comprehensively advising the son Ludwig about the planned change in studies.

In the autumn semester of 1908, the student from Munich started to attend lectures in mathematics in Göttingen. He attended ones given by David Hilbert and Felix Klein, who were so well known that they attracted many non-local students. It was an advantage for him that it was also possible in Göttingen to attend a seminar in mechanics; namely, one jointly organised by Klein, Prandtl and Runge.

Consequently, a new, closer relationship developed between the Föppl family and Ludwig Prandtl. The Göttingen professor also took personal

care of the student son of his former teacher. Prandtl always asked him about how the other members of the family in Munich were doing. When Ludwig Föppl told him, in December 1908, that his sister Gertrud would become engaged in the near future, the young scholar could not suppress a certain agitation. As my uncle Ludwig told me later, he looked very sad on hearing this news.

On the 31st December 1908, he wished his colleague a happy new year and also congratulated Gertrud on her engagement.

3rd January 1909, letter from August Föppl

“Thank you very much for your nice letter at the start of the new year. However, I must tell you that the good wishes expressed in your letter unfortunately failed to reach fulfilment. The engagement of my daughter Gertrud was broken off shortly after it had been announced.” (It can be assumed that Prandtl was not indifferent on receiving the news of a change in circumstances.)

August Föppl then continued, “I would also like to thank you very much for the friendly acceptance and support given to my son Ludwig. My son Otto will now also be coming to Göttingen! Initially, I was not keen on the prospect that he wanted to give up his job in Gotha again so soon. I place a great value on persistence and determination in conducting one’s life. I hope that he will fulfil the expectations you have of him.”

So, engineer Otto Föppl, the older son, also came to Prandtl in Göttingen and worked as an assistant with the young aerodynamics researcher from the 1st January 1909 until the 1st June 1911.

The town of Göttingen was soon also to have a special significance for the daughter Gertrud, but in a different and much more existential sense than for her brothers. I will therefore now recount how Gertrud came to leave Munich for Göttingen.

At Easter 1909, Prandtl made his decision to ask Gertrud to marry him. What then happened is chronicled in the recollections of Ludwig Föppl. “Prandtl had planned a recreational trip to Gardasee and to Bozen during the Easter holiday. As was also frequently the case on such occasions, he made a stop in Munich and visited us and talked with my older sister

Gertrud. Shortly after this visit, a marriage proposal was made in a letter from Riva:

‘Riva 20th April 1909

My dear young lady, in the solitude of the mountains I came to the decision to ask you a question which I have been carrying around with me for some time already ...’

This piece of news gave me great pleasure, as I knew that she would not be in better hands than in those of Ludwig. My parents were precisely of the same opinion. Gertrud’s decision was made soon to accept the proposal of marriage. She gave Prandtl her consent to marriage in writing. As he wanted to travel on to Bozen, he asked her to send her answer there (poste restante) to await him. He also told her how many more days he intended to stay in Riva but, for some reason of absentmindedness, he forgot to tell her the name of the hotel in which he had reserved accommodation. As Gertrud did not delay in sending her answer, she sent this by post to Riva (poste restante). Prandtl thought that her letter must, if her answer were to be immediate, reach him at the hotel at his next destination. When he arrived in Bozen, he waited in vain for the letter from Munich.

For Gertrud, an anxious week was to come in which she heard nothing from Prandtl. At the end of April, I had to travel to Göttingen, in order to be there for the start of the semester, and no reply to Gertrud’s letter had been received. I tried to reassure her by saying that I would inquire, on my arrival in Göttingen, whether Prandtl had already returned from his trip. But, I learned that he was not yet back, but was expected soon. I told Gertrud this immediately. After I was informed of the day of his return, I went to see him in his flat at Kirchweg 1a and, after the customary greetings, I brought up the question of whether he had not received the letter which my sister sent to him at Riva. Taken by surprise he uttered, ‘A letter sent to Riva? Every day I enquired at the post-office in Bozen about a letter from her and finally I had to return to Göttingen.’ After this misunderstanding had been clarified, there was pure joy and we greeted each other as brothers-in-law. The same evening he sent a telegram to Gertrud to reassure her that everything was alright and, the next day, he told her what had happened in a letter.”

Mother and father Föppl greeted the union with great warmth. August Föppl wrote the following letter on the 10th May 1909,

“Dear Colleague,

I am very pleased that you and my daughter have decided to get married. I give my blessing to this union with all my heart. I have always respected you highly not only as a scholar, but also as a person, and I know no other person whom I would welcome more as a son-in-law. As our relationship will become even closer than it has been already, I will be required to address you with the informal ‘*Du*’⁸ in future, and I would like to do this right away. Gertrud has always been a good and loving daughter. I shall miss her very much. We hope to see you together with our other sons at our home at Whitsun. We can discuss the details later.

Your old teacher and new father-in-law.”

Mrs. Emilie Föppl wrote,

“As well as my husband, I would also like to address you with the informal ‘*Du*’ by greeting you warmly as a dear son. I am very pleased about this union. I have for many years had a special liking for you and I am utterly convinced that my child will find happiness in life on your side. As Gertrud has been raised to look for happiness in the true fulfilment of her duties in her own home, I hope that she will be everything that you wish as a partner in life.

May God bless you and accompany you throughout your life.

My sincere best wishes, Your faithful mother E. Föppl.”⁹

The following are extracts from the letters written by Prandtl during the time he was engaged.

5th May 1909

“My youth was quite unhappy, as a result of the misfortunes of my parents. But my even temperament helped me to overcome even the

⁸ Translator's note: German has two ways of expressing “you”: “*Sie*” in the case of a formal relationship and “*Du*” when two friends, close acquaintances or family members talk to each other

⁹ Author's note: In this context, I would like to draw the attention of the reader to the fact that the account given in passing by Prof. Th. von Kármán in his book, “The Wind and Beyond” [15] is not at all correct.

saddest periods without completely losing the joy of living. Later, I was able to experience exceptionally good fortune. If providence will now ordain that we will both unite in harmony and that we come together to enjoy a lasting union, then it will have given me much more than it has taken away.”

9th May 1909

“We men are unfortunately almost never capable of returning to our wives, to the same extent, the selfless love which they devote to us. Women devote themselves completely to their domestic duties for the sake of their husbands - whereas they must share their husband with his occupational interests.

In my case the situation is particularly difficult. You will have to cope with two rivals: a worthy woman who, however, casts a spell on everything surrendered to her with almost a divine power and another who is indeed still as young as a bud, but who casts out her net in a seductive manner in the direction of all of those who are receptive to her beauty. Shall I reveal who they are? They are science and airship navigation.

This semester, in particular, I am swamped with work! I have to deal with the extension of my *Modellversuchsanstalt* (model research testing facility) - which has already been talked about in parliament, in England - the lectures on airship navigation, for which I have, of course, to prepare additional material, various talks which I will give (one for the general meeting of the *Verein Deutscher Ingenieure* (The Association of German Engineers) and one for the Frankfurt exhibition (ILA – *Internationale Luftfahrtausstellung*¹⁰) at which I am both an exhibitor and also the head of the candidates for a prize).

If I were able to find the time, I would also very much like to become involved in the construction of a flying machine. But, for a number of reasons, I will have to let this ambition remain just that for the time being.

You asked what I do as a rule on Sundays. Well, I write letters and read up on the literature. After having my midday meal in the ‘Englischer Hof’ in the company of various young lecturers, we usually go together for a short walk; either a short stroll in a neighbouring village or an excursion

¹⁰ Today known as “ILA Berlin Air Show“

somewhere in the highlands, depending on how we feel and what the weather is like. For example, today, we went for a stroll through the charming valleys, where the cherry trees are in bloom, to the magnificent Hanstein castle. The thing about Göttingen which would give you very much pleasure is that everywhere one is so close to nature that one can generally live just like living in the country, because the newer parts of the city are laid out as a garden town.”

2nd July 1909 - Prandtl made proposals to his wife concerning possibilities of accommodation, “1. Prinz-Albrecht-Straße 20, on the first floor, fashionable, attractive location. At the rear, bordering the astronomical observatory property” (at that time his friend Schwarzschild worked there), “twelve minutes to the institute, nine minutes to the market.”

He also mentioned another flat in his correspondence which was further away and presented the following considerations. “With a distance of twice that to the institute, 40 minutes more would be required each day for walking, taking into account 288 working days a year, which would amount to eight full days and nights. When I weigh up the pros and cons I cannot come to a conclusion, because the advantages are balanced out by the disadvantages. I hope things are better for you than they are for me. Hopefully you will be inclined to something specific.”

Apparently, Gertrud had made a decision from a distance and chose the flat in Prinz-Albrecht-Straße.

10th July 1909

“So, today, I have sent off the sketches of the furniture. None of the sideboards are what I am looking for, so I have again worked on a design myself.”

The sketch still exists and I have once again recognised precisely the sideboard which stood in my parents’ dining room.

How many routes he took and how much writing and thought he devoted to this private matter, quite apart from the enormous workload he had, which was also of importance to him, can be appreciated from his letters.

Prandtl described moving into his new flat as follows. “Moving in took place as follows: Got up at half-past five - and from 6 a.m. to 8 a.m. I had a balloon filling (freeballoon) - at 9 a.m., the packer came and I helped him until 11 a.m.. From 11 a.m. until 1 p.m. I had to run a seminar - midday meal - 2 p.m. until 3.30 p.m., loading the furniture, 3.30 p.m. until 4 p.m. transport, 4 p.m. until 5.30 p.m. put everything into place in the new accommodation. Then there was finally time to take a break. At 9 p.m., last but not least, a meeting of the seminar committee.”

The wedding was approaching. On the question of religion, it was agreed that Prandtl would remain in the Catholic Church, but that Gertrud’s protestant background would determine the form of the wedding. On the 11th September 1909, Ludwig Prandtl and Gertrud Föppl were married in an evangelical church in Munich. The wedding reception took place at the house of the Föppl family in Heßstraße 10.

My aunt, the sister who was ten years younger, told me in her old age that, despite her residence in a Swiss boarding school, where she learnt French, she was able to attend Gertrud’s wedding. In contrast to her grown-up brothers, she considered the new brother-in-law to definitely belong to her father’s generation, as both associated with one another as colleagues.

The relationship between the two scientists gradually changed, however. From that time on, the father-in-law kept more to family conversations - rarely did he participate in conversations about scientific matters.

A second marriage was celebrated three weeks later in the Föppl family. The older son Otto married the daughter of a colleague from Munich. The young couple also moved to Göttingen. Otto Föppl, who had written down a part of the results of his research with the title “Wind forces on plane and convex plates” in his dissertation [8], later became professor of the theory of strength of materials in Braunschweig.

When my mother came to Göttingen at the end of September in 1909, she was very much charmed by the life in this small town and it did not take her long to feel at home.

They came back from her honeymoon which had led them to Lake Garda. At the railway station in Göttingen, they boarded an open carriage, which drove them through the town at a leisurely pace and took them to Prinz-Albrecht-Straße (now called Keplerstraße). During the journey my father pointed out a number of important buildings to his young wife, for example, the Institute of Physics with a view of the Leine river and the university library. The curve in the Hauptstraße was soon reached and then they drove a short distance along the Weender Straße in the direction of Quentins Eck. My mother, coming from Munich, was very much amused to hear that the short stretch from the Auditorium to the Markt was the main arterial road of Göttingen. As they travelled along the route, my father gave her some suggestions regarding places to go shopping. On their way they passed the town hall and the Gänseliesel (the goose girl, a bronze figure which is the symbol of Göttingen). The little horse now turned the light vehicle round the corner at the market, driving along the Lange Geismar Straße up Kurze Geismar Straße, through the old Geismar Tor, from which the mighty stone lions looked down like sphinxes. Soon after, the journey was ended, as the coach came to its destination, after a long journey at house no. 20, Prinz-Albrecht Straße. The time had come to move into the six-roomed apartment which my father had in the meantime rented. On the advice of relatives, he had already engaged a housemaid, who now greeted the couple and helped with unpacking.

The next morning my mother wanted to look around the town and do a few errands. As she went into a shop in the Weender Straße, she was served with particular attention. Then, she was surprised to hear the saleswoman say, “Yes of course, *Frau Professor*, shall we send the things to your home?” Startled by the fact that the woman had recognised her, she could only say, “But, how do you know who I am?” “Well, we saw you driving past in a carriage yesterday with the professor.” My mother felt a little spellbound but, at the same time, amused. In this town, which she had just walked through as a stranger, she was now recognised. In Munich, she was accustomed to walking along the street unnoticed. Here, however, she was expected and was given the attention due to the wife of a professor in a university town. The pair in the coach had, without becoming aware of it, attracted the attention of many passersby.

My father, whose hair was brunette and who had a black full beard, appeared serious and mature. In contrast, next to him, my mother appeared very young and delicate, with her blond pinned-up hair. At that time, she was just 27 years old.

After a short while, she became accustomed to the new role which she had acquired after her marriage. But, when she was woken up with a knock and the following words, "*Frau Professor*, the water is hot", she first had to think before she realised, "That is me, I am *Frau Professor*."

Once she said to me, "It is certainly also very nice to be able to experience together with him his promotion, sometimes having helped him, and to be able to share in the joy of his step-by-step advancement. I have been undeservedly very fortunate." She was attributed the high respect afforded to her husband and also treated as a person for whom people have respect.

Although she had already, for several months, been confronted and become familiar with this new world, which she believed she knew a little already from what her brothers had told her and from what her fiancé related to her, everything turned out different to her expectations. She was soon completely occupied with her new life. As her husband did not have his own secretary at that time, she dealt with his paperwork for him. Both of them had learnt the same shorthand - *Gabelsberger*. This facilitated their working together. She was therefore able, at the same time, to gain an insight into his intellectual world and, above all, become familiar with the circle of people around him. Her clear, decisive manner was often a fortunate complement to his nature since, even with regard to minor matters or matters of secondary importance, he was prone to reflection and careful consideration. In everyday matters, the attention to detail with which he patiently explained his position and reflected on the various possibilities was somewhat touching. In contrast, for my mother it was easy to come to a decision and this was an advantage when a small decision regarding everyday life had to be made without delay. A scene which is imprinted in my memory, through repetition, illustrates this. At breakfast, my father opened the post which had just arrived and became engrossed in reading the letters. All of a sudden, he stood up, as if something urgent had to be dealt with. Nevertheless, he took the time to

look out of the windows on all sides of the apartment, in order to view the sky, checked the temperature on the outside thermometer and deliberated about which coat he should put on. His decision would be made more difficult if suspicious-looking clouds cast the landscape in shadow: should he take an umbrella with him? He asked my mother for her opinion. She did not hesitate in making a decision. Without glancing out of the window, she said with cheerful optimism: “You won’t need an umbrella!” “That’s good”, he said, “But you will have to accept responsibility”, and then left his umbrella at home.

Both Prandtl and his wife took pleasure in going for long walks. Both on Saturday afternoon, as well as Sunday, they walked through the woods close to their home sometimes going beyond the nearest villages.

A first social occasion took place in the Prinz-Albrecht-Straße, according to a note, on the 7th December 1910. The young married woman now had the task of proving herself as a hostess, after having been invited by the families of her colleagues, in turn, during her first year of marriage. My father was very happy, after all the years of being a bachelor, to finally be able to invite his married colleagues to his own home. The Hilberts, the privy councillor Klein and his wife, Professor Runge, Professor Wiechert, Professor Simon and others came to visit him for dinner. From the expressions of satisfaction of my father, it can be concluded that the evening was a success.

But, my mother was very much aware that frequent dinner parties would take away the time that her husband might otherwise have spent on his nightly workload. For this reason, they avoided committing themselves to too many social obligations. On the other hand, Gertrud’s brothers often came to the house to enjoy a pleasant Sunday dinner.

Apart from these social occasions, my father and mother also enjoyed the time they spent together at home. One of the rooms was furnished as a music salon, with the Bechstein piano, which my father bought when moving into the apartment, standing on the side of the room with a window. There was hardly a day when the piano was not played. It remained an indispensable need of his to sit down at the piano, at least once a day, in order to become engrossed in the world of music. Without

having to have music before him, he played energetically as his fingers touched the keys and, in so doing, created rhythms from the richness of his imagination. His playing was inspired by the ideas of Bach or Mozart, Beethoven and Brahms, which he transformed and developed into his own, original structures. His improvisations did indeed resemble each other a little in style, but his musical inspirations were so rich that they always sounded new and original. There was never a repetition. Once, when we expressed our admiration, he said, "Well, I took that motif from Haydn, it was not mine". But, he was able to freely improvise a theme which he then further developed into a fugue. His ability to express himself musically, depending on his mood, appeared to be inexhaustible.

For us, his playing had a special significance. One sensed how much his music was an expression of his whole personality. When he came home from the institute late in the afternoon and he proceeded to the piano, he sought relaxation in playing. And his fantasies spread a mood of harmony and the joy of living filtered through art.

We later asked him, at a stage when we had begun to have an understanding of music ourselves, to try to play a fugue in three parts. He paused to reflect and then, to our amazement, at once played, with his usual interweaving the ever-recurring theme. It was a wondrous surprise for us to experience how his ability, which we had put to the test, could be so confidently demonstrated. We were now also allowed to invent the theme ourselves. For him, this was a new game and, with a serene feeling, he solved the task.

At this point, I would like to recount an incident told to me by my mother which I remember well. Once, when my parents were invited by colleagues of my father who also had a piano, the lady of the house said she would have very much wished to have asked my father to play the piano but, with much regret, this would not be possible, because, for some time now, one of the keys no longer struck a tone. He played preludes for a while but was forced to concede that, even when the key was struck with some force, no sound could be produced. While the other guests amused themselves in an adjacent room my father started to examine the piano, unobserved by the rest of the company. He cautiously opened the piano and soon found the reason why the key was not

producing a single sound: a thimble had fallen down between the wires and had become firmly clamped in position. After he had removed the thimble, he sat down at the piano and began to play mightily, from the deepest bass note all the way up to the treble tones, in rich harmonies. The guests listened in surprise from the room next door. As the lady of the house opened the door between the two rooms, he said she must have made a mistake, as all of the tones of the piano could be heard unmistakably. He had just tried himself. She looked in disbelief and wanted to indicate to him the key that produced no sound - "Look, the key is working perfectly!" The host now started to insist that even yesterday the key had produced no sound. My father said he wanted to show her something that he had found and gave the thimble, to her to the amusement of the other guests. He was then asked to play again. The cheerful agreement of the small group of guests was a just reward.

Now and again, my mother travelled. She visited her parents and then continued her journey to the mountains for relaxation. The closeness of the relationship between my parents is indicated by the letters that they wrote to one another.

Letter from Ludwig to Gertrud dated the 4th August 1912.

"The end of the semester has arrived. I celebrated by sleeping for a long time. The only positive thing which I have done was to write this letter to you, even though there are another twelve letters waiting to be written! Monday 9-11 a.m. Sommerfeld, 11 a.m. -1 p.m. a double lecture which I squeezed in, in the afternoon gymnastics, then evening meal with Ludwig Föppl, at home here. Kármán then came as well, they stayed until 11 p.m. and we worked on an article. Otherwise, I would have liked to write to you yesterday.

Yesterday was an important day here. The Zeppelin ship 'Hansa' flew in a loop across Göttingen (the municipal authority and the *Verein für Luftfabrt* (aviation association) paid for the event). The whole of Göttingen was either standing around or on the roofs to watch. We were on the roof of the veranda and saw it in all its magnificence. The bells rang, the towers were decorated with flags and there was a great deal of jubilation. It was a shame that you were not there!"

A letter from Gertrud to my father dated 15th August 1912, finished as follows.

“Goodbye my dear, dear husband. When I stroll through the woods alone, I usually talk to you.

I send a thousand greetings to you, yours Gertrud.”

About these times Ludwig Föppl reported the following.

“Following the teaching examinations in Munich, I went back to Göttingen for the winter semester of 1910, in order to study for a doctorate. The following four and a half years often provided me with the opportunity of getting together with the newlywed Prandtl and his wife. Once and for all, I was invited to the Prandtl’s home for Sunday dinner. I look back with pleasure on these Sundays, which were always harmonious occasions. Prandtl was someone who likes his food. He tucked into the Sunday roast with visible pleasure and gave a free hand to his fantasy, in combining various tastes, in the choice of the different dishes that were placed on the table. After taking a short break after dinner, Prandtl sat at the piano, a beautiful Bechstein, and fantasised. I listened to him, sunk in a chair, with much pleasure and admired his talent for translating his momentary mood into music, without having to have a score in front of him. Of course, the piano sometimes had to cope with being an experimental guinea-pig. Prandtl would, for example, place sheets of newspaper on or underneath the wires and so investigate their effect on the sound of the piano. As he had an absolute sense of pitch, he was also able to tune the piano himself. Prandtl could submerge himself in playing the piano to such an extent that he forgot about everything else. For him, the instrument constituted a source of spiritual relaxation.

An integral part of my visits to the Prandtls was going for an after dinner walk. Usually our route led up the Hainberg to the Kaiser Wilhelm park or to the Kehr, where we had a cup of coffee. Prandtl’s lively mind observed every special feature on our way. He was able to share the same pleasure as a child on seeing the first blooms in spring and listened attentively and eagerly to the songs of the birds. His attention was drawn by the wind and the weather. He was always able to produce spontaneous anecdotes about his observations, thereby always making these walks a source of pleasure. The playful instinct in him was also put to the test. I remember he liked to play with the coffee set after the coffee had been drunk, using the cups and saucers as building blocks, placing one on top

of another to form towers and so tested the stability of these constructions. Sometimes, a cup was broken into pieces, which then had to be paid for, accompanied by many apologies to the waitress. These Sunday walks made us all feel good. Prandtl had the need, at least once a week, to go for a good long walk. It provided a counterbalance to his way of life. The professorial gymnastics which took place in the late afternoon on Saturdays also served this function.

In this way, many delightful years went by in which Prandtl's reputation grew, as a result of his diligence and his good ideas.

As my liking for engineering clearly came to light at this time and both my doctoral thesis and my habilitation thesis are concerned with problems of mechanics, meeting frequently with Prandtl was exceptionally stimulating and fruitful for my scientific progress. If I ever had any kind of difficulty, it was often sufficient just to talk with Prandtl, in order to be freed from the deadlock that was causing difficulty. This assistance was granted not only to me as his brother-in-law, but also to all young people who came to him with similar concerns. His kindness and philanthropy had no limits. So, he was very much liked both by his students and assistants, as well as his colleagues. Certainly, his kindness was also taken advantage of on occasions.

I also often met together with Prandtl during the summer vacation, as we spent some weekends together at the Starnberger See in the country house of my parents. He always took a briefcase with him, which was full of work which had not be done and letters which had not been answered, which kept him at his desk, above all, when the weather was not so good. When the weather was good, he enjoyed the garden with us and the attractive landscape, as well as swimming in the lake. At a vantage point in the garden, which allowed a view over the lake and over the whole chain of the Bavarian mountains, we often stood together and Prandtl looked around and gladly talked about all the features that he observed carefully. In particular, the evening mood, which was especially impressive from this viewpoint, could make him extremely enthusiastic. Often, when he saw that the sky had taken on a particularly beautiful colouring, he called us and drew our attention to the different hues. A special wish of his was always to occupy himself with observing the weather. From our vantage point, it was possible to predict the development of the weather situation quite well. Prandtl repeatedly observed approaching storms from here and followed unique cloud formations in their genesis and development. He

often remained there until the first drops of rain fell. One year, in which a newly planted spruce hedge had grown so high directly in front of our viewpoint that it blocked the far view which had previously been there, we decided to construct a small mound of gravel, in order that we would have a higher viewpoint. We took many wheelbarrows full of gravel from a gravel pit to there. Prandtl helped with hard, physical work like a comrade, even though it was harder for him than the other, younger ones. He always gladly took part in our activities, enjoyed the fun, and often contributed new points of view. He willingly adapted to every situation and was never a spoilsport, even when we joked about his physical awkwardness. One was never aware of him being a highly educated and well-known professor. He was always equally friendly and modest, in just the same way that modesty is a characteristic of those who are highly educated. He also played tennis with us on our tennis court, although he had not practised and reacting fast was not in keeping with his unhurried and thoughtful manner. Nevertheless, we were always pleased when he played with us. There was often something to laugh about. For example, if there was an imperfect stroke, he wanted to give us a detailed analysis of the stroke and we made him aware of the difference between theory and practice.

I remember with particular pleasure the walks taken together with Prandtl in the village of Ammerland and surroundings. He was always a charming and interesting companion. Every pool we passed stimulated him to carry out an experiment and he had to throw at least one stone into the water, in order to study the spreading of the waves. Once, I went with him along the lake when there was a strong west wind and together we watched the group velocity of the waves of different heights. After he had drawn my attention to this phenomenon, which up until then had been unknown to me, we sat on a bench and he began to give an explanation with the aid of a few formulae which he wrote down on a piece of paper. He drew a conclusion about the interference between two waves having almost the same frequency, according to which the group velocity was equal to half the speed of advance of the individual waves. In this way, he constantly made a connection in his mind, using his observations, between the laws of physics and the phenomena on which they are based.

This was the essence of his astounding ability: the intellectual analysis of observations with the aid of the basic laws of physics. Since he had possessed this way of thinking from his youth and he employed it

involuntarily at every turn, it did not require special intellectual effort on his part. So, one had the impression - even in relation to his work - of a result being achieved without any effort. I often had the feeling that he had an immeasurable fountain of knowledge about physics which he could effortlessly draw on at any time, in order to enrich a question currently under discussion. This explains both the tremendous breadth of his scientific achievements, as well as also the wide base of his scientific interests, extending over the whole area of natural sciences. Whether it was a question of pure physics or purely technical problems, about astronomy, geology or mechanics, he always surprised everyone by his deep, often very specialised knowledge and original conclusions. Time and again, he was able to enter into discussions with various colleagues in his faculty about their specialist areas, without special explanations having to be made.

I had the good fortune to have close ties to the two most important representatives of the field of mechanics in Germany; namely, my father August Föppl and my brother-in-law Ludwig Prandtl. I learnt a great deal from both men; not only about science, but also in purely human terms. Even if I only stand in the shadow of these two great figures, nevertheless, I believe I am, more than any other, able to judge the lifework and way of life of both these men. Moreover, what surprised me over the years was the recognition of the generosity with which Mother Nature had endowed them with talent. Though both men worked as scientists, they did not correspond in nature or character. Of course, there were similarities in the characters of both men in their uprightness and reliability. Also, the diligence of both of them, which accompanied them like a constant stream throughout their lives, does not have to be especially pointed out, since this is essential for success, in science as well. However, with regard to disposition and manner of working, they were totally different. Their lifestyles also bore a different stamp. Two types of scientist can be distinguished: one the classicist and the other a romantic, as Wilhelm Ostwald described in his book *‘Große Männer der Wissenschaft’* (“Great Men of Science”). The latter is characterised as a genial, talented man who achieved much at an early age in an onrush, without much effort, whereas the classicist developed slowly and constantly, first achieving success after many, arduous years of work. If one applies this classification to August Föppl and Ludwig Prandtl, the former can be described as the ‘classicist’ and the latter as the ‘romantic’. August Föppl

can attribute his success to his disciplined, persevering work. In contrast to this, success appeared to fall into Prandtl's lap without any effort. With his doctoral thesis, written when he was 23 years old, he opened up a new field of research with his theory of elasticity. At the age of 29 years, with his work on the boundary layer theory, he introduced a new era in hydrodynamics. Truly a romantic ascent! But, August Föppl was the thoughtful teacher, whose lectures and research are characterised by crystal clear presentation. Prandtl did not have such success as a teacher. While he was able to give particularly stimulating instruction to advanced students and doctoral students, he sometimes had difficulties in lecturing to beginners in the field. The reason for this may have been that he himself did not have the slightest difficulty understanding the basics of mechanics when he was a student. The basic principles of mechanics were more or less self-evident to him. Therefore, he was not able to understand the difficulties which his students could have with the subject.

Despite the high level of mutual respect between these two distinguished men, there were such strong contrasts between them that these occasionally produced minor strains in the relationship between the father-in-law and son-in-law during those times spent together over several weeks in Ammerland, although it should be said there was never any serious bad feeling between them. The difference in age between the two men was only 21 years, but these years spanned a period of radical change that separated two epochs from one another. My father was still rooted in the authoritarian and rigid outlook of the second half of the nineteenth century, whereas Prandtl was moulded more by the social ideas and the notion of progress associated with our century. It was for him, in every respect, difficult to subordinate himself to our father, which we ourselves had accepted as a matter of course from childhood on. August Föppl's strong personality also had a great moral influence on those around him, so that he was referred to as the 'conscience of the faculty' by colleagues. With heart and soul, August Föppl was pleased about the great scientific successes of his son-in-law. Indeed, he was the first one to notice the inspired talent of Ludwig Prandtl.

From my experience of life, I have come to realise that a highly talented person is placed under a kind of involuntary compulsion to order his life according to the demands of his talent. He can only feel satisfied when an opportunity is presented to use that ability. As long as this opportunity is denied, he will be driven by the necessity to strive for such an occupation

in which those talents can unfold. If he is fortunate in finding a sphere of activity for this, he will feel the determination to now unfold his talent and look for further challenges, in order to achieve the greatest thing possible.

Prandtl only tackled problems that lay within the sphere of his exceptional talent. Though his interests in natural phenomena were so diverse, he restricted himself to specific research tasks and so made economical use of his intellectual ability. In this way, he was successful in achieving impressive advances in breaking new ground in research, so that a monument has been erected for all times to his name.”

5. 1911 — 1918 Everyday Professional Life

In the first years of marriage, which turned out to be so harmonious, Prandtl was faced with plenty of new tasks. The *Modellversuchsanstalt* (model research testing facility) which, from the very beginning, was intended to be only provisional, was now no longer adequate for carrying out research on aeronautical technology, which was continually developing. In 1911, my father started working on a plan, again at the suggestion of Felix Klein, for the establishment of a new, extensive research institute. The privy councillors F. Klein and von Böttinger supported the idea that the new institute should be established as a Kaiser Wilhelm Institute. But, the Kaiser Wilhelm Society was of the opinion that the Prussian state should make a substantial contribution to the costs of construction and maintenance of the institute. As a result of this, therefore, realization of the plans for the institute was delayed until 1925. Nevertheless, the first stage of construction was completed already in 1918. When the First World War broke out in 1914, the project was first of all abandoned. In contrast, the planning of a *Reichsversuchsanstalt für Luftschiffahrt* (German Reich Research Institute of Airship Navigation), in which Prandtl was involved in collaboration with H. Hergesell in writing expert opinions [13], was accelerated. The experimental institute was established in 1912 with the name *Deutsche Versuchsanstalt für Luftfahrt e.V.* (DVL) (German Research Institute for Airship Navigation, Registered Association) in Adlershof.

A completely new enterprise was set up outside Göttingen, in 1912, in Arenshausen, as an inspection office for air-screws. The measured values were passed on to aircraft factories. My father had an additional workload as a result of further requests for information about technical problems and expert reports to be written as a consequence of this. The possibility of determining wind pressure using measuring equipment was so new and convincing that consideration was given to more general uses of this method. Bridge builders, for example, were interested in studying wind pressure on the piers of a bridge and it was possible to produce a satisfactory result using these measurements. Repeatedly, inventors contacted Prandtl in order to obtain an appraisal of their projects. I remember that one of these believed, indeed, that he had invented a

perpetual motion machine. On another occasion, Prandtl was asked by an unknown inventor to pass judgement on his work, which was a description of measuring equipment presented for consideration.

Prandtl gave the following reply in 1909, "I would like to respond to your inquiry in the following manner. In my opinion, it would not be possible at all to measure wind pressure using the equipment described by you in the enclosure to your letter ...". Prandtl suggested an improvement and supported his suggestion with a scientific explanation accompanied by a precise drawing. On conclusion of the exchange of letters, a solution was indeed in sight. Although he was not happy when such inventors wrote to him, he always conscientiously answered each letter. I would like to include a few examples here by way of illustration.

5th December 1912

"Dear Mr. K.,

I have now had the opportunity of thinking over your project in detail and I believe it deserves to be realised. But, however, I do not hide from myself the fact that there will be exceptional difficulties which need to be overcome."

22nd March 1912

"Dear Mr. M.,

In response to your worthy request, I must unfortunately reply that we cannot accept aeronautical inventions for general expert assessment. The *Modellversuchsanstalt* does, however, accept commissions for experimentally determining air forces on models. The costs incurred are charged to the applicant, which amount to about DM 60 for each day of experimentation."

9th June 1912

"Dear Mr. A.,

Your request addressed to the privy councillor Böttinger has been passed on by him to me. After taking note of your explanations, I can only advise you not to pursue your idea of a fan aircraft, as it will certainly result in complete failure."

The following letter, written in 1911, is about Prandtl's wish to help the air pioneer August Euler to come to the Göttingen area to hold an air display. Euler was the first German to have taken a flying test and therefore received the pilot's licence No. 1. He organised the first air mail route service. Later he developed the bases for German air traffic law. The purpose of Prandtl's letter to senator Friedrich Jenner was to prepare the event.

“... Euler wants to fly on the Kleiner Hagen (a small rise near Göttingen). He considers the formation of a barrier using a body of men and safety staff to be entirely adequate, even if a relatively small number of personnel were to be used. He thinks that it would only be dangerous with a public who had paid for entry to the event but, when it felt it was only tolerated, it would be much more peaceful. A short explanation in the newspapers of the absolute necessity of keeping the airfield free would, in his experience, be effective. (‘The flight would not take place until the field was free.’) Euler would like the whole of Göttingen to see something of his flights. Only access to the aircraft and entry to the starting place will be reserved for invited guests. The costs of the event will comprise transport and travel costs, materials consumed etc., which will be paid for by Euler, and Göttingen will only have to pay the costs for erecting the barrier and the tents for pilots, and also for the groups of attendants (just a few people). Regarding the payment of costs, there is a possibility, since something will be offered to all the inhabitants of the town, that the town of Göttingen will make a contribution. The *Luftschiffverein* (airship society) will also consent to a contribution and, for this contribution, acquire the right that its membership card will entitle the holder to entry to the starting place. Altogether, the event should be an enjoyable event for Göttingen, if the weather is fine on the day.

With best wishes, yours sincerely L. Prandtl.”

Prandtl had already established contact with August Euler in 1909, following an exchange of letters, at the first “*Internationale Luftfabrtausstellung*” (ILA, International Airship Exhibition, today known as ILA Berlin Air Show) in Frankfurt am Main. This resulted in Euler, in the spring of 1911, offering to organise flight demonstrations in

Göttingen, to support scientific interest in flying. Prandtl took this offer as an opportunity to invite representatives of aeronautics at that time to a meeting in Göttingen. As a result, in November 1911, an aeronautical congress was initiated, at which a number of interesting specialist lectures were presented [37]. Prandtl remembered 11 years later [41] that “The congress took place in high spirits, not least because of the very successful social part of the proceedings, as I have never experienced at any other before. The fact that all of those assembled were completely agreed on the objective they were striving for did not make an insignificant contribution, ... Therefore, it came as no surprise that the general opinion was expressed that such an event should take place again in the near future. The mandate was offered to us, the Göttingen Association, to see to it that this meeting would take place. ... ” Von Böttinger, Klein and Prandtl gladly accepted this mandate and made preparations so that, in 1912 in Berlin, under the honorary chairmanship of Prince Heinrich of Prussia, the Scientific Aeronautical Society was founded which still continues to exist today with the name *Deutsche Gesellschaft für Luft- und Raumfahrt e.V.* (German Society for Aeronautics and Astronautics, Registered Association).

There were also letters of a private nature in which suggestions, as well as material help, were requested which I would like to include in my account in order to characterise the deep-rooted fundamentals of true kindness.

The messed-up life of someone who had previously lived in Göttingen, who apparently was a neighbour, is manifest in correspondence stretching over some time. The man approached Prandtl with the request to grant him a large loan, as he was in difficult circumstances, as a result of speculating. Prandtl was prepared to help him and to act as an intermediary between the various members of the family who had fallen out with one another.

Prandtl’s letter dated 1st September 1910,

“I was very sad to read about your misfortunes in your letter. You will not be disappointed by your old next-door neighbour: I will lend you the money.”

Z. replied,

“Dear Professor Prandtl!

Thank you very much indeed for treating me so kindly in helping me and thereby getting me out of a very difficult situation. Your readiness to provide assistance is a true sign of your friendship and it has helped me twice over, since all of my personal friends - or should I say so-called friends - have left me in the lurch.

Yours very truly, Z.”

The disharmonies in the family were also later resolved.

That was Prandtl's way: If someone asked him for help, he was always spontaneously ready to give it. I know of still other instances, at a later date, when petitioners who approached him obtained a loan from him.

I would like to quote another communication about a completely different matter which, in my view, is of equal interest. In a letter dated 1913, Prandtl gave his agreement to membership of the *Kepler Bund* (Kepler Association). The Kepler Association for the Promotion of Natural Sciences proposed the following requirements of science and basic principles for the natural sciences:

1. The independence of science,
2. The objectivity of research,
3. Supporting natural sciences and natural philosophy,
4. The recognition of the insufficiency of the natural sciences to constitute a philosophy of life on its own,
5. The recognition of the neutrality of the natural sciences in questions of philosophies of life and religion,
6. To support the right to believe in God; i.e. the compatibility of a belief in God with the doctrines of natural science, as a logical consequence of point 5.

Prandtl made the following statement in conjunction with his declaration of membership:

25th March 1913

“I am replying now to your circular, after a long delay, at the end of the university semester. I have considered it with genuine sympathy and find

that I can acknowledge all six points which are listed and that I completely agree with the intentions of the association, if the practical work of the association were actually to be implemented in the way described in the 'Guidelines'. Following the earlier statements, apparently coming from the opposing side, I had gained the impression that the aim of the Kepler association was to awake the interest of those interested in the natural sciences for the old, affirmative religions.

On the other hand, on the basis of the guiding principles listed in your circular, I may indeed assume that the Kepler association, just as it opposes the submission of a religious outlook to the ideas of natural science, also opposes interference from ideas deriving from religion in the assumption-free practice of the natural sciences (belief in miracles etc.). If this interpretation of your aims is correct, I would gladly be prepared to become a member of the association.

I would briefly like to draw your attention to one incorrect point which I have noticed in your circular. You refer to an 'artificial enmity' between the natural sciences and religion, for which monistic-materialistic circles are to blame. In my view, the affirmative religions, which have opposed research on nature - in particular, the theory of evolution - bear greater blame, and monism is only a reaction, though one which however goes beyond the aim, against these attempts at retrogression."

The burden of work increased particularly in these years. Prandtl saw that he would need to look for an assistant to aid him in his scientific work. Only one young scientist applied for the position which became available as an assistant in the *Modellversuchsanstalt* (MVA), a man who had worked in the area of hydrodynamics. As Prandtl showed him around the rooms of the MVA and pointed out the equipment and apparatus, they had a lively conversation. Apparently, this graduate engineer was very talented and very suitable indeed for the position. His name was Albert Betz, who later became the director of the AVA, and was appointed as Prandtl's assistant on the 1st September 1911. The research they carried out together only continued for a few years before war broke out. Then, Albert Betz reported for duty as a volunteer for military service. But, in the following year, it became apparent that he was indispensable at the institute and so Prandtl wrote on the 25th June 1915 to the curator, "I ask you most courteously, your honour, to see cause to appoint *Dipl. Ing.* (graduate engineer) Albert Betz, who previously was employed by me as

an assistant and subsequently has been a volunteer in the military service, and who has now been released from military service and made available to me, to his former position, in order to that he may once more collaborate in the reconstruction of the *Modellversuchsanstalt*.”

This request was duly granted. His final release from military service allowed him to return again to his old workplace.

The majority of assistants and mechanics working at the institute had, for the most part, since August 1914 been called up for military service, so that Prandtl had to continue his work in these troubled times without trained assistants.

In 1912, the *Motorluftschiffahrt-Studiengesellschaft* (Motorised Airship Study Society) was dissolved and the *Modellversuchsanstalt* was then taken over by the university and incorporated into the Institute of Applied Mechanics. The operating costs were taken over by the Ministry of Culture, Education and Church Affairs. The success of the MVA was evident and the equipment which was developed there for the first time soon also served as a model for other research institutes active in this field of research. But, the First World War resulted in an interruption to the planning of an enlarged testing facility. Nevertheless, in 1915, the army command expressed its interest in the further development of the *Modellversuchsanstalt*. The research equipment had continuously been made available on an ongoing basis to the army and navy, but it was hardly sufficient. So, in April 1915, Prandtl wrote a new memorandum, in order to expound the need for constructing a new building. The following text is quoted from this memorandum:

“The direction which the work of the *Modellversuchsanstalt* has taken suggests that it is very much in the greatest interest of the army and the navy administration to help in the creation of a large aerodynamics laboratory, by granting the necessary non-recurring and running funds needed for all, at present foreseeable tasks, for the further development of military and naval aeronautics.”

The memorandum was given personally to Prince Heinrich of Prussia, in Kiel, who handed over the plan proposed by Prandtl at once, with his

personal endorsement, to the War Office and the German Imperial Naval Office. Prandtl received the following reply:

“Kiel, 30th April 1915

My Dear Professor Prandtl,

On the occasion of my visit on the 27th April to the Max Oertz construction dockyard, Hamburg, which I used to inform myself about the progress of seaplanes and land-planes, which is extremely important at the present time, your memorandum was given to me by Mr. Oertz, on the same day, as well as the offprint from the journal of The Association of German Engineers (specialist area airship navigation) in three copies with the comments that it was important that these papers be passed on to the appropriate office holding responsibility and the polite request for me to act as an intermediary.-

As I was convinced of the importance of the subject matter of the documents, as well as the need for extending and supporting the Göttingen testing facility, I expressed my readiness, in so far as this is in my power to do so, and have accordingly immediately sent two copies to the Secretary of State for War as well as to Admiral Dick from the RMA, with a brief accompanying letter in which I have tried to outline the kind of interaction that would exist between the Göttingen institute and airplane builders, with a special comment that we have now indeed really moved away from the study of empiricism and that science now primarily supports and promotes the construction of aircraft through scientific research, as well as the establishment of facts.-

Although I am personally not able to judge or influence the future financial deliberations of the authorities which I have referred to, I am nevertheless pleased that at least I have been able to draw attention to a matter which is very dear to my heart and which, moreover, as a result of the talk by Mr. Oertz, with the help of his design drawings, convincingly proves the close relationship between science and constructional design; so, an aim has been achieved which I have dreamed of and which may be pursued further, primarily thanks to your efforts.-

The events of the years 1914/1915 have naturally resulted, particularly in the past 9 months, in my not having been able to concern

myself with these details, up until now, but now I am fortunate that the opportunity has been given to me anew.-

These few lines are simply to inform you of this.

I send you my very best wishes and hope that it will be possible to duly support you in your efforts in a fitting manner

I remain, Professor Prandtl,

your

very sincere, grateful and devoted

Heinrich Prince of Prussia”

Shortly afterwards, a meeting took place in Berlin about which Prandtl soon informed Felix Klein. His shock about the losses suffered and the harshness of the conduct of war is made clear in his letter.

Berlin, 11th May 1915

“Dear privy councillor,

The result of today’s conference at the War Office is simply overwhelming, if not simply shattering (particularly when viewed from my personal standpoint).

The new *Modellversuchsanstalt* is to be built immediately, using war funds, with the greatest of speed on the Böttinger meadow, in order that the war can still benefit from the measurement results.” (Privy councillor Böttinger, the commercial manager of the Bavarian paint factory in Elberfeld, made available his own piece of land, which he had purchased in 1907 for the project.) “I promised to have the first results after half a year, which was said to be reasonable. Consequently, the gentlemen are still expecting the war to last a long time. I have already reclaimed my assistant and will, in any case, limit my teaching activities, and perhaps I will have to give up the deanship. I will tell you more when I see you. Prandtl.”

Just like Albert Betz, it was possible to bring back the other young co-worker Dr.-Ing. C. Wieselsberger from military service. G. Fuhrman had already fallen in battle in September 1914 in Belgium. Betz was appointed as an assistant on the 15th May 1914 and Wieselsberger on the 1st June 1915. Dipl.-Ing. Max Munk had already received a post as an assistant in April. In this way, it was possible to guarantee a continuation of the

planned work of expanding the testing facility. In July 1915, the brother-in-law Dr. Hans Thoma was persuaded to come to Göttingen as the building supervisor for the new project. In the meantime, Else Föppl, Gertrud's sister, had also married a talented engineer. The collaboration with Thoma, who was released from the imperial shipyard in Wilhelmshaven until the 1st March 1916, agreeably accelerated the progress of the work on the new building.

On the 29th May, Ludwig Föppl wrote the following in an army postal services letter.

“Signals command 6,

I have heard from Gertrud that you now will receive your new institute. Many congratulations! How envious all of your colleagues must be that you have the opportunity to serve your country in such a way. I would also like to congratulate you on having obtained such a capable worker as Hans Thomas as an assistant.”

23rd June 1915

“You are now also working hard in the service of the country by accelerating the new construction of the *Modellversuchsanstalt*. We wireless operators have noticed that the enemy is undeniably superior when it comes to flying.”

In the course of many months of active work, a new high-powered wind tunnel was built with a settling chamber now of 4 x 4 metres and an air jet diameter of 2.25 m. New possibilities of research have therefore been opened up.

Professor Betz wrote [3], “Although, during the war, military interests had the highest priority, it is nevertheless striking that the testing facility was given very much a free hand in the selection of its tasks by the authority holding responsibility. At that time, there was a conviction that basic research is of great importance and that the greatest success could also be achieved by helping the researcher to realise his ideas without restricting him in his work.”

Based on this view of the freedom of research, one can understand the inquiry of a biologist about whether animal flight can be measured. Prandtl's answer was as follows.

20th August 1915

“Dear Doctor,

Unfortunately, circumstances are not such that I can say many favourable things about the matter. The *Modellversuchsanstalt* for aeronautics, which is the subject of current concern, is being built using resources for funding the war and serves solely the purpose of research into aeronautics. Our research methods involve the maintenance of a large, strong air-stream in which models of aircraft or individual parts of such model aircraft are tested with reference to their air resistance. Other facilities have not been planned up until now and will only be added if there appears to be a military interest in such developments. However, as things stand, it is planned to further extend the institute during peacetime. The question of whether, at a later date, special consideration might be given to biological aerodynamics, is still a long way off and very uncertain. As you know, I have a sympathetic disposition to such questions, although I have for a long time been increasingly convinced that aeronautics will benefit very little from the study of animal flight. In my opinion, one would be more likely to be able to draw conclusions of value to aeronautics from observing the flight of large birds (storks, condors, large seabirds). Already the flight of the smaller birds, still more the flight of insects, is so far removed from the preconditions for human flight that the study of such things is not really useful. I do not want, of course, to dispute at all that the investigation of such matters is attractive and instructive from the scientific perspective. From what has been said, I am sure you will understand that I cannot give you any assurance, for the present, that the biology of flight will be allocated much scope at the institute. Nevertheless, I think I can say that when the institute has achieved a state of steady development, it may well indeed be possible to procure such equipment and apparatus as may be necessary to carry out such experiments of the kind you describe.”

In the new building of the *Modellversuchsanstalt*, the concern was to be able to pass on the promised measurement results to the army command. For this work, a capable mechanic was urgently needed.

On the 8th December 1915, Prandtl wrote to the Imperial Naval Office, “As a result of the orders placed by the imperial shipyards with the Göttingen testing facility, there has been a great increase in work, which can only be dealt with by the current number of personnel after long delays. I would therefore ask, most sincerely, whether the Imperial Naval Office is able to provide me with an additional worker to carry out this work. The most valuable would be a technician who is able, following appropriate instruction, to read the measuring equipment, to calculate the measurement results and prepare the pertinent results in illustrations and graphs.”

As his suggestion was not accepted, Prandtl turned to the deputy general command in Magdeburg, in order to bring about the release of his former mechanic Julius Lotze.

He wrote on the 15th February 1916,

“In Göttingen a *Modellversuchsanstalt* for aeronautics, under my direction, is currently being built from funds made available by the War Office administration.

Since it has not been possible to obtain a sufficient number of precision mechanics for the construction of the measurement equipment, I recently approached the Gruson works in Magdeburg-Buckau, in order to arrange for the return of my former mechanic Julius Lotze. He was made available to the Gruson works, as a mechanic for its cannon workshop, about a year ago, as a result of a War Office order. As Mr. Lotze is not only a skilful mechanic but, due to his previous occupation, he also knows precisely the special requirements of the work at the research institute, his assistance with the aforementioned work would be especially valuable.”

Prandtl was successful in bringing Lotze back to Göttingen where he was a great help in setting up the new testing facility.

It the meantime, it had also become necessary to appoint a new secretarial assistant. This gave Prandtl the idea to ask his colleagues if they could suggest a suitable secretary. He was of the opinion that, through personal contacts, problems could be reliably solved; even those of making appointments. Professor Wiechert, director of the seismography institute, had a first-class secretarial assistant, Ms. Frieda Kreibohm, who also

worked as a technical calculator. The question was posed of whether she had a sister who could be appointed to the job. But, at that time, her sister was only 16 years old and was still at school. When she was offered the possibility of having the job immediately, she decided she would not cut short her last year at school. Until that time, Professor Wiechert was able to release his secretary to Prandtl on a half-day basis. The measurements taken during the experiments had to be evaluated by carrying out calculations. On the same day on which the younger sister, Hilde Kreibohm, concluded her schooling with the customary examinations, she went in the afternoon to the testing facility. She stayed there 50 years; that is to say, all of her working life. She advanced from being a junior secretarial assistant to being the director's secretary. When I visited her, I only asked her, "Were you able to use a typewriter?" "No", she replied, "at that time there were no typing courses. I received an old typewriter from Professor Betz which he brought to our house, to try out and I simply practised on my own, for hours on end."

The number of personnel in the office and the workshop was constantly increased and, meanwhile, the institute buildings went more and more towards production. In 1918, the number of personnel reached a maximum of fifty. Dr. Wieselsberger and Dr. Betz ran their own department for new constructions and theoretical work. Amongst the assistants were also a number of students undertaking voluntary military deployment, so that the calculations could be carried out in accordance with requirements. On the 7th March 1917, it was possible to generate a "wind" in the new wind tunnel for the first time. This date was noted by Prandtl himself.

As the way from the old to the new building constituted a substantial waste of time and as the small solid brick hut had become inadequate, it was transferred in 1918 to the new Böttinger plot of land. With this move, a substantial contribution to the completion of the large building project had been achieved.

With the new building completed and, from 1917, on a large number of personnel having been made available by the military administration, it was possible to carry out theoretical research work, besides the experimental tests. Prandtl now had the opportunity of taking up the

airfoil theory again, on which he had begun work in 1910, and bring this to some degree of completion. The aim of this difficult theory was to explain how the relationship between lift forces and drag can be affected by the design of the wing. At a meeting of the *Gesellschaft der Wissenschaften zu Göttingen* (Göttingen Society of Sciences) on the 26th July 1918, he presented the first communication about his airfoil theory [33].

Th. Von Kármán described the importance of the airfoil theory in an article on the occasion of Prandtl's fiftieth birthday [16]. "Prandtl's main contribution to aeronautics is, without doubt, his airfoil theory. To be more precise, the discovery and determination of so-called 'induced drag', by which means the path was opened up for making a rational design calculation for aircraft; in particular, for determining the effect of span, for a comparison between monoplanes and multiplanes, and for the effect of décalage and stagger, on a stroke. The analogy between an airfoil and a vortex line was well known; also the fact that with finite spans for the airfoil, the circulation at the end of the wing cannot simply stop, but that so-called 'vortex braids' have to detach themselves had been established by Lanchester. With a brilliant insight, however, Prandtl recognised that a systematic use of Helmholtz's vortex theory, with an assumption of a weak load on the wing surfaces, is able to produce a complete theory of ideal airfoils which provides all the information about lift force distribution, power demand etc., which are independent on the profile resistance. The discovery of the minimum resistance of an ideal wing, the so-called 'induced resistance', has almost the same significance for airplane construction as the discovery of Carnot processes for the construction of caloric machines: both produce a standard against which the quality of the construction can be evaluated and an organising principle by which means otherwise unclear, empirical material can be made clear and understandable, at a single stroke...."

6. Everyday Domestic Life

In the spring of 1914, my parents moved to a sunnier, more modern apartment with a bathroom and central heating in the Bergstraße (now called Calsowstraße). The main reason for the move was that they were expecting a child. In November 1914, my parents announced the birth of their first child, Hildegard. Their second daughter, Johanna, was born two and a half years later. Now, the large apartment became full of life. At that time, the house was located right on the outskirts of the town and, adjacent to it, there was an avenue of plum trees and some country lanes which led to meadowland and allotment gardens. Houses and apartments were not provided with their own gardens, but the close proximity of meadows and woods provided a wonderful playground for us children, in the days to come. In these surroundings, my sister and I grew up with a large degree of freedom. My mother, whose own father was very strict, did not want to raise her children too strictly. She knew how to control us with a loving hand and tender understanding but, at the same time, she did not tolerate bad behaviour from us. Of course, she was the one who took on the task of bringing us up, as our father, whose thoughts were constantly and completely filled with his plans, gladly gave this task to his wife. When we two children sometimes impetuously asked him to play with us, especially when he came home tired, he was hardly able to put up resistance to our onrush. But, my mother intervened in good time and would say, "Leave your father in peace! He wants to take a little rest now!" Incidentally, I remember with great clarity that my mother sometimes said, "You really don't appreciate what a good father you have."

The post-war years were marked by shortages everywhere. Even the ration of coal was not enough to heat our stove. When our father was at home - and this was not very often and normally on Sundays - we were told to be quiet and to disturb him as little as possible. I remember a small incident which took place in our family living room. My mother was just taking care of the stove. She was kneeling down on the ground and was poking the embers. While she was so occupied, my sister and I somehow had a silly idea which made her furious. My father sat bent over his work at the table. The admonishing, reprimanding words of my mother were simply ignored as the mischief went into full fly. She turned to my father

for his support, as her hands were dirty from handling the coal and so she herself was unable to carry out the necessary corrective measures. “Ludwig, give the children a smack”. Our father moved his papers a little to the side and approached our play corner. We were very anxious about the uncustomary punishment which our father was about to give us. However, we knew that it would not be so bad. He hesitated as he stood by us, turned to my mother and asked her to clarify what he was supposed to do, “But where should I smack them?” My sister and I couldn’t help but to break into laughter, thereby relieving the situation. Even my mother could not stop herself from laughing. I can still remember clearly how my father tried to explain why his question was perfectly justified, as our mother should have defined the punishment much more precisely, depending on the type of offence, as he himself had not witnessed the incident. It was not in his nature to punish us physically - for him, the idea was absurd. In this way, we frequently were able to escape punishment when he was around, although we now and then disturbed him. Later, he had a special influence on our upbringing, due to the constantly calm and loving words with which he made us listen to reason and behave in the right way.

His peaceful nature was evident as he sat at the table and worked, completely absorbed, as he wrote or carried out calculations. His supporting wife mostly kept us consciously away. She encouraged us to go outside and play and, as I have already mentioned, my father was mostly to be found at the institute and we were allowed to bring our friends home to play.

As a result of the scarcities of the post-war years, in particular with regard to food, circumstances were generally difficult. Prandtl reported this to a Swedish colleague, Professor Oseen, in Upsala, with whom he had corresponded for many years, “In the poor German fatherland, things look quite bleak and they will certainly become worse. Half of all Germans should be in a sanatorium, if they are to overcome undernourishment. Food is indeed in short supply here but, because of the close proximity of the town to the countryside, conditions are significantly better than in the large towns and cities. If the need arises, one can walk to the villages, where there is always something to eat.”

My mother mostly went twice a week through the woods to Herberhausen, to visit the Christmann family, whom she knew very well and from whom she received milk for the children and often a piece of butter and a few fresh eggs. At the weekend, our father also had the time to accompany her there. On those occasions, we all sat in the overheated sitting room and the adults conversed while we children went looking round the yard and in the stable. My parents knew all the paths in the Hainberg and sometimes it was already dark before we returned home. For us, the weekends were always associated with a time for enjoyable little ventures. The inhabitants of small towns, who still had no public transport at that time, must have been able to get around much more by walking than their counterparts today.

Even during the week, my father's regular, short marches to his workplace were a customary habit. On his daily journey to the institute, one could observe Prandtl immersed in thought, as if he were looking inwardly, hardly noticing passersby. But, he observed many little things on the way with great attention. In spring, he saw the first blooms that were standing behind garden fences in the small front gardens and observed the snowdrops or, later, the violets or roses with pleasure. He was very familiar with the layout of the gardens and followed their flowering times year by year. He never failed to refer to his observations during dinner at home. On his way home, he was often accompanied by younger colleagues, who valued the opportunity of having the possibility of discussing scientific problems with him. These discussions often continued for a while in front of our house, although it had already passed the time intended for dinner. It is said that a young physicist made the following observation, "If one is too lazy to think about a problem which has come up, one only needs to mention this to Prandtl. Either he will be able to settle the question immediately — because he had already thought about the same problem for some time already — or, because the thought would preoccupy him and not go away, he would think about it and tell you the answer a few days later."¹¹

¹¹ Taken from the lecture by A. Betz "Das Lebenswerk von L. Prandtl [4]" [English: The Lifework of L. Prandtl]

7. Glider Flying

Specialist research was not brought to a standstill in the years after the war, even though, as a consequence of the Treaty of Versailles, severe restrictions were placed on powered flight in Germany. The dismantling of some factories also had a serious effect on aviation. On the occasion of a meeting of the Scientific Aeronautical Society, the Riedinger balloon factory in Augsburg was visited, which has already been referred to in this biography. A newspaper reported on the event in the following way, “On entering the large hall, the friend of the fatherland initially experiences a gloomy feeling as this shelters the remains of the flying machines which, here as well, became the victims of the destructive frenzy of the entente. This went so far that even the baskets of the captive balloons had to be cut up into pieces.”

As far as flying is concerned, there was now a new impulse coming from students who were enthusiastic about aviation and who were dedicated to glider flying. This activity was not in contravention of the Treaty of Versailles. Flying groups became established at some universities which even built their own gliders through teamwork. This form of flying as a sport did not serve any military purpose and could develop freely, undisturbed by monitoring by the victorious powers. The editor of an aviation magazine in circulation at that time, *Flugsport*, Oskar Ursinus, had the idea of setting up a gliding competition. The young constructors were required to appear with their gliding equipment on the top of the Rhön hill. The most diverse types of planes were freighted there and their pilots assembled to compete with one another. The area around Rhön was selected because there were no trees on the hilltops and the wind constantly blew, acting both as an upwind as well as also a headwind. In the first competition in 1920, the participants were only able to stay in the air for about two minutes. The individual flights were precisely timed. In 1921, during the second competition at Rhön, the winner, W. Klemperer, was able to increase his flight time to 13 minutes and, in so doing, also achieved the world record. In order to increase this performance, great efforts were made to improve the flying equipment. The competitors were also prepared to learn still more about the theory of flying, to improve their individual skills. So, from this time on, seminars were arranged on the Wasserkuppe (the highest mountain of the Rhön

range), in order to instruct the young flyers about aerodynamics. Prandtl and von Kármán, Runge and Madelung taught them that what is important is correct functional construction and explained how they could make use of air currents when there are favourable weather conditions [21, 29]. In 1922, an article in a Berlin newspaper reported a record flight lasting three hours. The number of participants in the Rhön competition grew and so did the enthusiasm for the new sport. The individual design and construction of the models, which were assembled by hand, reflected the personal dedication of all of those involved. There was therefore an excellent spirit of comradeship in the groups. On the Wasserkuppe, modest huts were erected where the sporting flyers could sometimes also stay over winter, in order to take advantage of the times favourable for practising. The Rhön glider-flying competition continued to exist for many years [48]. On the 25th July 1926, Prandtl received a letter from the organisers of the competition, from which the following extract is quoted.

“Dear Professor!

We are pleased to enclose a list of the aircraft registered to take part in the competition, as well as a season ticket and a rosette for you to wear, as member of the honorary committee, and hope that we shall be able to greet you at the Wasserkuppe.”

Around this time, at Whitsun, our family made an excursion in the Rhön area. We travelled by narrow-gauge railway from Fulda to Gersfeld. Our hiking trail up to the top of the hill began at this point. Below the hill, it was sunny and warm, but on top of the hill we were very much exposed to the wind and the sky was clouded over. As we reached the top of the hill, a plane was being prepared for flight. The glider had to be pulled with a rubber line along a short track, in order to gain height in free flight. Our father watched both with fascination and deep satisfaction until the plane disappeared from our field of view. After the midday meal, which we had in the main house, our father was called, as the plane had landed once more on the hill and the pilot was eager to talk to the professor of fluid dynamics about the flight and ask him for advice about questions which had occurred to him. In the early afternoon, it started to rain mildly and the hill soon became enveloped in rain clouds, so that flying had to be completely discontinued.

8. An Offer of a Professorship in Munich

In the summer of 1920, Prandtl received an offer of a professorship at the Technical University in Munich, where his father-in-law, August Föppl, had submitted his offer of resignation on reaching the age of 66 years. August Föppl made the proviso that he would like to retain some smaller duties in his laboratory, but made it clear that he would like to withdraw from giving lectures in mechanics with a lecture hall full with 400 students. With regard to the new appointment, it was planned to divide the responsibilities formally associated with the professorship, in order to reduce the burden placed on the incumbent, so that the working conditions associated with the appointment appeared to be very attractive. As the reader can readily appreciate, the prospect of returning to their home in southern Germany was a great enticement for my parents. But, on the other hand, Prandtl consciously delayed his final decision.

At this point, I would like to quote a few lines from a letter to the privy councillor Dr. Duisberg, the general director of the Bayer paint works. The prospect of receiving funds from the newly founded Helmholtz Society had appeared on the horizon; money which he could use for his constantly pressing research plans and which might have kept him in Göttingen.

20th November 1929

“Since you were so kind, when we met in Nauheim, to encourage me, following the prospect of an offer of a professorship, to stay in Göttingen with hints of financial support for my research institute, I would now like to take the liberty, regarding this still unsettled issue, of putting the following thoughts into writing.

The attraction for me of my position in Göttingen is my research work. Moreover, my teaching duties are not of such great importance because of the small circle of those who are interested in this area at the university. I will have to bury forever the plans of research work which I had in mind already before the war for the KWI (Kaiser Wilhelm Institute for Aerodynamics). There only remains the possibility of being able to carry out the experimental investigations on a much smaller scale. But, even to realise these less ambitious plans, substantial funds would be needed to cover running costs.”

The question of how the matter was to have been regulated in relation to financial support is not known to me. However, in the meantime, Prandtl received news from Munich that the professorship could not now be divided, because of the need to save money. Prandtl was not prepared to accept the burden of such a large number of students. This would have meant him having too little time for his research. In August 1921, he turned down the offer of the post in Munich. But, he proposed other suitable candidates to the appointment commission.

Exactly one year later, the offer of a professorship was made once more to Prandtl. As a result of skilful negotiations, success had been achieved in arranging for the professorship in mechanics to be divided into two areas of responsibility, with two full professorships. One of these had already been given to Ludwig Föppl. This time, Prandtl decided to accept the offer of a professorship in Munich. His written acceptance was given on the 30th December 1922. But, the move was subject to a delay, as he had no success in finding accommodation in Munich. It was a period in which there was a high rate of inflation in Germany and the costs of renting accommodation, just like the prices for all “commodities”, were constantly increasing. In this phase of intense planning – a number of conditions associated with the post still had to be negotiated such as, for example, an application for Prandtl to have his own assistant and an extra budget for a laboratory – an unexpected offer was made by the KWG. The promise was made to Prandtl, if he stayed in Göttingen, of establishing a new Institute of Hydrodynamics next to the already existing institute buildings of the AVA. Once more, there was a turn of fate and Prandtl decided to stay in Göttingen. However, there was once more a setback, as the funds authorised by the KWG could not be paid out, following the downfall of the Minister of Finance. My parents became occupied once more with plans to move. I still remember a little of the back and forth associated with this time. A small incident comes to my mind that made me aware of the importance of the interdependence of our personal fates. As we once went gathering daisies from the nearby meadow with our mother, we sat down on a bench at the edge of the woods, and she took one of the flowers from the bunch and started plucking the white petals, one by one, in order to decide in a playful manner where we would end up: Munich-Göttingen, Munich-Göttingen etc. Unfortunately, I cannot remember which place

the petals decided would be our destination. But, I was deeply aware of how much of a burden the unresolved question was for my parents.

From this last phase of development, there are letters addressed to Ludwig Föppl whom Prandtl kept informed of the current state of affairs. They show the extent to which he strove to be fair to all of those involved.

Prandtl to his brother-in-law Ludwig Föppl,
13th July 1922

“Recently, Schröter asked me whether I would be prepared to accept the offer of a professorship in Munich. I explained to him that I had given serious thought to accepting, but that I would not be able to absolutely commit myself before I had negotiated with the ministry.

There is one matter about which I would appreciate your view. In recent times, by way of the office of the dean, there has been little progress in the development of my scientific ideas. However, I am not short on ideas, as the numerous doctoral students which I have at present (almost a dozen) have continually compelled me to think out new things for them. I therefore now have the keen desire not to suddenly cut off everything and leave my doctoral students to their own fate just like that. It is therefore very important for me that I stay here still until next Easter.”

17th January 1923 to his brother-in-law

“As you know from letters from the family, I have now accepted the offer to go to Munich, but the time when I will take up the position remains unclear, until I have found accommodation there.”

27th April 1923 to his brother-in-law

“In view of the prospects which have been held out to me here, I naturally want to have some measure of certainty, if I go to Munich, that good chances of carrying out research in hydrodynamics remain open there.”

2nd June 1923 to his brother-in-law

“Today, I must unfortunately tell you that the matter of the ‘new offer of a professorship in Göttingen’ has reached an acute stage. It is thought

that it will be possible in the shortest space of time to offer me 40 million DM on an annual basis each April for the scientific department of the research institute which is to be added, and a single payment of 500 million stable value per April for the construction of the hydrodynamic department. I replied to the letter from the Kaiser Wilhelm Society, in which the managing director asked me to reply, as quickly as possible, whether, with the settlement of the granting which has been notified I would stay here, in the manner indicated by the enclosed copy:

‘2nd June 1923 to the director Dr. Glum:

It is not yet possible for me to immediately give you my final answer, as you requested, in the event of a definitive authorisation for the sum which has been offered by the ministries, as it is not appropriate for me to make my decision without having had a period of several days to reflect on the matter; not least, because the decision will also have important consequences for my future personal life. As I have already made known to the university curator, yesterday, I appreciate that it is quite a remarkable achievement that it has been possible, at this time, to attain such large sums from the Reich and Prussia. The dedication to this task given by the Kaiser Wilhelm Society and also the Ministry of Culture, Education and Church Affairs, which made known the achievement of this goal in such a short time, naturally also places an obligation on me to give serious consideration to the matter.’”

13th June 1923 to his brother-in-law

“As you can appreciate from the enclosed copies of my simultaneous letters to the ministry and the rectorship, I have reached a decision, following a long period of reflection, regarding the offer of an appointment as a professor in Munich. I have decided to stay in Göttingen. However, I cannot get over the feeling that it is very sad that nothing will now come of collaboration between us. Naturally, you will now have to reconsider the question of who is to be offered the appointment and I would like to wish you success in the search for a suitable candidate. If you find a candidate who is gifted as a teacher and who gives lectures with great enthusiasm then, in the end, you may consider yourselves to be more fortunate in gaining someone with such an ability than if you had appointed me, if I had perhaps - contrary to

my good intentions - not been able to draw myself away enough from research.”

13th June 1923 to the Bavarian Ministry of Culture, Education and Church Affairs

“I have the honour of informing the Ministry of Culture, Education and Church Affairs herewith that, with regard to the offer of an appointment as a professor at the Technical University in Munich, the matter has taken an unexpected turn. As the Prussian Ministry of Education and the Kaiser Wilhelm Society for the Advancement of Science has held out the prospect of granting a very substantial sum, by today’s standards, in order that I may realise my earlier plans for a hydrodynamic research institute. The intended authorisation will amount, according to a communication from Berlin, to a sum of 500 million DM, referred to April prices.”

In a letter dated the 27th June, Prandtl made suggestions for potential candidates to fill the vacant chair in Munich to his brother-in-law. Such a suggestion is made in the following communication.

“I am only aware of one candidate who can meet all of the conditions mentioned; namely, von Kármán in Aachen. He has produced excellent and sometimes pioneering work. At the same time, he is, as you will know and as I also later became aware, an excellent teacher. I am of course fully conscious of the fact that his appointment may create difficulties because of his origins, but, in my opinion, such principles should not extend so far that this would harm the scientific life of the university.”

At that time already, in contrast to his colleagues in Munich, Prandtl advocated without prejudice the selection of a highly respected Jewish scientist.

14th July to his brother-in-law Ludwig Föppl

“My extensive report with building plans and an estimate of costs for the hydrodynamic research institute was sent to Berlin last Thursday. As those authorities involved in decision making themselves have a great

interest in making headway soon with the project, I believe there will not be a long delay in making the decision.”

22nd July to his brother-in-law

“In the Reich’s ministry, there appears to be a favourable attitude to dealing with the matter quickly, in a positive sense. In the Prussian Ministry of Finance, however, a decisive statement cannot be given before a final notification has been given by the Reich’s Ministry of Finance.”

24th July to his brother-in-law

“I would now be able to come to a decision to give those in Berlin a deadline of eight days with the proviso that, on the expiring of this deadline, I would make the decision to go to Munich. At the same time, suitable accommodation is naturally a prerequisite.”

29th July, letter from Gertrud to her brother

“I often have the feeling that these days, which are as unpleasant as possible, will not be particularly favourable to the rebuilding of the institute. I have taken much trouble to persuade my husband to give up these plans completely, but I have observed that he holds steadfast to the project.”

5th August to his brother-in-law

“Those in Berlin have reacted in a cross manner to my threatening letter and they say that they have tried in every way to speed things up. The matter is very complicated, because of the many authorities involved in the matter.”

7th September to his brother-in-law

“I have spoken on the Wasserkuppe with the gentleman from the Reich’s Ministry of Finance holding authority in relation to aeronautic matters, who has confirmed to me that there is an intention to support the supplementary building to the institute under all circumstances; above all, because of increased interest in aviation in Germany which is expected as a consequence. Under these circumstances, it seems to me that I have no right to still avail myself of your patience in Munich.”

11th October to his brother-in-law

“In the past few days, I was in Berlin at a meeting of the Scientific Aeronautical Society and, at the same time, I called at the Kaiser Wilhelm Society. They were very unhappy there about the last governmental crisis, as there had just been success in gaining the support of the Minister of Finance, Dr. Hilferding, for including my institute in the budget when he had to retire from office. Otherwise, it would have been possible to achieve a decision in my favour, but however in an unfavourable way for you, in the shortest period of time. Now, once more, I do not know how the matter will end.”

29th October 1923 to his brother-in-law

“If you ask me whether I still believe that my institute will materialise, I have to reply, of course, that things are looking very bad at the moment, since things are starting to get going in Sachsen whilst they are at a standstill in Bavaria. But, in the end, what is important is not my personal view, but that of those in authority on whom I have become dependent. I will, however, try once more tomorrow to put pressure on those in Berlin to reach a decision. I would rather wait for a rejection from Berlin than throw in the towel myself, because I want to come to an amicable agreement with the Kaiser Wilhelm Society, with which I will have to further collaborate.”

28th November to his brother-in-law

“Following a renewed cabinet crisis, I have considered with some feeling of sadness that my leaving Göttingen is almost certain and have talked much with Gertrud about how we wish to set up home in Munich. Then, I received a message from the KWG that a new possibility appears to have opened for the Göttingen institute, as a result of finding an industrial sponsor. This news had the same effect on both me and Gertrud, as we were both sad about the prospect of having to give up Munich once again. In fact, we are both very attached to Göttingen and Munich, but only one of these two alternatives can become reality. As I now no longer have an adequate overview of the situation, it is for those in Munich to decide how long they can postpone the decision.”

28th November 1923 to the Rector of the Technical University Munich
“Dear Magnificence,

It is exceptionally embarrassing for me that I write once more to ask for a short extension, instead of a final answer. I do this at the urgent request of both the KWG and the local faculty. As a result of the cabinet crisis in Berlin, the possibility of an authorisation of the planned institute, for which there were already good prerequisites available, has come to nothing.

The chief executive of the KWG, who has shown himself to be exceptionally calm and effective in the matter, has not, however, thrown in the towel but, on the contrary, has surprised me with the prospect of assistance from a very wealthy industrialist, who would play an important role, and he encumbered me to let him have several more days of time. I am well aware that I do not have a right to insist on a postponement by Munich University. However, the request from the KWG is sufficiently well founded for me to pass this on to Munich University. If the possibility were to exist of setting up the second part of the research institute in Göttingen and that a precondition would be that I stay in Göttingen, I would have to consider it my duty to devote myself to this task and therefore to continue my lifework of investigating the laws of airflow and water flow. If this possibility were to be lost, then my efforts would, for the most part, go to waste and I am convinced that, in this case these could be better utilised in Munich.”

3rd December 1923 to the Rector of the Technical University in Munich
“I have the honour, your magnificence, of informing you that, according to a communication which I have just received, the building of the institute should be considered to be secured. I am therefore forced, in accordance with the agreement which was made, to finally renounce the offer of the post of Professor of Technical Mechanics in Munich. Even up until a few days ago, I myself still expected that the outcome would be the opposite and I find it sad that nothing will come out of the many plans which I had already prepared for my work in Munich. The task which will now be assigned to me, to begin with, will now probably result in great difficulties for me, in view of the constraints of time. But, it will, even if it is only implemented in essentials, give me plenty of opportunities for working in those fields which are dear to my heart.

I ask your honour to inform your colleagues in Munich that even though nothing now has come of my move to Munich, I have a strong attachment to Munich and would be prepared in any way to offer my support, should this be required.”

5th December to his brother-in-law

“You will have heard from your rector that I have received an assurance that I will have my institute and so remain in Göttingen. Actually, I ought to be pleased about the future possibilities of research, but it has not yet reached the stage at which I am able to overcome my sadness regarding everything which I had imagined in relation to Munich and which has now come to nothing. This thoroughly outweighs my joy for the time being. In addition, there still remains the worry that, nevertheless, something will interfere with the building of the institute. But, I say to myself, again and again, when others offer me the possibility of carrying out extensive research, then I may not, as one who is considered to be the leading specialist in this field in Germany, myself bring about the downfall of the project. I also firmly hope that I shall still be able to derive much satisfaction from this work, when the worst is over.

The children, who spend much time outdoors, are well. The Bergstraße offers the possibility of pure rural life. We are therefore very happy that we will stay here. They also have such nice friends. For us adults, above all, it would have been the Hainberg which we would not have been able to take with us, which we would have so sadly missed.”

On the 3rd December, Prandtl finally turned down the offer of a professorship in Munich. The KWG had accordingly been keeping a look-out for a private donator, so that the plans for a new institute would not have to be dropped. The general director of the W. Hoene AG (corporation) was able to make funds available to help make the planned new building possible. Half of the sum required was granted by the new Minister of Finance, Luther.

9. Establishing the Institute and New Projects

The work which Ludwig Prandtl had carried out from the very beginning of setting up the institute did not now have to be given up. Together with well-trained assistants and reliable mechanics, the Göttingen research work was continued, even in the phase of commencement of building. The building under construction was intended to offer the possibility of free, less earmarked research, independent of the more practice-oriented research testing facility, whose task it was to investigate the properties of airplanes, turbines and other models using the methodology of flow technology. In the one and a half years that now followed, in which the new Kaiser Wilhelm Institute was established, a special effort was required on the part of all employees. But, the planning and advances made gave the impetus to all of them to dedicate themselves to their work with much joy and enthusiasm.

The engineer Walter Müller told me, “For me, just as for the others, there were no fixed working times”. He took it for granted that, if it was necessary, he would have to stay in the institute the whole evening, if the measurement results still had to be calculated or if research equipment had to be put together for the following day. “The idea of being a specialist was also unknown: each person could do everything.”

In the meantime, research did not stand still. With the boundary layer theory, important secondary problems arose in connection with turbulence phenomena. Some articles by Prandtl in the new field of turbulence research appeared in various scientific journals. In this way, at the same time as establishing the new institute, there was continual further development of theoretical knowledge and, indeed, the initiation of quite new projects.

One of the new projects was the Flettner rotor ship; a particularly interesting piece of work whose scientific aspects were taken care of by the assistant Dipl.-Ing. Jakob Ackeret (Swiss), whose investigations produced technically useful results in 1924. The product of the work was the so-called “rotor ship”. The precise determination of the energy output of rotating cylinders, which were intended to be exposed to the

wind as revolving turrets on a ship, meant that they could develop a larger propulsive power than the conventional stretched sailcloth. The engineer Flettner, the inventor of the rotor ship, successfully completed his project with the aid of researchers specialising in flow phenomena. The experimental ship was built at the “Germania” dockyard in Kiel. Prandtl was invited to go there a number of times, in order to give his expert opinion on the functionality of the ship. After the ship had proven its worth during a number of trial runs, it was possible to use the “Buckau” in the coastal area. Prandtl referred to this in a note dated the 12th November 1924, “I went for a trip in the Buckau with Prince Heinrich, Busley and many others to Eckernförde (6.2 sea miles, with a 6m wind)”.

My husband remembers seeing this original ship, which everyone viewed with amazement, in the outer Elbe and that the monotonous, singing noise of the ship echoed far beyond the boundaries of the river.

In December 1924, Prandtl wrote a circular letter.

“We have received numerous letters of different kinds regarding the sailing ship invented by Flettner, so that it was not possible to reply immediately. A number of typical questions are answered below. We ask you to make do with this.

1) Publications by us about the matter referred to are not yet available, but these will follow. At the beginning of next year, a report by Dipl.-Ing. Ackeret will appear in the Journal of Aeronautics and Motor Air(ship) Navigation, one by Dr. Betz in the journal of The Association of German Engineers and one from Prof. Prandtl in the journal *Naturwissenschaften* (Natural Sciences). In addition, the publisher Vandenhoeck and Ruprecht in Göttingen will produce a brochure written by Mr. Ackeret, entitled ‘*Das Rotorschiff*’ (‘The Rotor Ship’).

2) With regard to other applications of the rotary cylinder, it should be noted that this would only have a value, as is the case with sailing ships, in those instances in which there is an interest in managing with smaller surface depths than has previously been the case. In all other cases, as with airplanes, windmills etc., the wing-like construction customarily used up until now should be favoured, because of its low air resistance.”

Shortly before this, on the 17th November 1924, Prandtl gave a lecture to the *Göttinger Physikalische Gesellschaft* (Göttingen Physical Society) about the rotor ship [30].

In the foreword to the brochure compiled by Jakob Ackeret, *Das Rotorschiff und seine physikalische Grundlagen* [1] (The Rotor Ship and its Physical Bases), Prandtl wrote, “The sensational success of the unique Flettner wind-propelled ship has suddenly made the public aware of things which, up until now, have only been talked about by the closest circle of specialists. One would like an explanation of why it is possible that a relatively narrow, fast rotating cylindrical tower can replace a sail area which is ten times greater”.

This short text, written for the layman, but which, however, assumes a certain understanding of physical principles explains the phenomenon quite clearly.

The discovery was explained to an interested public in a lecture given in Göttingen. This lecture on the Flettner rotor ship, illustrated with slides, by Professor Prandtl was announced to take place in the town park on Friday the 20th February 1925 at 8 p.m.

An account of the lecture was given in the local Göttingen newspaper on the 22nd February 1925.

“Professor Prandtl presented a lecture yesterday on the Flettner rotor ship before a well-filled house. As is in the nature of things, the lecture was, to a large extent, of an academic nature, but it was presented in such a way that even a layman could understand it. It was very interesting to hear from the mouth of the man who had contributed so much to the realization of the Flettner invention about how, starting from scientific principles and studying the nature of airflow, it was possible to achieve a result that roused great and justified attention throughout the whole world. The lecturer illustrated his talk, which was from time to time interrupted by applause, with slides. At the end of the presentation, Professor Prandtl raised the question of whether the rotor ship would be of importance for shipping. He answered the question which he had posed by saying that the use of the rotor ship would depend on economic considerations.”

Sadly, the hopes that were attached to the propagation of this type of ship - since it was expected that it would reduce the costs of freighter shipping - have not, however, been fulfilled.

That this discovery did not achieve success in practice was, in fact, the result of economic factors. The costs associated with the maintenance of the “technology” on board could not have been met, for example, by fishermen using the design for their boats. After all, without constant maintenance by a mechanic, who would be responsible for the faultless functioning of the fast rotating rotors, it would not be possible to guarantee the boat would be able to undertake a long journey.

Today, there is renewed interest in the energy-saving principle of the rotary, revolving turret, which is nowadays called a turbo-sail. For example, the marine biologist Jacques Cousteau recently undertook a research trip lasting two and a half years in such a wind ship. In June 1985 he arrived at the port of New York.

Another area of research within the scope of the research facility, at that time, was the wind resistance of vehicles on land. Initially, a series of experiments was carried out with the aim of reducing the wind resistance of locomotives, in order to save energy. An investigation was made of wind pressure on a scale model 1:25 whose front and sides were covered. Calculations indicated that, in this case, a train travelling at a speed of 90 kilometres/hour could save 80-100 kilograms of coal per hour [23]. These experiments were later continued with success using a motor railcar, standing in Göttingen, which was constructed according to the test model. As children, we were sometimes taken along to the test track in Northeim, a town north of Göttingen.

In the meantime, the extension of the research facility had been completed. Engineer W. Müller remembered a small mishap which took place at a time shortly before the inauguration. The director’s office had been laid out with black and white rubber tiles from the firm W. Hoene, giving it the appearance of a chessboard. Prandtl expressed complete displeasure on seeing this floor covering. He exclaimed, “Perhaps this pattern would have been fitting for a slaughterhouse”. He stayed transfixed at the door and said, “I am not going in there!” It was,

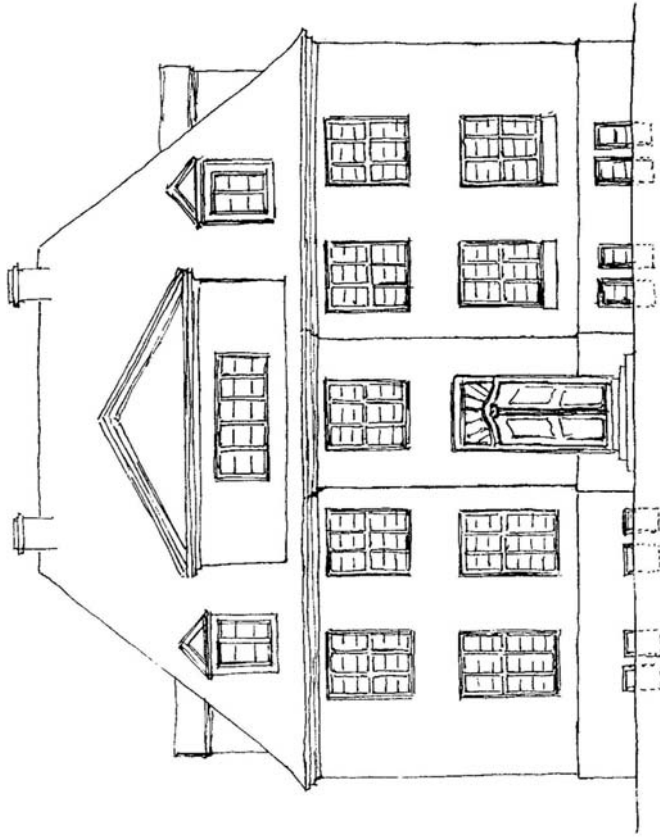
however, possible to change the tiles. The tiles were replaced with beige-marbled tiles, which were fortunately laid in time before the ceremony took place.

On the 16th July 1925, the formal opening was celebrated festively in the presence of the then President of the KWG, Adolf von Harnack. On this occasion, W. Hoene was awarded, as planned, the title Dr. h.c. (an honorary doctorate).

At this point, I would I like to mention that the awarding of such an honorary degree to an industrialist had quite a tradition. Klein was basically of the opinion that when he had gained the support of a rich industrialist to donate money for the building of a new institute, it was appropriate to acknowledge this by the granting of an honorary degree for that person's services to science. Although a vote against this procedure had been made in the meantime during a faculty meeting, an exception was made by a majority of members of the same faculty in acknowledgment of the support of Hoene.

President von Harnack handed over the new Kaiser Wilhelm Institute to Prandtl with the following words,

“We are looking extremely carefully for a good researcher. When we have found him, we will direct torrents of benevolence on him and we will provide him with as plentiful funds and research facilities as possible, in order that he will have the freedom to do what he would like.”



Sketch made by L. Prandtl of the
KWI for Fluid Dynamics which was established in 1925

28. 3. 24
Prandtl

10. The New Kaiser Wilhelm Institute

There had already been an exceptional expansion in the range of work carried out at the research facility. During the war years, the institute had focussed on research associated with airplanes, but now investigations were being carried out of the effects of wind pressure on iron bridges, electric lines and high buildings, in order to determine the best way to protect these constructions against damage caused by storms, by providing greater stability. “The legal regulations governing constructions existing up until now are out of date and need to be urgently revised”, an insightful journalist reported.

The new tunnel, which had a diameter of four metres, now also made it possible to investigate the behaviour of larger parts in an air-stream. For example, it was possible to suspend the vanes of a windmill of normal size in the apparatus. The question was posed of how these designs could be improved, in order to make the greatest use of the energy of the wind. With a wide variety of research themes being investigated in the various parts of the institute, it was necessary to have two directors to manage the institute. Ludwig Prandtl and Albert Betz took on this responsibility. The latter was appointed as deputy director of the institute and took charge of the independent organisation of the *Aerodynamische Versuchsanstalt* AVA (aerodynamic research establishment). Prandtl had overall responsibility for the institute and mainly devoted his time to the work of the new Institute for Fluid Dynamics. In 1926, there were fifty-five employees at the institute.

Colleagues from other institutes were guided through the new research and work rooms and then entered their names in the visitors’ book in the director’s office. My mother and we children were also once allowed to look around and marvel at the beautiful models in the wind tunnel. A new research facility, which was of special interest, was shown to us: a rotating laboratory. It was intended for experiments on models in which it was possible to reproduce, on a small scale, the flow processes over a large area on earth. The behaviour of liquids was investigated during rotational movements [25]. For us children, it was a special attraction to enter the laboratory and be rotated, like riding in a carousel. Dr. Busemann, who carried out his special scientific work there, was so kind

as to let us take a ride on a number of occasions. We were cut-off from the outside world by the laboratory walls. We were told that the feeling of dizziness is produced by glancing momentarily at stationary objects. But, even in the enclosed laboratory, we were not free from feeling dizzy at high rotational speeds, as was Dr. Busemann, because he had become accustomed to the experience as a result of constant training. Our father, who also entered the laboratory with us, informed us about how movements of the body are retarded on one side by centrifugal forces and are accelerated in the other direction. We tried to turn our arm with all our might against the direction of movement. This was impossible and remained so until the speed of motion was changed down again. We finally left the rotating laboratory with a feeling of happiness and enriched by this very special experience. Next, we went into the building where the wind tunnels were located. With our father's guidance, we quickly felt at home in the large rooms. We tried out each of the tunnels in succession, according to size. Our father's concern to amuse us children as best he could was really touching. Another assistant, who was ready to help, accompanied us and switched on the fan, at the switchboard, according to our wishes. It was wonderful to stand at the opening of the duct with a strong wind blowing so that our hair was waving and our skirts fluttering. We felt as if we were standing on a ship with this refreshing, moving element beating against us, at the same time, carrying us away. Suddenly the strength of the wind had increased so much that we could only move through, between the tubes, with difficulty. We were aware that just a very small amount of wind pressure more and our feet would no longer have adhered to the floor, and we would have been blown against the wall. Finally, we went to the largest wind tunnel at that time, in which a number of models were hung, fixed on threads. They were removed for a short time and then all the control levers were operated. This time we were satisfied by the terrifically loud noise made by the fan working under full power. The forces which were let loose were very quickly subdued and conquered. You can well imagine how much we enjoyed this impressive noisy machinery, as well!

The following day, I told my friend Lilli Misch everything we had seen and done, and about the great pleasure we had had. As our primary school was not far away from Böttinger Straße, we two little girls decided that, straight after school, we would go and ride on the carousel.

But, our plan came to nothing. When we arrived at the institute, I told the porter at the gate that I wanted to see my father. He was not in the director's office and not in the institute at all, but in another building. The porter tried to contact him, but it was a long time before he came. He laughed with embarrassment when he saw us, but sent us home with great firmness. He did not show that he was annoyed about being taken away from his work, but I was made aware, all at once, that he had become unavailable to me and I had difficulty in understanding this. My friend, who now lives in America, also remembers very well our plan and the scene which brought everything to an end. If my mother had known what we were going to do, she would have held us back from carrying out our plan. She never called her husband at the institute from home: her respect for his work prevented her from doing such a thing. She knew that he had too much to do and that he always committed all of his energy to ensuring the success of the research facility and its diverse research tasks.

Year after year, from now on, there was an annual institute party, which was celebrated in a rural guesthouse. The younger members of the institute looked forward with pleasure to dancing in the evening. Before the dancing started, the partygoers organised entertainment, with very imaginative ideas, to the amusement of all of those present. One year, the programme for the planned events was laid out on the individual tables. But, on Prandtl's table, however, one number was intentionally left out of the programme. In the programmes on the other tables, item number 3 "Prandtl will play" was included. Whilst Prandtl himself was giving a short speech, a kind of technical tool was skilfully and unobtrusively brought to the table. There was an air of anticipation in the room. Everyone was amused. Prandtl, whose attention was drawn to the unknown object, involuntarily grasped it and began to play experimentally. In the meantime, the guests from the other tables had come to look on and observe events at close quarters. But now, however, my father became aware that he had been "set up", because of his fondness for playful occupation and himself ended up laughing at this unplanned performance.

Despite a work programme that was always fully occupied, these years were ones that were particularly happy for the head of the new research facility. A memory of these times has been preserved by Margarethe Winter, née Weppner, in a text which appeared in the Göttingen monthly magazine.

“I would like to report on a quite entertaining incident which I once experienced in the company of the well-known Professor Prandtl. By chance, we both left the former AVA together on a delightful spring day. Professor Prandtl had a desire to go for a short walk and asked me if I wanted to join him. He noticed that I had difficulty in walking, which resulted from recently having had phlebitis. He commented spontaneously that my problem was also a question of flow in the bloodstream, about which he would like to reflect, and that he should sometime discuss the matter with a physician. Unfortunately, we never returned to this subject.”

11. Trip to London

A special event took place in 1927, when Prandtl travelled to London to deliver the Wilbur Wright Memorial lecture to the Royal Aeronautical Society. About one and a half years prior to this, he had begun to have private English lessons, supported by his wife Gertrud, who herself spoke good English. It had been a handicap for some time that he had to have publications from England and America translated for him, although he was able to understand the specialist terms used in the texts. His very capable teacher, Beatrice Dammers (whose mother was English) gave him support to the best of her ability. It is quite astounding how he was able, with such a large workload, to learn a language which he had not learnt at school to such a level that he was able to present his well-prepared lecture in London in English.

His trip to England was reported in the press in both England and Germany. The following extract is taken from the Daily Chronicle dated 09.05.1927.

“England to honour German professor. A quiet, retiring German, who cares nothing for ceremony or fame, but who is acclaimed the greatest living authority upon aerodynamics, is coming to London this week to receive from England an air honour, which in all the history of flying has only been given to six men. This famous scientist is Professor L. Prandtl of Göttingen University and the coveted distinction to be conferred upon him is the Gold Medal of the Royal Society.

Previous recipients have been:

1909 the Wright brothers

1910 Professor Chanute

1915 E. T. Busk and Professor G. Bryan

1926 Professor Lanchester.”

This announcement made public that Prandtl would himself receive the exceptionally highly valued medallion in person.

It should be mentioned that the flight from Hanover to London with a German Lufthansa machine was Prandtl's first journey by airplane. For him, it was a quite special experience. He noted his observations, with times, using keywords.

“Thursday, 12th May 1927

4.58 Rotterdam, the Rhine estuary, sunshine (it is afternoon, 16.58)

5.14 over the sea, low tide

5.25 large sea port

5.56 sea channel with town

6.06 large sea port (Dunkirk)

6.20 over the sea, very misty

6.27 last land abeam, airplane lying completely calm in the air

6.35 land in sight, port, steep coast.”

Göttingen newspaper 14th May 1927

“Professor Prandtl in London

As has been reported from London, Professor Prandtl from the University of Göttingen, arrived by airplane from Germany. Professor Prandtl is to be awarded the highest honour that British aeronautics can offer; namely, the gold medal of the Royal Aeronautical Society.”

Daily Telegraph 14th May 1927

“Professor Prandtl arrived in London by air on Thursday night. In conversation with the press representative yesterday he said, ‘It is a great honour the Royal Aeronautical Society are about to bestow on me and nobody realises it more than I myself. If I have been able to throw new light on the science of aeronautics, that in itself is sufficient reward for me. The Gold Medal of the Royal Aeronautical Society is more than I ever dreamed I should receive, even in my most ambitious moments.’”

On Monday the 16th May, Prandtl held the important lecture [32].

On 17th May, Colonel Forbes-Sempill (flyer and flight specialist), chairman of the Royal Aeronautical Society wrote the following to Prandtl,

“Dear Professor Prandtl!

First of all, I want to take the opportunity of thanking you in the most sincere manner possible for your wonderful lecture, illustrated by the most remarkable series of slides and cinematographic films that have ever been the good fortune of the society to see. Your lecture has aroused the greatest possible interest and we are already receiving demands for the Society’s Journal in which it will be reproduced.”

From the “Morning Post”

“Colonel Master of Sempill, chairman of the Royal Aeronautical Society, said yesterday, ‘but we have chosen a German this time because Professor Prandtl is, in our opinion, and in the opinion of all people who are competent to judge, the greatest authority on the scientific side of aeronautical science. He has particularly distinguished himself by propounding what is commonly known as the Prandtl boundary layer. By his years of experimenting, he has given us an insight, denied to the greatest men of science in the past, of what happens to the air surrounding an airplane in flight’ ”.

Subsequently, an article appeared on the 18th May in the Göttingen newspaper:

“As has been reported by Wolff’s telegraph office, Professor Prandtl from Göttingen University gave a lecture on Monday in London to the Royal Astronautical Society, which received particular attention, because the German scholar, who is, according to the unanimous view of all British scientists a leading authority in the area of science, was the first non-British or non-American citizen invited to give a lecture to honour the memory of Wilbur Wright. The Royal Aeronautical Society stressed in its invitation to him to give this lecture that, just as the Wright brothers made practical flying possible for the first time, Professor Prandtl made it possible to understand why and how air keeps an airplane in the air. As has already been reported, Professor Prandtl will be presented the gold medal of the Aeronautical Society, which has only been presented to six men before him.”

The reader may wonder why I have included a number of confirmations of the special honour. This should be viewed in the context of the situation prevailing during the post-war period. Most people in England still viewed the disagreeable Germans with a critical eye. The fact that air-vice-marshal Sir Sefton Brancker, in his introduction to the memorial lecture, referred to Prandtl as “a distinguished member of a great nation” in his introductory remarks certainly made him conscious that he not only stood before the forum of scientists, but also that he had to represent his fatherland humiliated by the victorious powers. This recognition was greeted with satisfaction in his home country.

I should also mention that the English professor Lanchester, one of the leading prize winners, had occupied himself with the same problems as Prandtl. In order that there should be no doubt that Prandtl had developed his airfoil theory as a result of his own work and intuition, the latter made the following comments at the meeting in London,

“In England, the airfoil theory is referred to as the Lancaster-Prandtl theory, with justification, since Lanchester obtained an important part of the results independently of me. He started his work on this subject matter earlier than I did. This fact is the basis for assuming that Lanchester’s investigations, as recorded in his book ‘Aerodynamics’ published in 1907, gave me the ideas on which the airfoil theory was developed. However, this was not the case. I had already formulated the basic ideas of the airfoil theory, in so far as these ideas were considered in Lanchester’s book, before I had had the opportunity of reading it. In order to substantiate this view, I would like to draw attention to the fact that Lanchester and the importance of his work were appreciated earlier in Germany than in England. The truth of the matter is that Lanchester’s treatise is very difficult to understand, as it places great demands on the reader’s intuitive imagination. Only because we had already been working in a similar field of research were we able to immediately understand what Lanchester was saying. Be that as it may, I would like to clearly state that, in relation to many specialist questions, Lanchester’s work went in different directions to ours: directions which were new for us and which produced many valuable pointers.”

“Prandtl brought the ideas referred to into an orderly system and simplified the picture of the vortex system.”¹²

In 1947, Prandtl once more gave his opinion on this problem [31]. “Perhaps it is not without interest when I mention that it was becoming aware of a contradiction which first inspired my occupation with airfoil theory. I am referring here to a mistaken idea about the vortex system of an airfoil in the otherwise worthy book written by F. W. Lanchester (translated by C. and A. Runge in 1909).”

¹²Theodore von Kármán, Aerodynamics [14]

Prandtl remained one more week in London and accepted a number of invitations. He also used the opportunity to visit his English colleague Professor G. I. Taylor in Cambridge, with whom he had a warm friendship extending over many years.

Many congratulations greeted him on his return to Germany. At the end of the semester, the students held a torchlight procession in his honour.

Göttingen newspaper, 14th July 1927

“A torchlight procession of the student body to honour the professor of aerodynamics, Professor Prandtl, who was recently awarded the highest distinction for his services to aeronautics. The procession went to Calsowstraße 15. A festive ovation was given. A representative of the student body, in his address, praised the service Professor Prandtl had rendered to aeronautics and therefore human culture: ‘We owe our understanding of flight to his research. The world looks to Germany and to our little town of Göttingen and to the meritorious scholar. The body of Göttingen students honours its teacher with a rousing cheer!’ A rousing ‘Vivant professores!’

As he gave a word of thanks to the body of students, with the humility of a true man of learning, Professor Prandtl now tried to present his services to science as if they were not of such great importance. He said that words of gratitude should go to the late Felix Klein, to whom thanks should be given for the aerodynamics institute. In addition, he pointed out that the contribution made by co-workers was very great. However much we praise the humility of Professor Prandtl, nevertheless, we firmly believe that the main contribution was made by him. Just as a good violin requires a good player, the aerodynamics institute needed Professor Prandtl in order to achieve what it has achieved. Professor Prandtl closed his speech with a word of praise for the German fatherland. The assembly broke into singing the German national anthem. Then, the procession marched to Theaterplatz, where the torches were thrown to form a heap.”

I still remember that evening with great clarity. Perhaps I had already slept for a little while, when I was called to the living room. It was wonderful to look down from above, from the open windows, on the large group of people carrying torches who had assembled in front of the house. My father stood at the middle window, the upper part of his body a little bent

forward, supporting himself with his arms stretched out to the side on the window frame.

The student who gave the little speech on that occasion was Gustav Messmer. He later studied for his doctorate with Prandtl. In 1939, he was offered the position of Professor of Applied Mathematics at the Technical University in Darmstadt, where he remained until 1949. From 1947 until 1949, he was Rector of the University of Darmstadt. Subsequently, in 1952, he was offered a professorship at Washington University. He died in Washington in 1981.

There was a change of personnel at the institute. A new secretary to the director was appointed on the 19th May, directly after the return of her new boss from London. Miss Seebach was told that the position had become available by acquaintances, as was often the case at that time. She told me that Prandtl asked her to write a dictation during the interview, so that he could judge whether the young lady would be up to the job. Then she was invited to start the job on a certain date and was permanently appointed with the proviso that she would have to complete a probationary period to his satisfaction. She then remained 43 years as a private secretary at the Institute for Fluid Dynamics, remaining in the post after Prandtl's death. A very experienced secretary was therefore also available to Prandtl's successors.

She told me that she still remembered the early days vividly. Prandtl dictated and she made shorthand notes, but he could not refrain from making stylistic changes to a letter before she typed it. Correspondence never remained lying around: he made sure that he replied both punctually and to the point. If someone did not immediately understand what he had intended, he responded with much displeasure. He was not someone who tolerated obtuseness. Otherwise, he was patient and calm when dictating. Miss Seebach adapted his style in an outstanding manner, thereby ensuring that the collaboration between her and Prandtl was first-rate. In addition, she was always ready to type scientific works for the assistants. She also typed Prandtl's book *Führer durch die Strömungslehre* (Essentials of Fluid Dynamics) [27] from dictation. She also still remembered the overbearing letters from inventors to which Prandtl replied in a patient manner and with great clarity. However, in their disappointment at not having received

recognition, they would once more stubbornly present their inventions, because they had often not understood at all the chain of reasoning of the professor who had demonstrated the errors in their thought to them. Then, the proof of some kind of erroneous conclusion had to be made once more in a much more detailed manner.

12. Trip to Japan

As my father made preparations for the next big trip we, his two daughters - now aged 12 and 14 years old - were able to actively join in. It was a tour around the world that was planned to last six months. The main reason for the trip was an invitation from Japan. A congress was to take place in Tokyo. Following the congress, it was intended to make a trip through America, where my father wanted to visit a number of universities.

Large overseas suitcases arrived at the house and my mother bought new clothes. My mother was supposed to accompany my father on this interesting trip, but the thought of leaving both daughters alone for so long without her maternal care was unthinkable for her.

In 1929, a trip to Japan was quite a sensational undertaking, compared with nowadays. Today, such a trip would not be considered to be something of an adventure. At that time, travelling to Japan meant taking the land route in Russia: there were no direct flights over such a long distance.

Included in my father's luggage was a Leica, which was the best camera available at that time. He wanted to have photographs to refresh his memory at a later date. He left Göttingen on the 13th September and travelled constantly in an easterly direction. My mother received numerous letters, which he sent to her during his long period of absence. He numbered these letters. She received more than 70.

Before I quote from a few of these letters, I would like to present a few extracts from a newspaper article, in which my father gave an account to journalists of his impressions of the journey immediately after returning home.

March 1930 - interview with Professor Prandtl

“Impressions and experiences during his journey to Japan and America: As we reported recently, the well-known Göttingen aerodynamics expert Prof. Dr. Prandtl returned to Göttingen on the 5th March, after spending almost six months travelling and, at the same time, circumnavigating the globe. In an interview given to one of our representatives, Professor Prandtl gave an

overview of his impressions during his travels, which are summarised in the following account:

‘The real goal of my journey, which took me through Russia, Japan and America, was Tokyo. At the end of October/beginning of November last year, an international congress for engineers took place, which I was strongly encouraged to attend. Of course, I could not let the opportunity go by without using some of the time to get to know other countries and, when the chance was given, to carry out general and specialist research. So, the period I spent away from home was correspondingly longer. The journey began on the 13th September and took me first, by train, to Moscow. Here, I visited a number of institutes. These institutes were astoundingly well equipped. At present, new, large research facilities are under construction. Despite difficult circumstances, the Soviet government is doing a great deal to support anything that serves the progress of technology.

From Moscow, my journey continued for ten days with the Siberian railways towards the far-east. This railway also gave an impression of being very solid. The stretch of track, the carriages and the engines were in perfect condition and we arrived with a delay of only three hours in Vladivostok. Originally, my plan was to travel through China but, because of the discord between Russia and China, this travel route is blocked.

Now let me recount my impressions of Japan. This is a country whose rapid advance is manifest at every turn. Colossal industrial development can be seen throughout the country. In no country other than Japan has so much electrification taken place. Every village in Japan has an electricity supply. This development is all the more astounding as, six years ago, a great earthquake caused tremendous damage to the country. Large cities and towns have been completely rebuilt or are currently undergoing reconstruction. Japan is a country with a great wealth of indigenous art. Marvellous art objects can be bought everywhere and one can have much pleasure acquiring them.

The congress itself, which was the real reason for my journey, was well organised by the Japanese. There were a large number of participants: there were thirty representatives from Germany alone. In addition, there were about 30 engineers who work in Japan and 200 participants from America. Regarding the hospitality of the Japanese, one can only make positive comments on their praiseworthy attitude. The members of the congress

constantly received invitations and a number of festive occasions were included in the programme.’”

The old Nippon still existed at that time. The turning point first came at the beginning of the 1930s, when the modern outlook of the European western world began to influence every aspect of life in the far-east island country.

“The research institutes made a good impression on me. Much support is also given to aerodynamics. They have more wind tunnels than us. After a stay of four weeks which, in addition to special scientific studies, was devoted to getting to know this interesting country, my journey now continued over the great ocean to America where I remained for two and a half months. I was particularly interested, of course, in the institutes of aeronautics.

In general, there were not many more facilities at the technical universities than we have in Göttingen. There were just more universities. At many universities, there were special laboratories for aeronautics. They have wind tunnels, most of which have a size up to that of the ones in Göttingen and smaller. The national laboratory in Langley Field near Washington is quite magnificent. Here, first-class work is carried out and some of the equipment they have surpasses that which we have in Europe. There is, for example, a wind tunnel with a diameter of six metres. Whole aircraft can be placed in this, so that it is possible to carry out better studies on propellers and motors.

What is my impression of the landscape? There are of course great differences. In the Siberian steppe, there was nothing but grass and then once more low birch woods; in the American steppe roughly the same, only other types of trees. There were stretches where many acres of pasture would be needed in order to feed just one cow. The grass was so sparse in such areas. The situation was, of course, quite different in Japan with its rice fields and colourful temples.’

Loving hands had arranged a garland on the door to his office in the aerodynamics institute on his return, and the room in which he received me was full of colourful flowers. And this certainly gave the same pleasure to this much-honoured man, if not more, as the presents of flowers with which he was honoured during his travels.” (End of the report about the interview.)

The experience of travelling around the world appears to me to have been so important in Prandtl's life - a period of time that was full of unusual impressions and, in addition, provided sufficient leisure time to observe so many things - that I would like once more to give an account of his travels, making use of his letters to add detail to my account.

The first stop was Berlin, where he met up with Professor Nägel from Dresden, who also participated in the conference and in whose company my father continued his journey.

15th September 1929

“After a train journey lasting 40 hours, we both arrived in Moscow at 11.30. Already on stepping out of the train, we were photographed and filmed. Then, we went on a short tour by car along streets with a glorious streetscape: a propaganda procession of school children with inscriptions and red signs, then to the Church of Redemption, where a mass was being celebrated with priests and choral singing, and then our tour continued around the Kremlin, with its many towers, to the hotel where I now have accommodation in a splendid room with a bathroom. The reception today and the first impression of the city, with its kaleidoscope of images, will certainly remain in my memory forever.”

He gave three lectures in Moscow, was invited by the German ambassador, attended a performance by the Bolshoi ballet, visited the Tretjakov picture gallery and the Museum of the Revolution.

On the 29th September, the long journey through Siberia in a sealed train began.

29th September

“Early this morning, our journey took us over the Ural, quite a flat (mountain) ridge, approximately 400 m, mainly covered with birch woods.”

2nd October

“We have now been four times 24 hours on the train and will soon have half of the journey behind us. Here, the clocks are set 5 hours earlier than in Germany. Yesterday evening around 10 p.m., we travelled over the River Ob near the town of Novosibirsk. This is quite a large river, such as I have

never seen in Germany. A thousand lights from the largest city of Siberia and two bright-lit steamships were reflected in it.”

2nd October

“This morning, in the distance, we saw mountains that were similar in appearance to the Black Forest. The forests with the golden-yellow of larch trees and the green of pines and the grey-yellow of the wilted grass are particularly beautiful in the early morning red of the rising sun.”

3rd October

“The main event of the day was Lake Baikal. The train travelled about six hours along it. But, it was 1 o’clock in the night as we arrived there. So, we were only able to enjoy the landscape from 5.15 until 6.45 in the morning grey and in the rising sun. The lake displayed surf with large white-caps. The water was dark-green, the sky had dark-grey clouds and the mountains on the banks were illuminated by the early rosy dawn. We slept once more from 7 until 9 a.m.”

6th October

“This is the last card from the Siberian railway. Today at 2 in the afternoon, we travelled along a bridge that is more than 1 km long, over the Amur river. From two thirty until three in the morning, we were in Khabarovsk, which is an important commercial town. The region is very charming and the blue mountains opposite are already in China. Many Chinese faces can be seen at the railway stations; mostly workers, some in European clothing and some in fantastic rags. By the way, the whole journey from Moscow is 9,330 km.”

7th October, Vladivostok

“The hotels are overfilled, as they are not equipped to cope with the large amount of traffic now passing through here, as a result of the closure of the Chinese railway. We had unbelievable luck: Nägel noticed the car belonging to the German consulate. After a little waiting, the consular secretary, whom we were asked to greet by the Russian Embassy in Moscow, appeared and arranged first of all to have our luggage brought into the consulate. As we were sitting there, much to our surprise, the wife of the consul invited us to reside with them.”

From Vladivostok, they travelled to Japan in a journey by ship lasting several days. On the 11th October, they were cordially received in Kobe. Professor Wieselsberger, the former assistant in Göttingen and Mr. Takao, director of an airplane factory, soon came on board to greet both travellers.

12th October

“Today, something quite special took place. Mr. Takao invited us to join an excursion with some Japanese women to look for mushrooms and enjoy these afterwards in a meal. We paid a fee to visit a site in the vicinity of the mountains on which many mushrooms grow and which is sealed off, to prevent unauthorised people from taking them away. We approached the area in four cars. We all met at a riverbank, greeting each other cordially by each bowing three times deeply. Then we travelled further by car, followed by a short walk lasting a quarter of an hour on a small hill, where the mushrooms, which were quite different in appearance from European mushrooms, were located. Each person had a leather basket and we started to gather the mushrooms. In the meantime, a small kitchen range made of earthenware was heated with charcoal. We used this stove, placed on a tablecloth, to cook a variety of dishes including chicken, various vegetables, a bean mash similar to curd cheese and eggs. Our meal was like a Japanese barbecue, placing the items on the cooking surface, frying them and then eating them as they were ready, while at the same time placing more items to be fried. We used chopsticks, with some degree of success. Then we drank Saki and we took many photographs. Altogether, it was quite a stimulating experience. In the afternoon, we visited an airplane factory.”

16th October

“Visit to the park villa of the owner of a factory outside the town of Kobe. We drove there by car. The house was located in a beautiful garden with a lake and bridges and a little hill, and a number of small houses where one could drink tea. We first took the main house to be a large tea salon, but we were assured that the family really did live there. The complete absence of furniture appeared quite odd. There were only pillows and armrests placed around and one had to sit on the floor. Shoes had to be removed before entering the house. In the garden, we first had a tea from seaweed, then we washed our hands in a ceremonial manner, waited in another pavilion until a gong sounded, then we were led by our hosts into the main house where we sat down on the cushions (in a horseshoe). The ladies

placed a small table in front of each guest with food on it. The ladies served us, but did not eat with us.

The next day there was a visit to Osaka (45 km from Kobe), a very interesting town with a fortress and temples. In the evening, we were invited by the general consul. Today, we had the opportunity to rest, which we all needed.”

20th October

“Now we are in Tokyo. The last two nights, we stayed in Kyoto in the well-known Mijako hotel, a true health resort hotel, built on a mountain. The view from the hotel reminded me of Baden-Baden, but the mountains were much more beautiful. In Kyoto, there are quite wonderful temples, three of which we had the opportunity to visit (there were actually at least ten we could have visited). Towards evening, we went for a stroll through the incredibly colourful shopping streets. Yesterday, we were in the town of Nara, where a number of temples are located and a place of pilgrimage, with Shintoist and Buddhist temples, all located in a wonderful park, where whole herds of tame deer were wandering around. There was an enormous statue of Buddha made of bronze, which gave a powerful impression in the gloomy, high temple hall.

Tomorrow, the day after tomorrow and the next day, I will give lectures lasting from 2-4 hours [38]; on Thursday, with Baron Schiba, who is the director of the Institute of Aerodynamics.”

3rd November

“The invitations continue to arrive. I can no longer count them, but will simply say that we were invited to tea in a magnificent garden, to a theatre performance, lunches and dinners, balls etc. and that each one surpassed the other in charm. The lectures have receded into the background.”

9th November

“The congress has come to an end and this morning we drove to the town of Nikko, where there are many temples. There is an unimaginable wealth of forms and colours. The large edifices are covered and interspersed all over with decorative figures; small figures up to the size of a hand which, in turn, are executed in a delightful manner, right down to the last detail, in red, green, blue and black colours. The temple timber-work is painted red

and smoothed. Tomorrow we will be travelling by car 600 m high up to view a waterfall and a lake.”

11th November

“Yesterday, we took Mr. Nägel to the railway station. From now on, I will have to cope alone. He gave me quite indispensable support, with his resourcefulness and good knowledge of languages.”

Prandtl travelled in an easterly direction on the following day, after leaving presents were given to him (pins with pearls and landscapes painted on silk).

18th November, on board the ship the “President Pierce”

“Yesterday was Monday the 18th November and today once more! - Yesterday with the Japanese, while you were sleeping, and today with the Americans.

We had sunshine for the first time today and also a beautiful sunset. Imagine a green evening sky, with an olive colour at the bottom changing to steel grey towards the top, with violet above this and small vermilion clouds in the green stripes. To the left of this area, the sky was dark blue, whitish underneath and brownish right on the horizon. Later, the green became yellow and then red, and now the colours are similar to the ones we are familiar with. The starry sky appears quite different from what we are accustomed to. Try to imagine the northern sky without the Great Bear.”

21st November

“The ship berthed for two days in Honolulu. We were greeted with Hawaiian music. I went over the gangway into the large customs shed and, much to my surprise, I was met by a man who asked me if I was Professor Prandtl and, on confirming that I was, he hung a garland of fragrant flowers around my neck. Here, throughout all the seasons, there are trees and shrubs in bloom, and how beautiful these are (bright yellow, light-red, dark-red, pale lilac, bright red-violet). They are all flowers which are not familiar to us in Europe and there are fruits of the greatest variety. The main products are pineapple and sugar cane. Honolulu lies at the slope of a large volcano. The mountains (at the edge of the crater) have very interesting forms. The mountain guide told me that I had been invited to a

lunch at midday of the following day and that I should give a short lecture on this occasion. None of my usual themes were suitable and so we agreed that I should talk about gliding. He took a seat in his car and then we drove up and along a pass on the other side of the mountain range (in the interior of the crater from a former time). The sides ascend steeply, the landscape is very romantic and the sea forms a background. In the evening light, we drove back along another route.

There were twenty men present at lunch, which was in a very beautiful clubhouse. A speech was made by the gentleman presiding over the occasion, in which he greeted me. Then, it was my turn to deliver a speech, the first time that I had spoken freestyle in English.”

When the ship reached land in San Francisco, after twelve days underway, the time had come for Prandtl to begin his American lecture tour, which took him to many well-known university towns. Following a stay in Pasadena, a few days were spent in Urbana and then he stopped in Chicago, Detroit, Wrightfield, Washington, Ann Arbor, New York and Boston in order to give lectures at these universities. He also seized the opportunity of visiting other locations with places of interest on the long journey across the American continent.

His travels took him to the island of Catalina. The boat had a transparent glass bottom. “One can see the underground garden, sea plants and many fish. On the island, in contrast to the mainland of California, where there are just highways and pedestrians in the outer suburbs are barked at by dogs as ‘suspicious figures’, there are attractive footpaths (or, to be more precise, bridle paths) where one can wander freely. Today, I took a walk along such a footpath, which ascended to a point where suddenly a view of the ocean was accessible at the crest of the mountain. In the distance, one could see the Californian mountains. It was approaching sunset and the sea, the smooth, always peacefully calm ocean, shone in the gold of the evening. Above this, I observed the blue sky covered with light cirrus clouds. Left and right of the pass, there was a peak on each side, both of which I ascended”.

He told his little daughter about the Grand Canyon in a letter which I would like to quote at this point in my account.

27th December 1929

“Now it is high time that I write to you on the occasion of your birthday. I am sending you a booklet with views of the wonderful area where I am today. Imagine a wide, elevated plain with a pine wood on it, 2,100 m above sea, which is about the height of the Karwendel peak. In the southerly direction, one can see blue mountains above the forest. But, now to the other side! There, a mighty river has eaten away a valley with 1,000 side valleys and everywhere one can see the exposed rocks. Above, there is some *Muschelkalk* (a limestone) and below there is red sandstone, as can be seen at Reinhausen and Bremke (villages near Göttingen). Then there are three to four other rock types, all lying horizontally. The river valley lies deeper than Mittenwald (a town in Bavaria) viewed from the Karwendel peak. The air is very clear and one can see over a long distance. The shadows are then almost sky-blue. In addition, one can see white, red, grey and violet-brown stone. A wonderful symphony of colours, changing with the time of day, from harsh colours in the blazing sunshine through to delicate, soft shades in the evening twilight. So much for now from me about the Grand Canyon. I think your mother will give you another present from me from the Japanese box.”

In Detroit, it was only planned to make a visit to a Ford factory.

Detroit, 16th January 1930

Prandtl, who this time travelled with just hand luggage, was met by an acquaintance at the railway station who intended to drive his guest to a hotel. Before reaching the hotel, however, the car stopped outside a restaurant, in order that both could have supper together. As the two gentlemen returned to the car, there was an unpleasant surprise: someone had broken into the vehicle and stolen the luggage. This deeply saddened the globetrotter Prandtl, not least because the leather bag contained not only his night-clothes, but also the Japanese honorary brooch and thirteen films which had not yet been developed, which he had taken along with him as his most precious travel commodity. His personal experiences had found their expression in these images. With the eye of an experienced landscape artist, he had pursued motives which were worth seeing and recording, in quiet appreciative joy, on this long journey, in order to have sufficient time for observing sights of interest and beauty of the most diverse kinds. The next day, he placed an advertisement in the newspaper.

The thief was asked to return at least the films for a reward. His efforts came to nothing and the event remained a source of distress for a very long time.

9th February 1930, New York

“On the first day of my stay in the city of New York, I visited the downtown district, which is the main business district. I took a look at the skyscrapers and the large bridges across the East River and went to the office of North German Lloyd. There, I was presented to the director as a prominent traveller who had made himself familiar with the conditions in Russia and Siberia. In the evening, I visited one of the hundred theatres in Broadway to see a talking film about - Disraeli! The characters in the film were superbly portrayed, and the characters’ voices were perfectly reproduced, as were also other sounds (walking, banging plates, fine music - everything was quite excellent). [Author’s comment: talking movies were not yet available in Germany at that time].

On Saturday morning, I went to the Natural History Museum, which is a first-class place to visit. In the afternoon, I went to the art museum (picture gallery with many Rembrandts, pictures by Frans Hals, van Dyck etc, Egyptian, Greek, Roman antiquities, exhibits from the Middle Ages and modern times, China, Japan, India, Persia - an overwhelming wealth of beautiful things”).

19th February

“This will be the last letter from America. The lectures I gave in Boston were very well received. On Saturday, I went to Harvard University, where I visited a few laboratories. In the film department, I saw embryonic tissue from chicken develop, cells dividing etc. The glass flowers in the botanical institute, modelled in natural forms and colours by a man in Dresden, which can only be seen at Harvard, are marvellous.”

My mother travelled in high spirits on the 1st March to Bremerhaven, in order to pick up her husband directly from the ship on his arrival back in Germany. Naturally, there was so much to talk about after he returned home that it took us several days to exchange news. Reports, comparisons and allusions, which flowed into the account of his visit to Japan, remained the main topic of conversation of my father at the table for a long time after his return. These were also a clear indication of how strong these

impressions, which my father had gained from this far-eastern country of a completely different, refined culture, had been received by him.

Children often retain a clear memory of frequently recurring themes and subjects of conversation of their parents. So, I would like to give a summary account of a few of my memories of my father's impressions gained from his experiences in Japan.

It was the way in which Japanese people behave towards each other which, I believe, made the greatest impression on him. He told me that he never saw children in the presence of their parents yell or cry. In everyday life, the Japanese are extremely friendly towards one another in everyday encounters. Their acquired modesty and self-control has become a way of life, which appears to us as particularly polite. The innumerable opportunities which the Japanese take to give presents, always tasteful things which are handed over with humble gestures, shows us their kind attitude in relation to living together as fellowmen. He particularly praised their generous hospitality. Their marked sense of neatness also contributes to strangers being able to feel particularly at ease. In addition, one is aware all the time that the Japanese are very diligent.

The gifts which my father brought back with him from Japan produced in us a feeling of having our own affectionate relationship with the Far East. His presents included two kimonos, which could be tied together with an obi at the waist, shoes made of wood, stockings made of lined linen, small hair grips and, of course, a pair of chopsticks.

13. Everyday Domestic Routine Once More

Our home had now regained its central figure and we became aware of how important our father was to us. The old familiar custom of going to the Hainberg on Saturday afternoons with my mother still continued, of course. After a stop to drink coffee, my father often had the desire to continue along the footpath on his own. He would walk along unfamiliar little paths - there were many of these in the local woods - and would set off to find a beautiful vantage point or a location unknown to other people from Göttingen, where rare flowers were to be discovered. Sometimes, I accompanied him on these "stalks" and he was always untiring in his efforts to tell me many things about plants, topographical features and the landscape. However, with all his wealth of knowledge, he had some difficulty in appreciating the slowness of his thirteen-year-old daughter, who was not always capable of following his explanations attentively. In contrast, I was always very fascinated by his intentions to make hidden paths through the woods passable by cutting off branches blocking our way. On such excursions through the woods, he always looked out for flowers and always returned home with a bouquet for my mother. He had a wonderful relationship to those things that surrounded him in nature. He was unflinching in his questions about phenomena associated with plants, rocks and clouds. He was not someone who could go for a walk without observing his surroundings. Those who accompanied him were enriched by his ability to communicate about his observations. He was particularly interested in cloud formations and the currents at various altitudes. At the same time, he would express his appreciation of the beauty of some cumulus clouds, and show enthusiasm for the changing moods created by wisps of clouds drifting along, causing the landscape to be lit in diverse ways.

In the evenings, when my sister and I had finally gone to bed, my mother would regularly read to my father for at least an hour. My father, who himself had no time for reading modern literature, listened with both interest and attention. These evening reading sessions were a source of relaxation for him and a break from his customary train of thought. The books which my mother selected to read were mostly biographies or novels which had just been published such as, for example, *Der Zauberberg* (The

Magic Mountain) by Thomas Mann. One time, my mother read from the book *Die Armee hinter Stacheldraht* (The Army behind Barbed Wire) by Erich Edwin Dwinger. My father was so moved by the narration and was so disturbed by re-experiencing in his imagination a realistic, brutish war scene that my mother had to lay the book aside in the middle of reading it. Oswald Spengler's book *Der Untergang des Abendlandes* (The Decline of the West) was also one of the books she read to my father and one which initiated some discussions.

When my mother died in 1940, my father was deprived, not least, of this nice habit of reading aloud, so that I decided to take the place of my mother for a while by reading to him. Later, my father satisfied his needs at that time in the evening by switching on the radio.

After the hour set aside for reading had come to a close, he sat down at the large table in the middle of the room, with no-one claiming his attention now, and spread his working papers out. And, while he occupied himself with his scientific problems, the hours passed by and the light was never seen to go out before 1.30 a.m. The neighbours became familiar with seeing the light from this room and it was said that it was possible to walk along the street outside, which was sparsely lit, in safety, because they knew that Prof. Prandtl would still be awake and that light would shine from his window.

There was a second table against the wall in his study that served as a kind of filing tray for the letters which had not yet been dealt with, as well as a place on which to store scientific journals. These piles continuously grew in height, so that some became so high we were afraid that one of them would fall over. My mother would then urge my father to think about clearing up the collection of letters and journals, at the same time helping him out with the process of sorting everything out. Although my father had chosen a guiding principle as a maxim, "No item sent by post can be so urgent that it becomes even more urgent as a result of lying around or, with the passage of time, it will have taken care of itself?", willingly accepted the suggestion of his orderly wife on Sunday mornings. Afterwards, he was glad to sit down at the piano and play preludes in a particularly cheerful way. Time and again, he urgently needed some document or publication before setting off for the institute and so he would start searching through

the piles without finding what he was looking for. He disliked wasting so much time, and the fact that his efforts were in vain depressed him all the more. My mother would then come to his rescue and search hastily for the missing item. My father might have said he was looking for a blue pamphlet, but she would discover a yellow one with the label he was looking for and ask him, "Could this be the one you are looking for?" Her talent of finding just the right one from the abundance of journals and papers was, for me, quite amazing. She frequently provided an invaluable service for her Ludwig and she was absolutely indispensable in such situations.

14. Holiday Trips

Over the years, we went on trips almost every time during the holidays. At Easter, we usually went to a health resort in the Harz, a forest area to the north of Göttingen, where we would meet the family of Professor Otto Föppl from Braunschweig. Usually, my father arrived a few days later, as he often had many things to do before he could join us. But, he made use of the holiday week, which he enjoyed, to go on long walks through the fragrantly smelling fir woods and enjoyed the pleasant company of the two families. For Whitsun, we had good accommodation in Sooden-Allendorf and here, as well, we came together with the family from Braunschweig. When my father went for walks with his brother-in-law, they always engaged in interesting conversations. My father was an undemanding holiday guest: he was someone who always made efforts to ensure that he did not disturb others and always showed his appreciation to others with kind words. He never imposed his status on others, even though he might have brought his importance to bear on them. On the contrary, he often rated others higher than himself and he appeared to expect a general attitude of mutual consideration and respect as being something which should be shown as a matter of course.

Most summer holidays we spent in the old Föppl house at Lake Starnberg. The name Ammerland had a special meaning for all of us, as it embodied not only the joy of carefree country life but, at the same time, evoked associations of warm feelings, which moved our hearts, because of the feeling of belonging together with our relatives from Munich.

In those days, the journey by train to Munich took almost ten hours. But, our expectation of arriving at the destination of our dreams made the journey pass quickly. I would like to recount an episode from one of these journeys. We travelled in advance with our mother, as our father's summer holiday began 14 days after the school holidays started. A gentleman joined our compartment in Würzburg who soon started an animated conversation with my mother. When he became aware that we came from Göttingen, he suddenly asked the question, "Perhaps you know a Professor Prandtl from that town?" I cannot forget how my mother spontaneously burst into laughter. My sister and I also laughed, but with an element of surprise, since we were unaware of how well known our father was.

My father also took very much pleasure in the casual atmosphere in the house of the Föppl family. For him, it was the most perfect place to spend a holiday that he could imagine: swimming in the clear seawater, excursions in the mountains which were nearby and, by way of a change, discussions about his academic speciality with his brother-in-law and colleague, Hans Thoma. During an excursion, we went up the Heimgarten mountain. I remember some natural phenomena which thoroughly fascinated and impressed my father. Looking down from the sunny top of the hill into a hazy layer, we could see our own shadows. What was quite unique about the experience was that we caught sight of a gentle halo in the colours of the rainbow around the head of each shadow figure. Of course, he knew the physical explanation for this phenomenon; namely, that the sunlight was refracted by the very small drops of water in the haze. But, nevertheless, he was still able to take pleasure in this wonderful phenomenon in such a natural and unsophisticated way.

In the summer of 1929, my father was to have a new honour bestowed upon him. At the general meeting of the *Verein Deutscher Ingenieure* (The Association of German Engineers), which took place on the 22nd June in Königsberg, the awarding of the Grashof commemorative medal to Prandtl was announced, during a festive occasion in the presence of 800 engineers. It was the highest honour that the society could bestow.

On the 3rd August 1929, Prandtl received the following letter:

“With the agreement of the managing committee of the *Verein Deutscher Ingenieure*, permit me to invite you and your dear wife to my villa at Lake Starnberg on the 10th August, on the occasion of the presentation of the Grashof commemorative medal.

Yours faithfully,

Oskar von Miller”

On the 10th August, on a beautiful summer morning, a number of gentlemen from Munich travelled in a private motorboat across to Ammerland, where we met them at the pier for steamboats and accompanied them along the meadow paths to our house. Mr. Oskar von Miller, the founder of the German Museum, was in their midst. His presence was greeted with great respect by the family. All the gentlemen were later invited to his beautiful country house in Niederpöcking. Around

midday, they took the motorboat together, to cross the lake in comfort to the other shore, where the festive ceremony was to take place. In the evening of the 10th August, the honoured guest was brought back to Ammerland.

For my father, there was another special place to visit in Upper Bavaria, which he normally went to in September when my sister and I had already returned to Göttingen with our mother. It is called Schleching and is located near Marquartstein. There, his two cousins Klara Prandtl and her sister Anna had a simple guesthouse. There was a strong bond between him and them, because of memories of common experiences of childhood and youth, and he was always especially warmly welcomed there.

In the summer of 1930, we journeyed to Dahme on the Baltic Sea. In August, the International Mechanics Congress was to take place in Stockholm. Wives of participants were, of course, also invited. My parents wanted to shorten the journey to Stockholm by travelling directly from Dahme to the capital city of Sweden. I should mention that the Föppl siblings met up at this congress. Amongst those invited to the congress were Prof. Otto Föppl, Prof. Ludwig Föppl, Professor Hans Thoma and Professor Prandtl, the husbands of the two sisters, as all of these members of the family occupied chairs in mechanics. However, at the large banquet, a place was only set out for one of the Prof. Föppls at the long table, since the circumspect Swedish assistants believed that a mistake had been made when they discovered that the name Prof Föppl appeared twice on the list. Ludwig Föppl, who was not allocated a place at the table, was therefore asked to take a place at the table of the ladies who were the stewardesses at the reception. As fate would have it, he became acquainted there with his future wife Christina. It must have been a wonderful family celebration at this social gathering taking place in the enchanting northern city.

In 1931, my mother went to the health resort of Bad Kissingen, in order to improve her state of health. One can gain an impression of how much attention was given to household matters, amongst others, by our father, from this conscientious little report written by him to his wife: “Marie is taking good care of us. To show her how much I appreciate her efforts, I am sending her to the theatre tomorrow evening to see *Land des Lächelns* (Land of Smiles) by Lehar. – The children got their school reports today. I

gave them a little reward for their grades: for the grades 1, 2, 3 and 4¹³, they received 40, 20, 0 and -20 pennies.”

At the request of his daughter, he also took the time in those weeks to go on a little bike ride. As we were riding our bicycles along one of the streets in Göttingen, a car approached us from the other direction, travelling at a leisurely speed. At that time, cars were only seen sporadically in the outer suburbs, so that pedestrians and cyclists felt little affected by their appearance, as they would not become restricted in the space available to them by the passing vehicles. I said, “We can stay together, next to one another without any problem as we don’t need more space than a car coming from the other direction”. My father responded emphatically, “No, we will ride one behind the other - one should always make it as easy and convenient as possible for others!”. That was one of the maxims that governed his attitudes and behaviour in relation to other people.

My confirmation took place in 1932. Of course, he went together with us in the evangelical church. He wrote a few lines in my little New Testament, which made me feel very happy, “Be true to yourself! Performing your duties - whether great or small - is the best basis for having complete peace of mind.”

¹³ Translator's note: in the German school system, pupils are given grades from 1 to 6, with 1 as the highest grade



Antonin Prandtl d. Ä. mit seiner Frau
Anna Charlotte, geb. Hauttmann

The grandparents

Antonin Prandtl Sr. with his wife Anna Charlotte née Hauttmann



Ludwig Prandtl's father
Alexander Prandtl



Ludwig Prandtl's mother
Magdalena Prandtl née Ostermann



Ludwig aged 4



Ludwig aged 6



Ludwig aged 10



Ludwig aged 12



Ludwig Prandtl aged 17



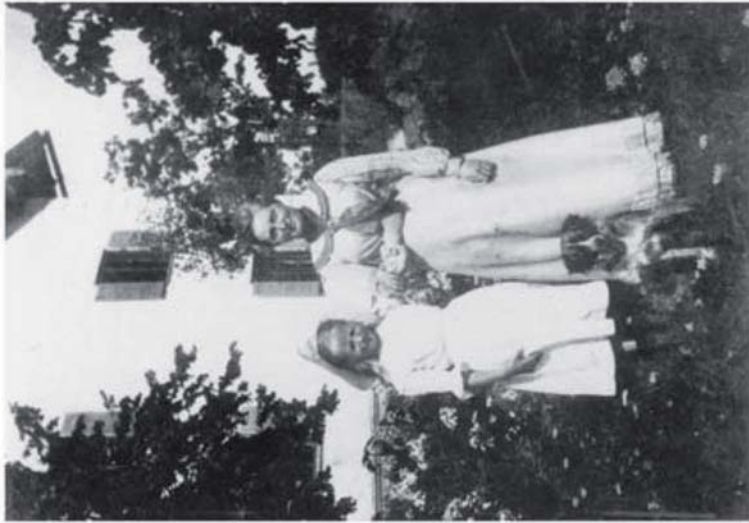
Ludwig Prandtl aged 20



Ludwig Prandtl in 1901
Professor in Hanover



Ludwig Prandtl in 1902
with the water channel he himself constructed



Getrud Föppl with her
10 years younger sister Else



1909, the recently married Ludwig Prandtl



Ludwig Prandtl playing the piano



Signed sketch (from nature) drawn in his youth



The friends L. Prandtl and K. Schwarzschild
with their wives, both of whom were recently married at that time



L. Prandtl with his first daughter Hilde



Gertrud Prandtl with her daughters Hilde and Hanna



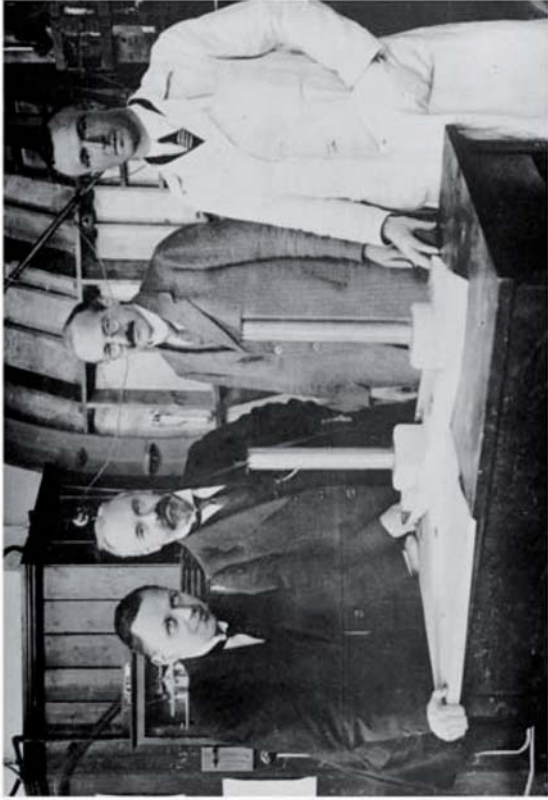
Modellversuchsanstalt (model research testing facility)
in Göttingen 1908



Aerodynamische Versuchsanstalt
(Aerodynamic Research Establishment) 1918



L. Prandtl with members of staff from the institute in 1918



L. Prandtl with a model of the Flettner rotor ship
From left to right: J. Ackeret, L. Prandtl, A. Betz, R. Seiferth



Ludwig Prandtl 1924



Eleonore von Seebach
at her desk in the institute in 1927



Staff of the KWI in 1939, from left to right:
Thiriot, Gärtler, Oswatitsch, Dumitrescu, Ehmig, von Seebach and Lyra



Ludwig Prandtl and A. Betz on the way to a lecture



The aviator Elly Beinhorn visiting L. Prandtl in 1931



Ludwig Prandtl with his daughter Hanna



Ludwig Prandtl in the Institute for Fluid Dynamics



On the way to a ceremony at the university



L. Prandtl with Prof. H. Blenk in 1938 in America



Prof. Ludwig Föppl, Prandtl's brother-in-law,
in summer 1940 in Mittelberg



Privy Councillor Max Planck, Prof. A. Sommerfeld
and Ludwig Prandtl in Berlin

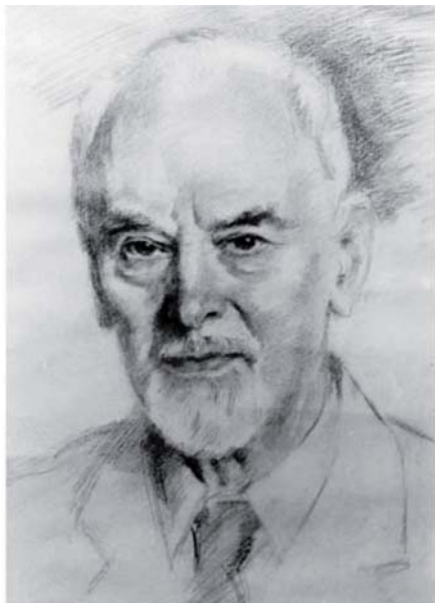
Federal President Theodor Heuss in Göttingen



Federal President Theodor Heuss
L. Prandtl and W. Tollmien



From left to right: A. Betz, O. Hahn, L. Prandtl,
K. F. Bonhoeffer (back to camera),
W. Heisenberg, Federal President Th. Heuss



Drawing of Gottfried Stein in 1950



Lu Schang née Hsin Cheng with her husband
and Johanna Vogel-Prandtl at the grave of Ludwig Prandtl

15. The Year 1933

We have now come to the year 1933 and the period in which we lived under the rule of National Socialism. As long as the Weimar Republic continued to exist, my parents voted for the Democratic Party, which reconstituted itself as the State Party in 1930. They were, however, not much concerned about political questions and placed their trust in the democratic government of the time. This republic appeared to have proved its worth, so that, despite the economic crisis and the constant disputes between political parties, about their enduring continued existence there appeared to be really no cause to worry.

In the house at Calsowstraße No. 15 or, to be more specific, on the floor above us, the raucous voice of a new election speaker could be heard coming from the radio, which rang out from the open window. We were told it was the voice of Adolf Hitler, who was said to have many enthusiastic followers. My parents did not pay much attention. Even the idea of buying a radio at that time was something they had given no consideration to. When the coup came, it was a completely unexpected event for them. It was hardly comprehensible that a man such as Hitler should succeed in coming to power. And so began the rule of the dictator, which was to last twelve years.

The “political corruptibility of the bourgeois spirit” (H. Plessner) was evident very soon in Göttingen. A large measure stemmed from a politically radical initiative of students, reflected in the increasing numbers of party members who, already before the 30th January 1933, had become acquainted with the ideas of National Socialism. Prandtl continued to observe the political developments calmly, just as before, since they had afflicted us through no fault of our own.

Nevertheless, he was troubled and outraged by the decrees which were to have an effect on his colleagues.

Dr. Marianne Wiener-Bernstein recounted, in an article in the Göttinger Tageblatt dated 7.8.1987, several statements made by colleagues of her father, Professor Felix Bernstein, who was forced to emigrate in 1933, after

he was obliged to leave his Institute of Statistics. The following is quoted from that article:

“Furthermore, I know that Professor Ludwig Prandtl, in his seminars complained about the Nazis in a very loud voice.”

In the following years, the new government was especially interested in aeronautical research, so that large building projects could be established on the site of the institute. Prandtl presided over the new, substantially enlarged complex as the first director. Such a development could, in general, only give satisfaction to someone who is involved in research. One would have expected that Prandtl would publicly behave in a way corresponding to expectations; namely, to comply with the political wishes of the supporters of the new projects; i.e. to conform. In fact, however, he did no such thing. Throughout the years, he steadfastly refused to join the party or to hang a picture of Hitler in his director's office. But, the alternative of either showing loyalty by joining the party or withdrawing from office was never put to him. But, I am sure that, if he had been forced to make this choice, he would have given up his post as director rather than compromising his convictions. The majority of younger colleagues at the institute also shared his view.

But, I remember an event from the 1930s as he joined us, already at the table, with a look of deep concern, and told my mother the following: He was accompanied on his way home by an assistant, who told him, as they were on their way, that he would now be joining the party for purely opportunistic reasons. Prandtl was frankly shocked by his attitude, but kept control of his emotions and advised him, in more of a fatherly manner, to refrain from taking this step: he should not avow the ideas of the National Socialists and he should reflect on the matter. The answer given by the assistant, as my father recounted at the dinner table, has remained engraved in my mind, “Dear Professor, we also want to become someone. You have achieved that already!”

I am still very much conscious even today, after many heated discussions of how much my father was affected by virulent campaigns against his Jewish colleagues. Much has already been written about what happened, starting with the laws of the Third Reich, which decreed that German professors of Jewish descent be forcibly suspended from office, and which

was later converted into an irrevocable dismissal, in a number of publications; for example, in the books of Alan D. Beyerchen [7], *Wissenschaftler unter Hitler* (Scientists under Hitler), Constance Reid [42], a biography of Richard Courant, Max Born/James Frank, *Luxus des Gewissens* (The Luxury of having a Conscience, a booklet accompanying an exhibition in the Berlin State Library, with contributions to the text by F. Hund, H. Maier-Leibnitz and V. F. Weißkopf [47]). I would like to quote a few extracts in which a reference is made to Ludwig Prandtl.

From the book *Luxus des Gewissens*

“James Franck, who had belonged to a unit of front-line troops in the First World War, was not dismissed from his teaching post. But, his pride and solidarity with his Jewish colleagues made him to go his own way. On the 17th April 1933, he announced his resignation.”

Prandtl was deeply shocked and saddened. On the 10.02.1933, together with his colleagues, he signed a letter addressed to Franck to try to persuade him to stay in Göttingen and not accept an offer of a professorship in Berlin.

“The importance and productivity of our faculty is based on a team of talented people. The team has already suffered heavy losses, with serious consequences. If you were to leave, the work which has been built up with a substantial contribution from you would be threatened with falling into decline, at a particularly difficult and perilous time”.

The letter was signed by Hilbert, Born, Windaus, Prandtl, Reich, Pohl, Neugebauer, Courant, Schermer, Eucken, Kienle, Angenheister and a few others¹⁴.

In the biography of the Jewish colleague Courant, the events which took place at the university, in so far as these were associated with Courant, are extensively and precisely described. The extent to which Prandtl became personally involved in helping the colleague, about whom rumours had been spread that he was a communist agitator and who was under threat,

¹⁴ In the year 1953, the year of the millennial celebration of the town of Göttingen, Franck, Born and Courant were made honorary citizens of the town

can be appreciated by reading the chapter “Spring 1933”. I would like to quote a passage from the book:

“... he (Courant) made up his mind to approach officialdom.

Seeking a colleague unaffected by the *Reichsgesetz* (Laws of the Third Reich) who could present his version of his activities to the administration of the university, he settled upon Prandtl. The professor of mechanics was generally considered a somewhat naïve man. But during the wild week following the announcement in the paper, he had acted with courage and decision, firing one of his assistants when he had discovered that the man was an informer for the Nazi forces at the university.” It is said that this assistant tried to defend himself against being thrown out and a colleague remembered hearing the following words when he took his leave, “Professor, you will regret it. You will remember me!” Nowadays, perhaps, it is very difficult indeed to understand the significance of mercilessly dismissing a member of the ruling party who was expected to render services as an informer to his superiors. I would also like to emphasise that Prandtl was, by his very nature, not one who was inclined to adopt radical solutions.

I would like to return to the text about Courant, with the following quotation. “It was decided that Courant should write a letter to Prandtl setting out the facts of his political activities after the war (First World War). Prandtl would then present the letter to the *Kurator*.”

I would like to quote another passage from Courant’s biography. It relates to the drafting of a petition which Courant’s colleagues Friedrichs and Neugebauer had formulated, in order to support him, and which was to be distributed to 65 colleagues. It contained a statement of the importance which Courant, who had taken over the Institute of Mathematics as Klein’s successor, had achieved. The author wrote, “sixteen did not respond at all. ... twenty-one refused to sign but wrote letters explaining their reasons.” For example, “they did not want to bring themselves as individuals to the attention of government” etc. Professor Kneser, a former assistant of Courant, was of the opinion that it would be more effective to formulate a letter to be sent directly to the minister. “The suggested letter, which was signed by Friedrichs, Kneser and Prandtl, began:

‘Each of the undersigned knows Professor Courant as the result of a number of years of close collaboration. To our knowledge in all of his

activities he has felt himself a German citizen and a representative of German science and has conducted himself as such. ... The mathematical facilities of Göttingen, which since 1921 have been developed essentially through his efforts, are of great significance for the scientific culture of Germany and will not without essential damage be separated from his person.’

It (the letter) concluded with a request that the three be heard in person ...”

After a period of two weeks, twenty-eight colleagues had signed the petition drafted by Friedrichs and Neugebauer. Here are a few of these signatories: Heisenberg, Hilbert, von Laue, Planck and Prandtl.

The passages from the text which I have reproduced from Courant’s biography appear to me to be important and, at the same time, demonstrate how much Prandtl, for his part, exposed himself, without flinching from the personal consequences his actions might have.

To clarify this point, I would like to quote a section from the *Beamtengesetz* (Law governing the actions of civil servants); specifically a paragraph of §4: “Civil servants who, in pursuing their political occupation do not ensure that they support the national state at all times and without reserve can be dismissed from office. In evaluating the actions of civil servants occupying executive positions, more stringent criteria will apply.”

What is also particularly interesting in relation to this matter is that these efforts to rehabilitate Courant resulted in success. The suspension from office was revoked. Courant later decided to retire from his professorship and then emigrated with a heavy heart, but under more favourable financial conditions, to America.

The interventions of the ruling power did not, however, spare any of the Jewish lecturers at the university. But, Prandtl did his best to counter unlawful acts. There were further suspensions. Prandtl wrote to his wife on the 16th September 1933 from Würzburg, “The curator has written to me that the minister has withdrawn the right of Hohenemser to hold lectures. So, things have already gone so far!” Prandtl had also tried to intervene on his behalf and to prevent his dismissal being implemented.

In the wake of intrigues initiated by another troublemaker at the institute, some other colleagues became the subject of incriminations, because they were involved in the matter as a result of making statements. With regard to the troublesome disagreements and accusations, a report was made to the administration of the *Kaiser-Wilhelm-Gesellschaft* (KWG), so that it could make a statement. A circular letter from the president of the KWG followed. In order to restore peace at the working place, seven employees who had made statements as witnesses were dismissed. This decision was not in keeping with Prandtl's wishes.

The embroilment of the incident, in which the name of the Georgian Dr. Nikuradse repeatedly appears, has never been completely clarified. Persons of various rank endeavoured to pursue the matter before the courts. In this context, I would like to quote from the file of a lawyer, in order to explain the situation as it stood at that time: "After Professor Prandtl initially refused to comply with the request for dismissal, a discussion took place in the presence of privy councillor Valentiner, privy councillor Wolff and the SS captain D. J. Weniger who suddenly became involved in the matter, in which Weniger declared to Prandtl that it was now irrelevant whether there was a misjudgement or not, the question of the dismissal of the seven employees was a matter which had been settled and which, by all means, must be carried out. Prof. Prandtl was only the executive whose role was to implement the decision. If he were to refuse, he would make himself the head of a revolt against the state and would have to contemplate the prospect of ending up in a concentration camp."

Despite this serious threat, Prandtl nevertheless did not give up intervening on behalf of his colleagues and making known the true events to the Prussian Ministry of Culture, Education and Church Affairs. On the 4th October, he requested a personal discussion there in Berlin, in order to fight for a renewed appointment of the innocent party through an appeal against the decision.

The conflict of opinion developed further, as can be appreciated from the following exchange of letters.

28th December 1933 letter from Prandtl to Planck

“I also cannot deny that I feel that the way in which I was treated by the new communication, in which my application was refused without giving any reasons, is an affront to my honour as a director of a Kaiser Wilhelm Institute. I attach such great importance to my duties in relation to my institute that I would not, without reflection, simply follow an official order from a higher office which I consider to be detrimental to the institute, without having taken exhaustive steps to find the last possibility of an agreement.”

29th December 1933 letter from Planck to Prandtl

“Do you not think it would be a good idea to let this matter finally rest? The three gentlemen (in the meantime, four had left voluntarily) will, when all is said and done, get off with a fright and, as for the rest, their scientific work will also be preserved, so that they will have the best possibility of making amends for what they have suffered. What causes me the most concern is the thought that you yourself believe that you have to devote your valuable time and energy to this adverse circumstance, in that you have been drawn into a matter for which others are to blame. I hope that the New Year will bless both you and your institute with better times.

With kindest regards from me to you

Yours sincerely, Planck”

Letter dated the 3rd January 1934 from Prandtl to Planck

“The reason why I have not let the matter drop, as you recommended, can be quite simply stated: I wish to remain loyal to those colleagues who have trustingly placed the advocacy of their affairs in my hands. Also, I myself have the keenest interest in ensuring that the image which has been produced by the deliberations about the state of affairs in our institute is corrected.”

The reader will appreciate from these quotations from the letters exchanged between Ludwig Prandtl and Max Planck the extent to which the former acted with unerring resoluteness, according to his own convictions. In the end, the three colleagues were able to keep their rightful positions at the institute, as a result of Prandtl’s unwavering intervention.

In the course of the unpleasant proceedings, one had to take note, with surprise, that Nikuradse had maintained confidential contact for many years, as an activist in the National Socialist party, with his party office. “In order to restore peace and the functioning of the institute”, Prandtl now announced his dismissal, although he thereby incurred the complete animosity of the SS captain Weniger. The attempts of the SS secret service man to harm the professor remained, however, unsuccessful. Despite the problems of the institute caused by the events associated with Dr. Nikuradse, Prandtl saw to it that he obtained a suitable position at the Breslau Technical University.

He behaved in a similar manner in relation to an incident which occurred in March 1934. The following account comes from the text “History of the Institute” by Kurt Kraemer [17].

“In March 1934, the law for the re-establishment of a civil service (which had served as the justification for the dismissal of Jews from the university) also had to be implemented at the *Kaiser-Wilhelm-Institut für Strömungsforschung* (Kaiser Wilhelm Institute for Fluid Dynamics) in the following way. The general director of the KWG, Glum, confidentially requested on the 10th March a declaration of loyalty from all those members of the institute who were formerly social democrats and demanded the dismissal of an alleged communist. Prandtl replied on the 13th March, ‘... You can remove me from the position of director of the local institute, if you are of the opinion that I am no longer suitable to hold the position, but you cannot insist that I dismiss valuable skilled workers simply because once, when they were young, they stumbled upon a youth organisation associated with communist ideas’. A further inquiry from the general administration to the Reich Minister of the Interior resulted in the response that exceptions could not be made, in principle, unless... The president, Max Planck, himself replied (confidentially!) on the 10th April stating that the coppersmith in question could only be employed in the future if Prandtl were to personally accept full responsibility and that the spokesman for the NSBO (cell of the institute) had no objections. And so it was.”

Although Prandtl lived mainly in the abstract world of his research, he was always prepared to take time in order to attend to the affairs and problems of his fellow men and colleagues, and to offer effective help.

Professor F. Schulz-Grunow wrote in his publication [46] “The Intellectual Legacy of Ludwig Prandtl”, “One should also not forget Prandtl’s willingness to help. He literally took care of the body and soul of his colleagues. During the economic crisis of the 1930s, he renounced his salary as director of the institute for the benefit of those colleagues who were in need and, when war broke out, we were all exempted from military service.”

The relationship between the two scientists Max Planck and Ludwig Prandtl was a quite personal one. Max Planck’s second wife was a school-friend of my mother from Munich (she was also my godmother) and the two close school-friends remained in close contact by writing letters, even after the marriage.

In private encounters, as well, one was also impressed by Max Planck’s ethical principle of the strictest fulfilment of duty. One had to consider it to be great good fortune to know that this upright, important man who was, in every aspect, a model for others, held responsibility by occupying the office of President of the KWG during the first years of the totalitarian regime.

In Prandtl’s area of the institute, the range of tasks continued to expand. The more the leading men in technology made the train of thought of aerodynamics specialists their own, the more their sphere of work expanded. As, in the summer of 1933, the 25th jubilee of the *Aerodynamische Versuchsanstalt* AVA was celebrated, a large number of well-known scholars and industrialists convened in Göttingen. During a visit to the institute halls, it was possible to admire very many different models. In addition to model airplanes, there were also models of streamlined automobiles, fast rail cars, as well as models of radio towers for which the wind pressure had been determined. The public also had the opportunity of participating actively in the new research.

The obligingness of the town of Göttingen was also very much welcomed. It released a piece of land at the airfield for the jubilee celebration, on which it was intended to set up a hangar especially for the use of the AVA. The under-secretary of state of the Aviation Ministry had also selected the date of this celebration for personally announcing the authorisation of a new phase of construction. A more modern, larger wind tunnel was to be built on the site in Bunsenstraße, which was urgently needed for research work. One year later, in 1934, the building project was begun in a spectacular manner with the first cut with a spade. Subsequently, after two years of building activity, in 1936, the new wind tunnel was put into operation.

16. Honorary Doctorates from Cambridge and Trondheim

In early July 1934, Prandtl went in the company of his older daughter to Cambridge, to participate in a meeting of the Congress of Technical Mechanics. He was the guest of his English colleague Prof. G. I. Taylor and gave a lecture [20].

In 1936, he was once more invited to Cambridge, where he was to be presented with an honorary doctorate.

Cambridge, 9th June 1936

“I have just had my first hour free after giving my lecture yesterday. It was well received. The time I spent with the Taylors was very pleasant and filled with conversation about a diversity of subjects. In two hours, the ceremony will begin. Fortunately, I myself do not need to say anything, which is good, as I am very hoarse today.”

10th June 1936

“The event yesterday was very ceremonial. Lord Baldwin, the prime-minister, is the chancellor of the university and conferred the doctorate on me. I will tell you more later. Tomorrow I will be in Farnborough in the morning and Berlin in the evening.”

Note dated the 3rd July 1936, from the local Berlin newspaper

“English honorary doctorate awarded to Ludwig Prandtl. The University of Cambridge awarded an honorary doctorate to the chairman of the *Gesellschaft für Angewandte Mathematik und Mechanik* (International Association of Applied Mathematics and Mechanics).”

Prandtl was invited to go to Trondheim in Norway on the 15th September 1935. Already one year earlier, the university wanted to award him an honorary doctorate of Trondheim Technical University. He was not, however, able to be personally present at the ceremony. He was therefore sent the certificate and the ring, together with the document. It was only two years later, in September 1937, that he was able to meet with his Norwegian colleagues in Trondheim. Prandtl gave notification of a lecture, in order that he might be able, for his part, to express his thanks

retrospectively for the honorary doctorate. After that, he was also invited to Oslo.

From that time on, the friendship between my father and his Norwegian colleagues was particularly warm. In the lean years after the war, Professor Brün from Trondheim sent us a number of bottles by private deliverer of valuable cod liver oil, although he himself was involved in the actions of the underground against the Germans during the period of occupation.

17. The Mountain House

At this point, I would like to tell the reader about an event of a private nature which took place in 1935 and which can be attributed, above all, to the initiative of my mother. My parents bought a small piece of land in Austria, in Kleinwalsertal (little Walser valley) and a modest wooden house was built on the plot of land. They always rejected the idea of buying a house in Göttingen, as did most of my father's colleagues in the 1930s. For them, it was much more tempting to buy a small property in the south. We had already known the village of Mittelberg for some years. My sister had spent a long holiday there in one of the children's homes. Later, this high-lying valley was, on a number of occasions, the destination for our winter holidays. The following is an extract from my mother's diary.

“As we spent Christmas again in 1934 in Mittelberg in Schuale's house and Ludwig recovered very well from a severe attack of the flu, the wish grew in me to buy our own home at this beautiful and healthy spot. During Easter 1935, we started negotiations regarding the position and building of the house, which then slowly grew out of the earth in the summer.”

My father himself drew the plans for the house, which were then used as a basis for construction. In December 1935, we spent our first winter holiday in the little house. The following account comes from the diary.

“In the first few days, when the central heating was not yet functioning properly, it was still far from being cosy. Later, however, the master of the house had gained enough experience that he was able to cure the problem. He took care of the house in the most loving way and once said that it was a wonderful toy. He could be seen a number of times during the day going around with a hammer and saw, putting things in order.”

The idea of moving to the house after retiring went through my parents' minds and they drew up plans. However, things turned out differently.

Relatives and friends found their way to us in the remote valley and told us about the pleasure of skiing and climbing mountains. The wonderful, clear mountain air refreshed both young and old, and the convivial evenings

with games, small talk and useful activities, for the most part with the genial host participating have remained fond memories.

Sometimes it happened that my mother had her knitting things in her hands but, with the wool in total disorder, my father watched how she impatiently fumbled around. It was obviously hopelessly entangled. He looked up from the letter which he was about to write, stared for a while, and then said, "Let me try and put things in order again". My mother thought he should save himself the trouble. But, now he could not be diverted from his purpose and just said, "I would like to do it!" The level of difficulty of the problem which had to be solved had an irresistible appeal to him. He now set properly about the task. He wound, passed through and tied the knots carefully, and everyone attentively followed his manipulations. He devoted himself to this simple activity with patience and quiet devotion. Watching him proved to be a source of entertainment. We observed curiously as he gradually achieved success in the task, which he brought to an end as if it were a game.

I would like to digress in my account by including part of a letter from a much later date. On the 17th April 1952, Prandtl wrote to Professor Marguerre from whom he had apparently received a book by post. "The packaging of the book is, it would appear to me, your own work. I find it worth remarking that the twine, which was certainly securely tied, unravelled in such a way that finally it could be recovered as a single, intact piece. This is a kind of sport of mine (one could also call it a game of patience). The solution was found without having to search in a definite way, and the twine was put in reserve for further use."

I would like to mention an incident which has remained unforgettable for one of my small cousins. A holiday visit! The beds for the various guests were so distributed that that my father shared a room with his nephew. At night, at 4 a.m., my cousin was gently woken by him. He told my cousin to get up and took him to the open window. There, he pointed to a star, which appeared in the sky shining bright over the mountains and told him it was Venus, a planet in the solar system. On this silent night, they enjoyed the beauty of the extremely clear starry sky together and became engrossed in thoughtful contemplation at the sight of the morning star bathed in glittering light.

One of our friends, a girl, still remembers even now, in her old age, a remarkable observation of my father. While accompanying him on a walk in Mittelberg, they saw a small grasshopper making graceful leaps. “Despite making continual technical progress, humans will never be able to reproduce something like this original little animal - it is a wonder of creation.”

Of the many visitors who lodged in our little house in the later years, I would like to mention one family. In the autumn of 1936, my parents let their new holiday home to a colleague who was also a friend, the philosopher Georg Misch, whose lectureship at Göttingen University was taken away from him, because of the “Aryan articles”. He also received notice to quit his accommodation, so that he gladly accepted my father’s offer. At that time, Austria had not yet become annexed to Nazi Germany, so that he did not have to fear any form of investigation there. Misch’s grown-up children felt compelled to leave Germany and before they emigrated abroad, they visited their parents once more.

Their son Peter had received a professorship in Canton, China. He wrote in our visitor’s book, “19th September 1936: Immediately before the departure to Canton, for the last time in our German mountains, to say goodbye to my parents whom, I am pleased, are well looked after in the cosy home of the Prandtl family. Particularly during the last days, it was nice to be together.” The daughter Lore (who later became the wife of the Noble Prize winner Felix Bloch), who came from Denmark, travelled via Mittelberg to Switzerland and the younger daughter, my friend Lilli, journeyed from there to England. Later, all three of them lived in America.

Professor Misch wrote the following in the guest book on the 7th March:

*“September, Oktober, November
und fast den ganzen Dezember,
dann wiederum im neuen Jahr
bis über Ende Februar.
So lebten wir 6 Monat lang
in Prandtls Haus am Bergeshang,
selbänder in der Einsamkeit;
die Berge ragen über Freud und Leid.*

*Und manche kommen und klopfen an,
ob man denn hier nicht wohnen kann?
Jawohl mit Behagen! Doch nicht jedermann.
Die Herrin des Hauses, auf die kommt es an!
Sie ließ es Freunden so lange Zeit.
Ist sie doch stets zum Guttun bereit.”*

“September, October, November
and almost all December,
the New Year too,
until the end of February.
We lived for six months
at Prandtl’s house on the slope of the mountain
we two in solitude;
the mountains towering over joy and sorrow.
And some come and knock on the door
to ask if they may stay there?
Yes, of course, with pleasure - but not everyone.
The lady of the house decides!
She allows friends as much time as they need.
She is always ready to do good.”

Misch left Germany at the end of 1937 and went to England, while his wife, the daughter of Wilhelm Dilthey, remained in Göttingen because of her delicate state of health. Her husband, following seven years of separation, returned to Göttingen in May 1945.

From the university newspaper No. 2 dated 1946

“Return of the Göttingen philosopher after emigrating: Georg Misch, one of the most important figures of German philosophy has returned from emigration and, now that he has taken up his old lectureship again, we have every reason to be grateful to him.”

In February 1938, my sister Hilde became engaged to the junior lawyer Wolfgang Weber. My parents were very pleased about this union. The head of the family, Rudolf Weber, was a critical man, full of character, who had retired from service as a minister in Oldenburg, because he was not willing to make compromises with the National Socialist government. Wolfgang’s

sister, Dr. Sophie Weber, was a paediatrician and later became the trusted doctor who looked after my children and constantly offered us all advice. But, approaching fate quickly took away happiness from the bride which was also a deep sorrow for us all. On the 16th September 1939, the wartime wedding took place in our house and then, with the call-up of the young husband, the painful separation followed. On the 29th June 1941, Wolfgang Weber fell as a first lieutenant at Riga.

18. Intervention on Behalf of W. Heisenberg

For a long period of time, there had been a serious controversy between the supporters of a so-called Aryan physics - aided by Alfred Rosenberg - and the supporters of “modern” physics. The representatives of the former group, who were opposed to quantum mechanics and Einstein’s relativity theory, insisted that physics should have a more “pragmatic” character. Moreover, as these experimental physicists (who included Johannes Stark and Philipp Lenard) viewed this as a political movement, they tried through their machinations to dominate the population of physicists in Nazi Germany. In 1937, their attacks were massively directed against the young professor of theoretical physics, Werner Heisenberg.

Many of Heisenberg’s colleagues, who had a great deal of respect for him, thereupon ventured to come to his defence by writing letters of protest to the ministry. Nor did the action taken by Heisenberg - he himself wrote a letter “to restore his honour” to the Reich’s commander of the SS, Heinrich Himmler - initially produce the desired result. A comprehensive and detailed account of this affair, over the course of a year, can be found in the book by Elisabeth Heisenberg, *Erinnerungen an Werner Heisenberg* (Recollections of Werner Heisenberg) [12]. Here, I would like only to briefly comment on the fact that Prandtl also became directly involved in giving effective help to Heisenberg, in the dire straits in which he found himself, by opposing these attacks and, in so doing, he was able to aid Heisenberg’s rehabilitation.

In the book *Wissenschaftler unter Hitler* (Scientists under Hitler) [7], the author Alan D. Beyerchen wrote in detail about the “Heisenberg Affair”, as well as the complete story. The manner in which Prandtl tried to help his younger colleague out of this situation is related in the following account of events given by Beyerchen:

“Heisenberg’s case remained unresolved until mid-summer. Important support came in July from Göttingen’s aerodynamics expert Ludwig Prandtl, who sat next to Himmler at a dinner sponsored by the German Academy of Aeronautical Research earlier in the year. Prandtl had waited until he felt the SS leader would be free of the pressing duties arising from

the annexation of Austria in order to gain a hearing for his defence of Heisenberg.”

On the 12th July 1938, Prandtl reminded Himmler about their talk in a letter.

“As I was your neighbour at the table on the occasion of the banquet of the German Academy of Aeronautical Research on the 1st March this year, I used the opportunity to raise the matter of certain difficulties faced by German representatives of the field of theoretical physics in the form of unjustified attacks made by a group of experimental physicists and I mentioned, in particular, the personal difficulties in this context of Mr. Heisenberg ... I would like, in this connection, to say a few words about theoretical physics. The difficulties faced by this speciality are mainly caused by a small group of experimental physicists who have not been able to keep pace with the research of theoreticians and who have been passionately opposed to new developments in theoretical physics, mainly because, in the system of teaching contemporary physics, there are substantial elements that stem from non-Aryan researchers.

But, amongst the non-Aryan researchers, there are those who are first class. I just remember in this context Heinrich Hertz, who died at an early age and who, making use of arduous and intellectually demanding experiments, was able to demonstrate, for the first time, the existence of electric waves: the same waves which today have gained great technical importance in radiotelegraphy and radio broadcasting. The physicist Einstein is absolutely first class.

Science is confronted simply with the fact that laws have been discovered which, in turn, have generated further developments and which cannot be ignored without destroying the system of theories which have been further built on them. In addition to theoretical physicists, there must always be experimental physicists, whose strength is in carrying out experiments about which the theoreticians must be allowed to make theories. But, it is scandalous when such experimentally oriented individuals now simply declare theories to be pernicious or objectionable, because they are unable to go along with them and believe they can sling mud at the advocates of the theory. I would like, in order to draw your attention to the opinion of the well-known theoretical physicist Max Planck, to send you an extract from a speech by this scholar.

With regard to Heisenberg himself, he feels even more insulted by Stark and it is imperative that a redress is made in an effective manner and that it is made clear that the central authorities, as well as the highest agencies of the party, are not in agreement with Mr. Stark. This is necessary simply because, if such insults continue to be made, it would greatly hamper the effectiveness of Mr. Heisenberg as an academic teacher, since the students - to the detriment of their future professional work - would be given to understand that what they could learn here would be of no value or, indeed, detrimental.

I consider it would be most appropriate if it were possible for Mr. Heisenberg to be given the opportunity to contribute an article, from his specialist area, to the *Zeitschrift für die gesamte Naturwissenschaft*, which appears as an organ of the Reich specialist group 'natural sciences' of the Reich student leadership. He would then be able to personally present his views. Regarding the question of the selection of this specialist area, I would be gladly willing to confer with Mr. Heisenberg."

I would now like to quote once more from Alan Beyerchen. "There seems little doubt that Prandtl's strongly worded defence of Heisenberg and theoretical physics played a crucial role in the affair. Less than two weeks later, Himmler wrote to Heydrich that he agreed with Prandtl's letter and felt that the Students League should let Heisenberg publish in their journal."

The chair of physics in Munich, which Sommerfeld had earmarked for Heisenberg, was, nevertheless, given to a physicist named Wilhelm Müller, about whom Prandtl, for his part, stated with such clarity as to leave no room for doubt, "Mr. Müller will contribute nothing to theoretical physics, absolutely nothing. Indeed, he has published, in polemic form, a work programme which can only be described as the sabotage of a discipline indispensable for the further development of technology." (Memorandum dated May 1941, quoted by E. Heisenberg [12].)

19. The Prevailing Climate at that Time

At this point, some younger readers who were not witnesses to the events of the time might raise the following question, “How could Prandtl turn to Himmler, the very man who was held responsible for the greatest crimes of the Nazi regime?” This question could only be raised by someone who is not aware of the circumstances existing then. The historian Christian Maier has provided a much better answer to this question than I am able to give; one that draws attention to the credulity and guileless attitude of the Germans. A contribution to the understanding of this problem was made in a lecture given in Tel Aviv, which adopts a differentiated approach. I would like to quote from this lecture, with the title “Condemnation and Understanding”, which was printed in the *Frankfurter Allgemeine Zeitung* on the 28th June 1986.

“They (here, ‘some Germans’ is meant) were, it is true, from the very beginning, able to perceive a great deal of the wrongdoings of the Nazi regime, but were not able to foresee what immense, unparalleled crimes their country was on the way to committing. If one had prophesied the holocaust to them, they would not have considered it possible that such an act of atrocity would take place; not only because they were mostly brought up non-politically and with a particular respect for the state. ...When would a whole generation later be expected not to have seized their vocational opportunities, because in so doing they would have often been obliged to come into close contact with those in power? What would we, today’s generation, have done in such a situation? Only if we are certain that we would have done things better under the circumstances prevailing and with the level of knowledge at the time would we be in a position to judge the Germans living then - excluding those who committed offences or perpetrated crimes. ... We also have every reason to resolve to do things better; all the more so, because we know today what a totalitarian regime is and how such a regime comes into existence. But, there is no cause for us to pose as Pharisees in our much more fortunate position.”

I think it fitting for me to conclude this chapter with a conversation which took place in 1943. My father returned from a walk in the company of a good acquaintance. He said, “Do you know what Ms. X told me? In the east, Jews are being assembled and killed! Who could believe such

nonsense! In the last war, the French also told such tales of the Germans carrying out atrocities on women and children in Belgium.” My father’s character was such that he was not able to consider such a thing as being possible, or even conceivable.

20. Congress in America

On the 1st September 1938, Prandtl set off on a trip to America, in order to participate in a meeting of the Fifth International Congress for Applied Mechanics in Cambridge, Massachusetts. At that time, he was already 63 years old. He was accompanied on the journey by Professor Blenk, Dr. Schultz-Grunow, Professor Schlichting and many others also taking part in the congress. They met on the steamship Bremen to make the passage across the Atlantic. My mother used the opportunity provided by my father's absence to go to a health resort at Kissingen, after being strongly advised to do so by her doctor. There, she received the following letter from my father.

7th September 1938

“Up until now, the journey has gone smoothly and has also been stimulating. The ship is very nice, the food is fit for a king, and the company is very convivial. Every morning I go riding on a camel and a horse (both equipped with an electric motor to vitalise them) and then I go swimming. The weather has often been very good although, now and again, we have the odd misty day and experience a somewhat stiff wind in the golf stream. We expect to arrive in New York tomorrow at 2 o'clock. We will be brought from the landing to the hotel and then everything will be done for us, for the next twelve days. A hundred and thirty lectures are expected to be given at the congress: three being presented in parallel, at the same time. Even so, I think 43 are still too many...”

Having arrived in Cambridge, Prandtl also met some good acquaintances of his amongst the foreign specialists, such as, for example, Professor von Kármán and Professor G. I. Taylor, with whom he was able to exchange a few personal thoughts, amongst other things. An account of the conversations which took place in Cambridge, in 1938, are given in the biography of Kármán [15] by his co-author Lee Edson. The book was first published by the latter alone, after Kármán's death. But, in this, a careful distinction has certainly not been made between what was actually said and what Kármán read into the matter retrospectively, through his own interpretation of events.

Amongst specialists in the field who were familiar with Kármán's book "The Wind and Beyond", the view was held that this biography had to be viewed critically. Professor Blenk made the following comment at a meeting of those upon whom the Ludwig Prandtl Ring had been bestowed, on the 9th May 1972, "The autobiography of Kármán cannot make a claim to historical accuracy; a point which should be borne in mind by every reader of this otherwise interesting book."

Prandtl, who was asked by the Berlin ministry to make a recommendation for a congress in Germany, had agreed to present an invitation from the German government to foreign colleagues and hoped, in so doing, to continue to be able to cultivate a scientific exchange with other countries through friendly co-existence. The fact that thereupon, in Cambridge, lively political discussions took place amongst colleagues from different nations, triggered by the invitation which was made known by Prandtl, has remained in the memories of those participants who are still alive.

Professor Blenk wrote to Dr. Rotta on the 9th July 1987, "I remember well the tense, at times, very unfriendly atmosphere which prevailed at the congress between those participants from Germany and those from other nations. There were many separate discussions about the necessity or the probability of a second world war of which we Germans mostly did not see the necessity. At the same time, we defended the politics, but not the ideology or indeed the crimes of Hitler, inasmuch as such crimes were known at all at that time. What we justifiably believed we had to defend was 1. the repeal of the Treaty of Versailles; 2. the regaining of military sovereignty; and 3. the unification with Austria to form a pan-Germanic Reich. It is interesting to read what an historian such as Sebastian Haffner in his book *Anmerkungen zu Hitler* (The Meaning of Hitler) wrote regarding this complex of questions."

Prandtl also tried in discussions with foreign colleagues to defend his country against derogatory judgements of contemporary Germany. At that time, he believed, without being in the slightest critical, in the good intentions and uprightness of his government.

Men who, like Prandtl, had grown up in imperial Germany, in whose mentality loyalty was closely associated with patriotism, felt it necessary to

justify the political events at home to foreigners by defending their country against supposed revilement. This attitude could also be seen in his foreign correspondence.

Soon after the German group had taken its leave, looking back on these conversations, G. I. Taylor wrote, amongst other things, the following.

27th September 1938 (three days before the Sudeten Crisis)

“Now I must ask you to believe that, whatever happens between our countries, the friendship and admiration which I, in common with aerodynamical people in all other countries, feel for you, will remain unchanged. I realized that you know nothing of what the criminal lunatic, who rules your country, has been doing, and so you will not be able to understand the hatred of Germany which has been growing for some years in every nation, which has a free press.”

Of course, Prandtl later had to realise his political mistakes, which are referred to here by Taylor.

On conclusion of the congress, it was planned that the participants would visit the World’s Fair in New York, which was just in the process of construction.

During the crossing of the Atlantic, which the group of German scientists had undertaken aboard the American ship “New York”, the passengers received the news of Hitler’s imminent occupation of the Sudetenland, which caused the ship’s administration to carry out an evading manoeuvre, in order to avoid any actions associated with war. The boat set course for the Norwegian coast but, as the political situation had become calm again and the crisis had indeed been overcome, as a result of the Munich Agreement, the ship’s guests could be put ashore on German soil, although with some delay.

There therefore now appeared to be a confirmation that the assumption that the intentions of the German government were peaceful had been correctly judged and that the grave predictions had been justifiably repudiated. In a reply to Taylor, Prandtl gave him to understand that he had not relinquished his former standpoint; namely, of wanting to defend

the existing state of affairs in Germany. However, his arguments remained more or less incomprehensible. The fact that one year later there would be a state of war was something which Prandtl who, as I have already mentioned, credulously believed the news printed in the newspapers, imagined at that time to be impossible.

When, on the 1st September 1939, war broke out following the invasion of Poland, the most sorrowful thoughts stirred my father: This generation already knew enough about the horrors of war. “Work will carry on as before” was his laconic instruction to his staff.

The first winter of the war resulted in some restrictions being placed on the people of Göttingen. In February 1940, families were evacuated from Saarland, in order to bring them to safety away from the armed conflict with France. Those who were living on the large floors in our house were allocated some refugees; two or three people being allocated to each floor. We were assigned the family of a miner with seven members, who were divided between the three tenants. My mother had complete sympathy for their plight and made our large kitchen available to them for the evening gathering of the extended family. My father himself also occasionally took the trouble to find time to be present, in order to converse with them for a longer period of time. Other house owners, however, only moaned about the burden imposed on them by the lodgers. The families from Saarland remained about three months in their quarters, until they could return to their villages back home.

Our family was subjected to several reverses of fortune in 1940 and 1941. At the end of July, my sister’s baby died soon after birth. In December, my mother died. I have already mentioned the death of my brother-in-law, who fell at the end of July 1941 at Riga.

It was a difficult time for all of us. My sister no longer lived with our parents after she married, so that, following the death of my mother, only my father and I remained in the large flat. My father missed the loving care and the refreshing vivacity of my mother with whom he had done everything together. Now, it was often very quiet in the house. I continued with my studies of philology and, to the best of my ability, to concentrate on my courses. The household was well taken care of by a reliable young

maid. As for the rest, I tried to adapt to my father's habits, so that he did not lack anything in his daily life.

As was his custom, my father continued to go for a long walk at the weekend, during which I accompanied him. In the Easter holiday of 1941, we travelled together to our relatives in southern Germany, to Munich, as well as to his female cousins in Schleching. With the support of these loving people, we were finally able to distance ourselves from recent events.

The engineer Müller remembered a remark of Prandtl's made at this time, "You know, it is difficult to cope with such a loss, but life goes on; so we will continue to work". Work, once more, completely claimed his time.

21. The Ideological Dispute Amongst Physicists

Although Prandtl was, as he had always been up until this time, overwhelmed by work, in the spring of 1941, he once more took the initiative to make a decisive statement on the policy of the National Socialists with regard to scientific policy adopted at that time. His concern was to inform those in power about his position regarding the unfortunate dispute between two camps of physicists.

In the year following Heisenberg's rehabilitation, the battle between the supporters of the so-called "Arian physics", on the one hand, and those supporters of theoretical physics, on the other, became radicalised once more. The main constant assailants were Prof. Philipp Lenard and Johannes Stark, who succeeded on the 1st December 1939 in filling the chair of theoretical physics in Munich, which was originally intended to be given to Werner Heisenberg, with a person of their own conviction. As he was a specialist in aerodynamics, Prandtl was asked for his opinion. He formulated his opinion in a particularly clear manner: Wilhelm Müller is not endowed with a creative mind and giving him the position of a professor in Munich would be a wrong decision. He referred to the appointment as an act of sabotage against further technological advances.

Prandtl wanted to resist the power of this overbearing Nazi group. He prepared a written defence of theoretical physics, which was directly addressed to Hermann Göring in Berlin. One cannot appreciate today how much courage was needed in order to take such a step; namely, to openly tell the truth and, in so doing, pointing out to the NS leadership the inadequacies in their evaluation of knowledge about specialist branches of science and branding their faithful supporters as incompetents.

A colleague of my father at that time, the aged physicist Friedrich Hund, whom I recently met, turned the conversation to this subject. He remembered with great approval the courageous text written by Prandtl.

The letter sent to Reichsmarshal Hermann Göring, dated the 28th April 1941, reads as follows,

“Averting a serious danger to the rising generation of German physicists. To put the matter in a few words, it concerns a group of physicists who, unfortunately, readily gain the attention of the Führer Adolf Hitler and who storm at theoretical physics and denigrate the most outstanding theoretical physicists. They know how to succeed in filling professorships in a quite intolerable manner etc. and use, as a substantiation, the claim that modern, theoretical physics is a sham created by the Jews, which one cannot quickly enough eradicate, to be replaced by ‘German Physics’. I have described in detail what this is all about in an enclosure. It is, in any case, indisputable that theoretical physics is a necessary specialist subject, particularly in the training of leaders in physics belonging to the rising generation. At the same time, its task is to logically order the totality of physical facts and evolve the laws of physics with the aid of these. Then, the technical physicist can draw up novel constructions in a methodical way and calculate their validity in advance. Training physicists without regard to theoretical physics can produce good underlings, but never good leaders who have the necessary, clear overview of the whole field and who have mastered their subject.

What the members of the group of physicists led by Professor Lenard have in common is that they lack a keen, critical way of thinking on a mathematical basis. Since they are not able to critically evaluate work in the field of modern, theoretical physics, which requires a truly great mathematical ability, they are also in the dark about the indispensability of this specialisation. In contrast to this group are those really competent physicists who have the necessary mathematical qualification to be able to unanimously appreciate the necessity of theoretical physics. I would like to ask you, esteemed Reichsmarshall, perhaps on the basis of my remarks, to consult two well-known physicists working in industry, Professor Ramsauer, head of the research laboratory of AEG, and Professor Joos, head physicist of the Zeiss works, who, because of their stance, regarding the terrorist behaviour of the Lenard group are sufficiently independent. I myself would like, because one could object that I am not an expert physicist, to stay in the background with regard to this matter (as a passing comment, I would like to note however that, early in my career, I received a doctorate in physics and that, since then, I have always followed the development of physics with great attention, so that I cannot be accused of lacking the relevant knowledge of the subject!).

The group of ‘German physicists’ referred to, with their howls of protest that modern physics is a Jewish sham, not only has the attention of the Ministry of Science, but also that of the student leadership. As has already been pointed out, it is active in making wild attacks on the most meritorious and respected representatives of theoretical physics and is making the students of this specialist field become alienated. They have also recently succeeded in getting through a downright unbelievable new appointment, which can only be described as being completely senseless, unless one were to understand the ‘sense’ of the action to be destruction...”

As an enclosure to this letter, in which he finally also asked for the matter to be presented to Hitler, Prandtl attached an eight-paged paper on theoretical physics, in order to explain the scientific foundations. This is included in its entirety as an appendix to this book. Copies of this manuscript were distributed amongst the circle of physicists at various addresses. Here is one of the replies to his letter.

Professor Dr. Joos, head physicist at the Zeiss works in Jena wrote on the 5th May 1941,

“I have not had so much pleasure as that when I received a copy of your letter for such a long time! I finally have the hope that the danger will be recognised at the highest level. You have done a great service to physics, regardless of whether there is an immediate effect or not! By the way, I find the account of theoretical physics quite wonderful!”

Prandtl’s attacking petition became something of a signal. The physicist referred to in his letter, Carl Ramsauer, who was elected President of the *Deutsche Physikalische Gesellschaft* (German Physical Society), presented an extensive, cleverly written text to the German Reich Ministry of Education, in order to take action against the machinations of the favoured “Lenard group”. His arguments were respected and indeed produced results.

A. Beyerchen [7], who reported on the matter, wrote, “From the summer of 1942 onward, Göring’s organization supported the professional physicists against further political interference”.

22. Trip to Rumania

My father spent the period between the 29th April and the 14th May 1941 on a trip to Rumania, after receiving an invitation from Professor Valcovici, one of his former doctoral students. He was invited to give a series of lectures.

The following is an extract from his report. "Bearing in mind that the trip to Rumania would cause me to delay my work - some of which is quite urgent - I had some grave misgivings about undertaking this trip and feared the result would be that it would not be possible to make up the lost time."

Despite his deliberations, he started off on his journey on the 29th April 1941. The flight took him from Berlin to Bucharest.

He wrote the following to his daughter. "We are having a very comfortable journey flying over a charming landscape resembling white cotton wool, with towers of clouds distributed at irregular intervals amongst it. Above us is the blue sky. Now we can see mountains again, behind which the cloud cover is dispersed. Now there are no clouds and we can see the Elbe, mountains, Prague, a pleasant landscape, a dam with romantic castles, undulating land and long villages."

My father was met by Professor Valcovici at the airport in Bucharest.

"1st May 1941. Today is Mayday. All the shops are closed, but there are many street vendors selling flowers, oranges and similar things (they sit or stand barefooted on the pavement). The layout of the streets is not uniform. The government buildings are constructed in a European style and the business premises have an American design (7 to 10 storeys high). There are many wide streets. In the afternoon, at a time when people stroll along the streets, there are so many individuals around that one can only advance along the street very slowly. In addition, there are many cars on the roads (they have an abundance of petrol)."

Following his return, he wrote the report, which I have referred to, about this lecture tour. I would like to give the reader the opportunity to read a few extracts from this.

“My trip to Rumania, on the instruction of the German Reich Ministry of Science and Education, took place between the 29th April and the 14th May.

I gave the following lectures:

- 1) A general lecture on the subject of fluid dynamics to the mathematics and natural sciences faculty.
- 2) Three lectures each lasting two teaching hours to students on the subjects of ‘compressible flow’, ‘low viscosity, especially boundary layers’ and ‘turbulence’. All lectures were accompanied by numerous photographs and, during two of the lectures, a film was also shown.
- 3) A general lecture was given on the 9th May at the Technical University in Timisoara.

The 10th of May was the Rumanian national day (day of national unification) with parades of schoolchildren and military parades, which I attended following the compelling request of the Rumanians.

The lectures, which were advertised on posters and in articles in newspapers, as well as by invitation cards, were very well attended at both locations. Speeches were given beforehand in German: in Bucharest, by one of the deans of the natural science faculty and one by my former doctoral student Professor Valcovici.

Here, I would like to quote the words of introduction given by the dean, Professor San Jonescu.

‘Ladies and gentlemen, the faculty of natural sciences of the University of Bucharest has had the honour, up until now, of having two of the most respected professors as guests.

These guests were Professor August Sieberg and Professor Adolf Butenandt, whose extremely interesting discourses have left a lasting impression.

Now, Dr. Ludwig Prandtl, doctor honoris causa, director of the Kaiser Wilhelm Institute for Fluid Dynamics and professor at the University of Göttingen, has been so kind as to accept our invitation.

Professor Prandtl will give a number of lectures on his specialist area of research during his stay in Bucharest.

Today, the subject will be fluid dynamics. Dear professor and colleagues!

Your lecture is not only of interest to mathematicians and engineers, but also to us biologists, since the same principles and laws that govern movement in inanimate nature also govern many life processes in animal and plant bodies. Moreover, I could indeed assert, when all is said and

done, that these principles may also be applied to the settlement and establishment of parts of a society or a nation. Therefore, I am convinced that your important discourses will be listened to with great attention from the auditorium. As dean of the faculty of natural sciences, it is my task to draw attention, with a few words, to the need for ever closer scientific collaboration between Germany and Rumania. As I have frequently said on such occasions and would like to re-iterate now, with equal conviction, collaborative research between different peoples and nations will, in the first place, draw them together.’ ”

Report on Timisoara

“In Timisoara, there were both secular and religious dignitaries present; amongst others, the orthodox bishop, who afterwards also came to the reception and expressed to me his pleasure about what he had heard and seen.

Professor Valcovici took care of me during my stay in Bucharest in the most obliging manner. He took me around the city and the university and also to his own quite large institute for pure and applied mathematics. In the afternoon of the 1st May, he organised a tea party in my honour in his charming house, at which a large circle of ladies and gentlemen gathered. In my estimation, this was the best circle of Bucharest society (very many university teachers, various former ministers and Rumanian officers). In addition, the German embassy was represented by Prince Solms. The gentlemen of Timisoara also took very good care of me. I was received at the railway station by the dean and a few professors, as well as also by a group of ethnic Germans. They accompanied me to a small guest-house, because the large hotels were all occupied by the German armed forces ... one sees many German (military) personnel and also officers on the streets and in the public houses.”

“The streetscape of Bucharest gave no hint of uneasiness of any kind. But, it is said that much is hoarded. The provisions available in the local restaurants - even beer and wine - which is produced in the country itself, are very good and also sufficient to satisfy the highest demands. Days without meat were introduced, but ham, smoked tongue and similar items were not counted as being meat. Also, because of the scarcity of flour, one had to fall back on the remarkable alternative that only old bread rolls were

allowed to be sold (of which, naturally, fewer were eaten than fresh ones). In addition, two maize bread days were introduced.

On talking to Rumanians, great sorrow was often expressed that they had to give up a number of parts of their country and, above all, it was stressed that anything would have been more bearable than having to have given up such a large Rumanian population to Hungary (in 1940, as a result of the second Vienna arbitral award, an area in Siebenbürgen which Hungary lost in 1920 was taken back with a million inhabitants). It was hoped that, as a result of resettlement, another solution would be found. On the return journey through Hungary, I had a conversation with a Hungarian from the area which was returned to Hungary who, for his part, was, of course, of the opinion that the remaining part of the former Hungary should also be returned to Hungary.”

The return journey by train enabled Prandtl to stopover in Budapest and Vienna. On the 15th May, he returned very tired indeed to Göttingen.

On the 10th November 1942, Prandtl was awarded an honorary doctorate by the University of Bucharest.

23. The Last Years of the War

I would like, at this stage of my account, to devote a few words to my father's attitude to honours and awards.

Those who think that, because Prandtl also received honours and prizes from the NS government, he had very close ties with the Nazi regime would not be able, on the basis of their suspicions, to convince those who really knew Prandtl very well, whether these be colleagues, scientific collaborators or friends. He placed no particular value on these honorary diplomas. They arrived at the house and were simply put in a drawer without him ever mentioning anything about them.

This is illustrated by the following example. A prize was created for students who excelled in making model aircraft: the so-called "Ludwig Prandtl Prize". The prize was awarded annually to the best young designer and the sum of RM 3,600 was given to the winner. However, no mention was ever made of the prize at home. It was only from other sources that I learnt anything about the award. "Your father has become very popular with the people of Göttingen as a result of the Ludwig Prandtl prize, which is awarded every year. Didn't you know that? There was a report about it in the newspaper."

To advance research, independent of the political situation in Germany, was essentially the only driving force behind his work. In addition, at that time, it was dear to his heart to finally conclude a great piece of work. In 1942, the third enlarged edition of his textbook *Abriß der Strömungslehre* appeared, which was published with the title *Führer durch die Strömungslehre* (Essentials of Fluid Dynamics) by Vieweg-Verlag [27]. This title was later kept by his former students Prof. K. Oswatitsch and Prof. K. Wieghardt, who produced a revised, extended edition.

Despite the ever increasing range of duties which took up his time, he did nevertheless remain the same unassuming, benevolent person who was always ready to devote his energy to a good cause. One example will suffice to illustrate this. Despite all the tasks taking up his time, he took care of a doctoral thesis of one of his students who was at the Russian front. The following texts are replies to Prandtl from that student, Hans Böhm.

17.1.1943

“Dear Professor,

I have just returned from guard duty. It is a wonderful, starlit and moonlit evening. It is an evening such as can be only experienced in Russia, and one which made time pass by and really set my thoughts in motion. I read your letter again and I am very pleased indeed with what you wrote. Your book is now finished and you have promised me a copy! You can believe how pleased I am about this. I would like to ask you to send the copy to my home, as I will finally have leave from the front at the beginning of February. I will then bring the book back with me to Russia. It will be something different to take out of my kit bag.

You want to read my dissertation? This is the thing which has pleased me the most, since I am sure you know how much it means to me. You want to revise the text. Hopefully, there will not be too much to correct. I often think about what I could have done differently. But, it is only afterwards that one realises one's mistakes or becomes aware of improvements which could be made.”

2.2.1944

“The constant tramping and the unsettled life on the front have prevented me from replying to your kind letter and I now hasten to thank you for the trouble you have taken regarding my query. I can hardly venture to think of success and I am very much waiting for a decision...

Yours, Hans Böhm”

In 1943, my father wrote in several letters about his trips to Berlin, where he frequently visited the central office of the Kaiser Wilhelm Society, as it was preferred to reach decisions on the basis of personal discussions. On the 4th March, while he was in Berlin, there was an air-raid. The path to an air-raid bunker via an unlit staircase proved to be fatal for him. He fell, hitting his head, and received a head wound. He was taken to a doctor, who had to sew up the wound immediately without the use of anaesthetics and then apply a head dressing. When he came back to Göttingen with his head in a bandage, we were at first alarmed. But, he simply laughed and said that everything was okay, and that we should not worry now about seeing him with his head in a bandage. However, he had a certain satisfaction from the fact that the doctors, after having stitched the wound,

told him that they admired his bravery; especially they as they had not expected this from a man of his age.

Despite his advanced years, he was still active at work. His motto was to invest just the same amount of effort in his work to advance science as he had done up until that time, even though there was a constantly increasing uncertainty about what would happen in the immediate and distant future.

We still had to survive the last few months of the war. There were frequent air-raid warnings at night. Although Göttingen remained substantially spared from destruction, the many hours we had to spend at night in the cellars brought great unrest to our lives. In November 1944, the first bombs fell in the town and from then on, the rule that when the alarm was raised everyone was expected to go immediately to the air-raid cellars was taken seriously, of course. Each new attack provided a reminder of the seriousness of the situation.

With the optimism of youth, not carefully reflecting on the uncertain trends of the time when encounters appear to be fateful, my college friend Helmut Vogel and I decided to enter into a firm commitment. We married in 1944. Even during the engagement period, a warm relationship developed between the father-in-law and his son-in-law. An equally friendly relationship soon developed to my future husband's mother and his sister, a very talented painter, who both often came to visit us from Bremen. I can still picture in my mind's eye my mother-in-law and my father sitting at the piano, as they practiced a piece of music for four hands. He valued the merry cheerfulness and worthiness of the woman from Bremen, who had such sympathetic understanding for each of us.

An impression of how immediately my father could comprehend music is shown by a note on a piece of paper. He quickly wrote down the notes after hearing the music on the radio, in order to retain the whole phrase in his memory.

In the last year of the war, 1945, one did not travel much. When Prandtl celebrated his seventieth birthday on the 4th February 1945, only a few people came to congratulate him and offer their personal best wishes. I remember that Prof. F. Schultz-Grunow could not be kept away by the

circumstances and dangers existing at that time from coming to congratulate my father, who greeted him with cordial surprise.



G.F. Händel, Concerto grosso
G moll, 3. (?) Satz.

*M. Erachtens das schönste von allen
Concerti grossi!*

*16.4.44 im Rundfunk
gehört. P.*

G.F. Händel, Concerto grosso

G minor, 3rd (?) movement.

In my view, the most beautiful of all
of the Concerti grossi!

16.4.44 heard on the radio. P.

Many former students and colleagues honoured their former teacher with a Festschrift (commemorative publication) [51] which contained twenty specialist contributions from the fields of applied mathematics and mechanics. Due to the circumstances of war, the volume could first be distributed only at a later stage. The introduction to this volume was written by Prof. W. Tollmien, Dresden. Because of the constraints of space, I can only include an excerpt here.

“With respect and affection, we come to remember, on the 4th February, a man who has truly made a mark on this epoch, as a result of his influence on the long and glorious history of mechanics. On this day, Ludwig Prandtl has reached the age of 70...

Prandtl's work would not have developed in such a brilliant and consequential manner if he had not been able to kindle a similar demand for sacrifices and passionate dedication to research arousing his own passion for science, in such a large number of students and collaborators. It was not the ingenious 'apercu', but the systematic clarification of a whole complex of questions which was his aim and which could only be achieved by the creation of his own school. To the many doctoral students whom he supervised throughout the years, numerous co-workers were added with the increasing expansion of the Göttingen institutes who, through personal contact with Prandtl, benefited from his encouragement. At the same time, Prandtl deliberately avoided, in the most careful manner, inhibiting the development of future researchers through the greater strength of his scientific personality. A sensible question would be raised which, it appeared, might be answered on the basis of the current state of research and some possible solutions were proposed for discussion. Then, with the patience of the true educator, he would allow the individuality of the student to unfold whilst, at the same time, he stood by when inevitably great difficulties arose in the solution of scientific problems to provide encouragement and advice, and help those who had reached a state of deadlock by providing renewed encouragement. The demands that Prandtl placed on scientific work were very high and true to the traditions of the *Georgia Augusta* (Georg-August University). In return, a brief word of appreciation coming from him was the highest reward that a young researcher working under him could be granted. Those who, like the author of this article, had the good fortune of working for a time at one of Prandtl's institutes will look back with gratitude to the intellectual community who were united by their service to the enterprise and honouring the person of the master.

Without contradiction, but also without any envy, Prandtl has been recognised by the whole professional circle as being the leading researcher in the field of mechanics for a quarter of a century. No less astounding is the fact that, after such an enormous achievement and on the threshold of his eighth decade, he had not taken his leave from engaging in active scientific research. On the contrary, in the last few years of his life, Prandtl had taken on, in scientific organisation, new executive functions for research in his country and he did not rest from carrying out his own pioneering research work.

What better wish could we, his colleagues and friends, have on the 4th February 1945, both for ourselves, as well as also for the celebration of a jubilee, than that his creative power will remain unweakened for a very long time to come!”

Professor J. Ackeret (ETH Zurich) also wrote an article for the same occasion [2]. I would like to present an excerpt from this.

“Prandtl has enriched technical mechanics by giving it quite a novel, new course. ...

When talking about research, the layman normally has in mind a jumble of complicated equipment and expensive instruments. However, Prandtl made his most important discoveries using apparatus that was astoundingly primitive. The boundary layer theory which, at a stroke, eliminated the impossibility of finding a mathematical solution to flows with viscosity was discovered by Prandtl using apparatus which had cost maybe 40 francs and was operated by hand. How right he was when he said to his co-workers on one occasion, ‘Such a telescope is indeed quite useful, but what is more important is the man who looks through it.’ ...

Before Prandtl, hydrodynamics and aerodynamics were in a state of early fossilisation. It seemed as if nature had become entrenched behind a wall of mathematical difficulties. Making constant first steps with experiments, Prandtl was able to find the way out of this abyss. With an unbelievable feeling for the essential, he was able to peel away the generality of the problem, so as to leave behind the essential core, and the mathematics were then just sufficient in order to solve what remained in a precise and neat way, producing results that could have a practical application. ...

His wealth of ideas was, from time immemorial, so great that he could branch off in many directions at the same time without him having to fear losing his sense of priorities. Prandtl’s work can only be appreciated in its entirety when that of his numerous students throughout the world is also taken into account ...

... Those, however, who had the good fortune to be able to learn and work in his presence will not only have a picture in their mind’s eye of the great researcher, but also a modest, extremely kind-hearted man and fatherly friend. ...”

In the journal *Luftfahrt-Forschung*, an article with the title “Ludwig Prandtl is 70 years old”, was published [19] without naming its author, from which the following is quoted.

“On the 4th February, Ludwig Prandtl, who is not only the most famous and successful scientist working in the field of aeronautics, but who for some years now has also been its organisational leading figure, will celebrate his seventieth birthday. Even if, in view of the circumstances in which we find ourselves and the wishes of the celebrant, the celebration will take place in a more subdued manner than would be considered appropriate in peace time, it will nevertheless, for all members of the aeronautic research community, be a day on which one may pause a moment, in order to bring to mind those decisive ideas which he was able to give to the young science of aeronautical technology. The fact that Prandtl has passed biblical old age but is still active in research ... is a source of joy to all of us ...

One would have expected that when Prandtl had reached the noble age of 70, he would have passed on the duties of professional life to younger shoulders, in order to be able to devote his time more intensely to his favourite occupations, or to solve those problems which had proven to be particularly hard nuts to crack and which had been left to one side earlier. He would also have gained time for all of those who had a special need to turn to the most experienced specialist himself, or perhaps to once again unearth – together with him – the ideas which had inspired him on the genesis of his theories and which today, labelled with a famous name, are sometimes used more as a catch-phrase than expounded with the deepest understanding. Despite the burning interest of all nations pursuing aeronautics, Prandtl has remained the leader throughout the decades in the further refinement of his theory pronounced in 1904. In addition, he solved numerous questions related to aeronautics and which had no direct link with the boundary layer theory. I only need to mention the airfoil theory and the profile theory at high subsonic speeds, the so-called Prandtl’s Rule, in this context...

Besides this, he worked on his textbook which appeared in a revised third edition with the title *Führer durch die Strömungslehre* (Essentials of Fluid Dynamics). Even though Prandtl placed no great demands on the educational background of the reader, he did not allow himself to stroll along bypaths which would only lead to a limited level but, instead, he took

paths that would provide the reader with access to the highest level. His illustrations and comparisons also captured the interest of more advanced students of the subject, just as much as did his lectures; particularly, when he digressed or went off at a tangent, many times offering more to advanced students than beginners in the field. He always endeavoured to generate acuteness in concept formation and a critical attitude in others.

His success was often based on the fact that he carried out his experiments in a playful manner, going beyond the limits defined by the technical question under discussion. In this way, using quite simple equipment, he frequently divided a non-transparent process into its component parts, making use of careful observations and his tentative, forward-directed mind. When, on the other hand, it was unavoidable that a laborious experiment had to be carried out in short steps, he would, if possible, free the technical task of all contingencies and deal with a related ideal case which appeared to offer a more accessible theoretical explanation later. In other words, he separated the technical requirement from the gap in the set of physical dogmas and made greater efforts to close the gaps, instead of investigating each technical procedure. The same basic principle of serving the general whole in an unselfish way instead of the - perhaps better rewarded - particular case is again found in his entire way of living. Although he was a renowned specialist in his field, his personal wishes remained simple. He remained faithful to the small university town of Göttingen, and one can only speculate about how many conversations took place on the pleasant, common ways home in this town, which are unfamiliar in a large town or city with their time-consuming traffic problems. He was able to determine who would obtain professorships, but he only intervened when this was asked of him and instances in which it was feared the wrong person would get the job. This attitude also bore fruit. His research institute existed, in the most difficult of times, not only from its monopoly, but essentially also from the standing which the unselfish readiness to help on the part of Prandtl and his co-workers had secured for it.”

In addition, Professor A. Betz wrote an article entitled “Ludwig Prandtl on his 70th birthday” [6], on the same occasion, but which first appeared in April 1947 in the journal *Forschungen und Fortschritte*. I would like to quote a paragraph from this work.

“Prandtl always aspired to gain real insight into the task he was currently considering, so that he almost always achieved his objective of truly understanding these processes and was able to reduce them to the basic laws of physics. Moreover, Prandtl possessed the capacity to be a wholeheartedly accepted leader for both co-workers and those outside this circle and, in this way, was able to influence the whole scientific world by giving it direction. The exceptional clarity of his thought and his unselfish dedication to his tasks, free from every self-interested thought, are the foundations which made this way of working and the achievement of great success possible.”

24. The End of the War

Our first daughter Agnes was born a few months before the end of the war. My father watched her develop with the greatest of interest. When he came home, he never forgot to see how she was and he always watched her characteristic movements attentively. He often sat next to her with his sketch book and drew her tiny head. He also tabulated her weight, to watch her growth. My husband was only able to share in the joy of seeing her developing when he was home on leave from the front, so that my daughter's grandfather partly assumed his role. He wrote to my sister in Munich, "The little one gives me so much pleasure, because of her liveliness and understanding and her trusting nature."

It was now the last phase of the war. We occupied only one of the three large rooms, in order to save fuel. Of course, my father could not give up playing the piano, so we managed to move it into his working room, which had been furnished as the living room. Hardly a day passed without him sitting at the piano, with melodious tones coming from the beautiful instrument. All, of those who had the pleasure of hearing Prandtl play listened attentively, moved by his musical inspiration. Once, when he played quite special harmonies, which flourished melodiously in different keys, we started to express our approval. He dismissed our applause and just said, "I simply just played for my dear Gertrud."

The war was coming to an end. As the front formed by the enemy troops advanced towards Göttingen, the district administration planned to blow up all of the institutes of natural sciences in the town. In order to prevent this, some professors who had a sense of responsibility regarding the matter decided to initiate a discussion with *Gauleiter* (district or "gau" director) Lauterbacher. They were united in holding the view that it was necessary to meet with him to hold negotiations. But, there was also another reason why Göttingen was in a particularly critical situation. In the course of the war, the town became filled with casualties, as 24 hospital units were established which could not be evacuated. The mission to persuade the *Gauleiter* is documented in the book, *Göttingen 1945 - Kriegsende und Neubeginn* (Göttingen in the Year 1945 - The End of the War and a New Beginning) [11].

“Professor Plischke went, on the afternoon of the 31st March 1945, in the company of Professor Prandtl and a colleague from Königsberg, Professor Baumgarten, as well as the Göttingen lawyer Dr. Beyer, to Lindau near Katlenburg, where they met Professor Osenberg from the Technical University Hanover, who was the head of the Four-Year Plan Institute of Production Processes. Together with Osenberg, they travelled on the following morning to Rothenkirchen near Einbeck to meet with the *Gauleiter*, but were first able to meet him at midday to tell him about their misgivings regarding the defence of Göttingen and the resulting consequences. Lauterbacher promised to contact the *Reichskanzlei* (Chancellery of the German Reich) about the statement that Göttingen, as a town with a strong tradition of research, should be saved from becoming a battle area.”

As the gentlemen met with the district director, immediately on their return, he had already received the instruction not to cancel the order to destroy. The professors were denounced by him as liberal defeatists. I remember that my father came home looking very tired and taciturn from this undertaking.

However, as a result of the initiative of some courageous citizens of Göttingen and wise civil servants in the town administration, the handing over of the town without a fight was finally achieved.

April 8th was a glorious Sunday and a day which still remains fresh in my memory. We had finally received the instruction to stay in the cellar. Previously we had been told we would have to assemble, with the other citizens, in the open air away from the town. On the evening before, a woman who also lived in our house, Frau E. Oesterheld, who had fled from Berlin a while ago, came to us. She made a note of this visit to Prandtl, on the day before capitulation, in her diary.

7th April 1945

“He was in his study, which showed no semblance of comfort. It was austere and was furnished like an office, with large filing cases on the walls. Only a large piano and several good oil paintings gave any elegance to the room. He sat at the table, which was covered with a wax cloth cover, having just listened to the news on the radio. His expressive, venerable,

scholarly face was filled with sorrow and concern. I told him about the instruction from the party that the women and children should assemble in the morning at 5 a.m. at the Rohns and asked him what advice he would give. But, I did not receive a straight answer to my question. He was obviously overwhelmed by the events which now followed in rapid succession and felt completely unable to make a decision for himself or others. His daughter, Frau Vogel, came in and we finally decided, after weighing up one alternative and then another, not to join the evacuation of women and children, but instead to stay in our air-raid shelter and wait in resignation.”

E. Oesterfeld reported the following about the events of the 8th April. “Alarms signalling the approach of the enemy could be heard around midday. All the occupants of the house went to the cellar. We sat there a long time in anxious expectation, without anything happening. Had the town indeed capitulated without a fight? Suddenly, the silence was broken as the house shook and the windowpanes crashed down. The shaking continued and the breaking of glass could be clearly heard. Suddenly, silence reigned again. Professor Prandtl said, ‘I will go upstairs and see how things look. If anything should happen, I am already an old man, so you don’t need to worry about what might happen to me’, the professor said in his typical modest manner.

But, he did return. ‘It looks pretty bad. It is a good thing that you did not remain upstairs, otherwise you would have all been buried in the rubble’, he said to the family that lived on the second floor. ‘Apparently, it was a grenade which must have first struck the gable. The whole staircase is lying under debris.’”

Although it had become quite quiet again, because of the shock, we still remained sitting a long time in the cellar. From this vantage point, we were able to observe the incessant rolling by of the tanks through the window directed towards the ground. Did it mean that, for us, the war was over? We considered that occupation by the Americans would mean we had struck lucky. We gained our courage once more and went back again to our home, to prepare a meal.

For my father, the walk to work on the next day was of great importance. He did not tell me about what he experienced on that day and the day

after. He was mostly silent and withdrawn. His wife and companion was not there as the person he could turn to, to recount his experiences.

Only very much later did I come to know, from the accounts of others, that the Americans had, before they occupied the institute, required all the scientific results which had been kept secret during the war to be handed over.

The institute was then taken over completely by their authority. For a number of weeks, my father was prevented from entering his institute. But, there was an occasion in the first week when his presence there was needed. He was picked up from home and requested to climb into an open military vehicle. He was escorted by six American soldiers. Our neighbours, who had observed this event, asked with concern where the professor was being taken to. After a few hours, he was brought back in the same vehicle. My father recounted the events of that day in a publication from 1949 [5].

“One morning, I was taken to the AVA site in a personnel carrier, escorted by armed soldiers. The officer in charge of the soldiers, a Jewish officer who spoke German, wanted a statement from me about what could be found on the site. He was initially extremely disappointed about the account I gave him. He asked me about the airplane motor models which he claimed we had built in Göttingen. I had to tell him that we had only carried out studies to find the best designs for individual parts; for example, air compressors.”

During the first weeks following the surrender of Göttingen, my father and I spent a great proportion of our time taking care of basic necessities; in particular, ensuring that we had enough food. This was indeed very time consuming. In order to buy bread, for example, which was rationed, we had to make our way to the market as soon as possible after 6 a.m., when the curfew ended, because bread was always sold out by 8 a.m. My father frequently made this journey alone, so that I could take care of my little daughter. Our domestic help had already returned to her village before the occupation by the American troops. In order that we could carry on with running the house, we needed to do things together. As there was neither gas nor electricity and we urgently needed firewood, I picked up our first supplies of wood from the nearby woods of the Hainberg, using a

handcart. Each person had their own problems, so no-one concerned himself with the problems of others. All households had to meet the same shortages as we did and were troubled by the exceptional amount of time and energy needed to fulfil basic requirements. The logs were sawn in the courtyard, with both of us sharing this arduous work.

Some relief from our discomfort could already be felt in May of that year, as the period of curfew was reduced and regular supplies were reaching the stores. Nevertheless, the atmosphere was still tense. In June, the mayor of Göttingen, Mr. Schmidt, wrote to the military administration, which had suggested setting up loudspeakers throughout the town, in order to make announcements to the inhabitants. "People are in too much of a hurry to listen attentively to the news or to read announcements nailed to the wall. Just waiting in a queue in front of the shops takes up several hours every day of a housewife's time."

We received an unexpected visit from Professor Nikuradse, who had told us that he would arrange a cartload of wood for us. Indeed, the wood appeared the following day. A little later, some young people from the KWI who were not busy came to us and sawed up the timber. The amount of firewood which we stacked up in the courtyard was quite considerable.

Continuation of the research in aeronautics, which had been carried out up until then, was strictly forbidden. But, instead of resigning himself to his fate, Prandtl now occupied himself with problems in the field of meteorology. Meteorology had, indeed, been one of his special interests for a long time. He used the time he now had to spend at home to carry out intensive work on this subject. Now and then, colleagues came to visit him, in order to tell him what was going on and to discuss the possibilities of making a fresh start with him.

Ministerial secretary A. Baeumker was also amongst the visitors. They had a lively discussion. The guest made do with having a soup at midday in the same room where the soup had been prepared on a stove. Baeumker, who was an aircraft observer in the First World War, then a representative at the disarmament conference in Geneva and later the official responsible for research matters with reference to aeronautics, had a great deal of

organisational experience. Now, he was preoccupied with plans for the distant future of the *Gesellschaft für Luftfahrt* (Aeronautical Society).

Matters related to things happening at the institute in the spring of 1945 were narrated in a comprehensive report by A. Betz and L. Prandtl, which was published in 1949 [5]. Here, I would like to quote a few extracts.

A. Betz: “An important event was the visit of Professor v. Kármán to the AVA on the 14th and 15th May in the company of a number of distinguished researchers. This provided the first opportunity of raising the question of making the institute accessible again to its directors and staff. As research work was forbidden as a matter of principle, v. Kármán saw another opportunity of occupying the scientists once more. He suggested they write reports about the results of their research work during the war, in the service of the occupying power.” These monographs were later translated into English.

L. Prandtl: “There were now frequent visits by American specialists, who requested that I show them my special institute, building No. 3, and tell them everything about it. ... I asked them to intervene on my behalf to obtain permission so that we could move freely once more in our own institute rooms. However, the situation remained that we were only allowed to move around the institute in the company of armed soldiers.”

I was later told about how Prandtl characterised the absurdity of the situation in which he found himself. He remarked, with a smile, on the soldier who was ordered to constantly accompany him with a machinegun, “Maybe the soldier is afraid of me?” The soldier replied in an embarrassed manner that he was only following instructions.

Prandtl: “The visits by scholars and specialists in the field increased constantly, and I had the feeling of becoming more and more a kind of museum attendant who was required to talk about the same things using virtually the same words every time (and, of course, depending on the circumstances, repeating the same little jokes).”

According to a statement made by an employee, one day, documents which a young scientist had buried at a secret location were searched for. He was

very consternate and, indeed, had every reason to imagine the consequences if the military authorities were to obtain a confession from him. "I take full responsibility regarding this matter of the documents", Prandtl said to him, "Don't worry, they won't eat me up as easily as they would you".

Professor Betz was equally frequently called to conduct tours in the institute, to answer questions or give explanations.

Betz wrote, "The questions raised during these tours frequently gave an insight into things which, for us, were quite astounding. For example, most Americans could not appreciate that we had essentially carried out basic research. Even the great problem of obtaining staff and materials during the war was frequently not understood by them. We were repeatedly asked the question of why such an important installation as the large icing tunnel was never quickly completed.

Other questions indicated an astounding lack of knowledge about things which had already been well known for a long time in Germany, although one had the impression that the person asking the question was a competent scientist. The question was repeatedly asked why we constructed swept wings and this required long and detailed explanations before the advantages of this form of wing on approaching sonic speed were appreciated. Now, swept-back wings are claimed to be an American invention!"

Prandtl was very pleased when the occupying forces allowed him, after a ban lasting eight weeks, to enter his institute again on a regular basis. However, it was insisted that a pass was issued to him for the time of starting work and another for the time of finishing work. This was a grotesque demand to be placed on the director of the institute! One day, Prandtl asked innocently, "Would it not be possible for me to have a pass that was valid for the whole day, just like the institute's office-boy?"

On the 8th June 1945, he told my sister in Munich, "In my institute, work has now restarted with about one third of the number of people and at a much lower level than before".

Some of the young, talented scientists soon found a new job in America or England, where they were offered very good possibilities of continuing their research work.

I would like to mention one more, small incident related to this time. Each week, at that time, a loaf of bread would be handed out to the staff of the institute. This “institute bread” tasted especially good, according to my father. Each day, he placed great value on being able to take a slice of it, which he ate in a state of meditation. Of course, he also shared it out. But, I also noticed that it put him in a particularly good mood when the bread was placed in front of him on the table. It was certainly not the idea of having plenty of victuals which pleased him so much, but much more the thought that this “institute bread” had a certain symbolic importance for him. After having been locked out of the institute for many weeks, it was a quiet pleasure to be able to work once more in his spiritual home, the Institute for Fluid Dynamics, even if this was under difficult circumstances.

Prandtl gave a detailed account of what was taking place at the institute to his English colleague G. I. Taylor.

28th June 1945

“My institute was able to survive the war intact, but then suffered much damage as a result of the American soldiers being billeted there for a number of weeks. Since the beginning of June, we have had access to the institute again. What we are allowed to do is laid down by the allied commission. We may carry out repairs and write reports, which the allied commission insists on. We may also work once more on a number of assignments which were not completed during the war and about which reports are also expected. We have not been allowed, up until now, to start on new projects. But, we still hope that we will be able to resume the basic research which we had to increasingly postpone during the war and of which we have enough, at present, to occupy us for a decade.”

Prandtl wrote the following on the 10th October 1945 to Taylor

“Every kind of resumption of our research work has been forbidden by the Director of Scientific Research in London. For a research institute whose function is to further and promote knowledge about its area of research with all its strength, this is a very hard demand. There are still many

problems waiting for a solution: on the one hand, in the area of turbulence research, on the other, in the field of flows close to sonic speed. Questions related to meteorological and oceanographic flows, in which, on the one hand, density stratification and, on the other, turbulence processes play a substantial role, belong to this category.”

Although the further development of scientific research was completely excluded by the strict measures taken by the military authorities and the sphere of influence of Prandtl himself was also reduced, his international importance, nevertheless, continued to flourish unchallenged. A Chinese woman who had carried out her doctoral research at the beginning of the 1940s, supervised by Prandtl, spent a few months again in Göttingen at the end of the war, which she survived in Berlin, despite the difficult times, in order to ask Prandtl for advice regarding her future research work. Lu Hsin Chen then returned to China, where she later became a professor of aerodynamics in Peking. She once said, looking back on the time spent in Göttingen, that Professor Prandtl had looked after her with as much kindness as a father. The living memory which she retained of her respected master had moved her to visit his grave in Göttingen, once more, with her husband. We stood together before it. She bowed three times reverently before the deceased, in a manner in which the Chinese show the greatest respect for their ancestors. In 1984, she sent me her translation of the ‘Essentials of Fluid Dynamics’ in Chinese. In an accompanying letter, she wrote the following:

16th November 1984

“As a colleague from my institute is going to Göttingen to collaborate in research with the DFVLR, I have asked him to give you this book. It is my translation of the book *Führer durch die Strömungslehre* (Essentials of Fluid Dynamics) written by my highly respected teacher Professor Ludwig Prandtl. I took on the task of translating the book in memory of the greatest teacher world-wide in the field of the fluid mechanics.

Lu Schang (née Hsin Chen).”

25. A New Beginning at the University

Already in July 1945, great efforts were being made to restart teaching activities at the university. Because of the process of denazification ordered by the military government, a number of former professors were dismissed, so that only a fraction of university teachers were now available to contribute to the new beginning. (In the War Diary of the military government in Göttingen dated the 8th August 1945, it was noted, “Of the 60% of university professors who were dismissed, none lodged a protest”.)

There were, of course, many other difficult problems to be solved at this time; for example, the preparation of authorisations for the admission of students, the refitting of the students’ dining hall and measures to ensure adequate accommodation for students. So, an appeal was made to the inhabitants of the town to give up rooms that were not essential for their own needs. Since there were only three of us living in our flat at the time, we also notified the authorities that we had two empty rooms which could be used as “students’ digs” and we put up with the disturbance caused by the intrusion of these young people in circumstances of hardship. Soon, there was not a single house in which there was not at least one student lodging in the garret.

On the 17th September 1945, preparations had reached a stage at which the Georgia Augusta became the first university in Germany that was able to open its doors once more to students. The British military government had limited the number of students to 3,500. However, this number was soon exceeded, as it was decided to also allow those discharged from military service after the war to start studying.

Although Prandtl was now seventy years old, he still gave lectures, just as he had before. Generally, the studiousness of the students was benevolently acknowledged. The atmosphere in the town had changed within a matter of a few weeks and a new spirit of freedom could be felt, despite the presence of the occupying power.

In 1946, the journal *Neue Physikalische Blätter* announced, “The *Georgia Augusta* is, with 4,775 students matriculating in the summer semester, the leading German university”.

Now, when the whole truth had become known, Prandtl, who was deeply affected by all that had happened, tried to come to terms with the events of the recent past and decided to put down in writing the understanding he had gained in the process; especially regarding future possibilities of scientific research. He wrote a letter to the Education Officer, Mr. Bird, to whom he wished to convey his thoughts on these matters. He gave his text the title "Thoughts of a non-political German concerning denazification".

I am sure the reader will not mind me repeating that Prandtl himself turned down any form of membership of the party and therefore was in no way incriminated or burdened when it came to making a new start. But, in keeping with his character, he could not be indifferent to the plight of those who were condemned, without exception, solely on the basis of party membership and who had shown neither a political interest nor were active participants. In accord with his invariably humane attitude, he considered it to be necessary to give the occupying power an informative explanation of the emergence of the NS and the mechanisms of the NS state which subsequently developed. Because of his statements, it was perhaps possible to achieve a more favourable judgement in some cases in which guilt was attributed.

Since that time, there have been many publications on this theme. They have, above all, preoccupied us Germans, even now and to an increasing extent, although in the meantime 40 years have passed.

The following letter was written on the 14th March 1946.

"Dear Mr. Bird,

At your suggestion, I have written a text about the question of denazification, which may be suitable for publication in an English newspaper.... If you feel that a discussion is needed about any of the points raised in my text, I am at your disposal, at all times.

Yours sincerely,

Ludwig Prandtl"

The text reads as follows.

‘The Thoughts of a Non-political German on the Subject of Denazification

Preliminary Comments

The question of the future political development of Germany and, in particular, the best way of eliminating all of those elements that could interfere with this development currently occupies very many minds in this country. The author of this text is a professor at a German university, an engineer and physicist, and one who is well known amongst specialists in these fields in England. I am more than seventy years old. My age and a life filled by scientific work protect me from the suspicion that I might be an extremist of any kind. What is more, I have never wanted to play a role in politics, but have simply wished to try to form a judgement on the basis of the sources available to me.

The Situation in 1932

As a consequence of the Weimar Constitution, the German parliament was elected on the basis of ‘German Reich lists’, which were prepared by the individual parties. This meant that there was an enormous fragmentation into small parties, a process which was, on the whole, repeated with almost the same intensity when new elections took place. A majority could only be achieved through co-operation between parties whose programmes differed greatly from one another. The resulting governments therefore rested on a very weak foundation and had to be helped to move forward through making compromises. It can therefore be appreciated that they could not deal with the problem of ultimately seven million unemployed, to which were added about a further seven million short-time workers. Moreover, the rural population was heavily in debt, as a result of years of maintaining forced low prices, which were too low, combined with high taxes for their products, and severely oppressed by the harsh collection of these taxes. They could do nothing to defend themselves against these measures, as they themselves were still fragmented and in the minority in relation to the industrial population and the other townspeople.

With such economic misery in the towns and countryside, it was no wonder that eventually the extreme parties - the communists, on the left, and the National Socialists on the right - increasingly gained in strength while, at the same time, they fiercely fought against each other. The rural population, whom Hitler offered an elimination of debts and the safeguarding of inheritance, joined him in great swarms. Many of the unemployed who disliked the methods of the communists now also migrated to Hitler, as he had

promised them work. The development forced a duel between the two extreme parties. Very many followers of the centre parties regarded the National Socialists as being the lesser evil compared to the communists, whose rule was feared would be based on Bolshevism, according to the Russian model. And so, in 1933, Hitler was able to form a majority government. The fact that the venerable Reichspräsident (President of the German Reich) von Hindenburg entrusted him with the Reichskanzleramt (Chancellery of the German Reich) was, indeed, in keeping with the rules of democracy, but it also resulted in Hitler gaining the sympathy of additional voters.

The Psychological Situation in the NSDAP following the Seizure of Power

Hitler was initially exceptionally restrained, evidently influenced by Hindenburg, and many who had disapproved of his manner hoped that the numerous moderate elements which had helped him to achieve his majority would now have a positive influence on the continuation of state affairs. This is how the large number of votes cast in the referendum of March 1933 is to be understood though, as a result of the occasional political pressure thereby applied, hardly any real gains resulted.

The party made great gains during this period. Its composition during the first few years after 1933 can be broadly characterised as follows. Its members were

- 1. those who had been in the party for many years, the so-called 'old campaigners' (amongst whom were many who had been unsuccessful in their own occupation, because of their own shortcomings, but also many idealists who had taken as their goal the fight against the danger represented by Bolshevism);*
- 2. others who were discontented and who, in this way, wanted to gain power or influence, partly because of the need for admiration and partly for egoistic reasons;*
- 3. those who were unemployed, who hoped for an improvement in their situation on joining the party; likewise numerous rural folk;*
- 4. but, now, also men with a serious attitude to life, who had indeed recognised the faults in Hitler's system, but who believed that the damaging influences, which mainly stemmed from the old campaigners, could be corrected. Many of this group also held the view that support had to be given to Hitler in order to arm Germany against Bolshevism.*

Those referred to under point 4 were able individually to achieve some good but, of course, they were naturally unable to exert any influence on large-scale politics, as was soon to be seen. A demonstrative withdrawal from the party, which a few courageous individuals ventured to undertake, taught the others that, in so doing, they would only be exposed to the severest persecution and would deprive themselves of having any further influence. Hence, those who believed that, in their small circle, they would be able to bring about

something good had to stay in the party and had to take upon themselves the realisation that they would have to agree with some things that contradicted their true way of thinking.

With continued expansion of the movement, the pressure applied by the party authorities to coerce people into joining the party and its organisation increased greatly. Membership was indeed categorically demanded of candidates for the civil service. Those who, for economic or other reasons, could not afford to abandon the career which they were striving for had to bow in the face of pressure, even if their actions ran counter to their inner convictions. Similar factors played a role even in the case of the fearful members of the older generation. It was not uncommon that private employers also exercised pressure in this direction on those placed under their authority. One can therefore readily understand how the enormous number of nominal party members arose.

Consequences for the Process being strived for of Denazification

The diverse structure of the party is such that it does not allow one to select a simple schematic procedure according to information obtained from the party membership book or a questionnaire. Rather, it is necessary to make a judgement based on the acts of the individual and their effects on the whole. Naturally, this system is more complicated to operate, but here we are talking about the fate of individual human beings, and therefore a greater expenditure of effort is both necessary and worthwhile. The new law on denazification in Bavaria is already going in this direction. When fellow countrymen participate significantly in making decisions, the danger that a few will try to lie themselves out of the situation is not so great. The population knows those who are amongst them and can distinguish between 'nominal party members' and true Nazis.

Every German who is concerned about his people will expect that those who have brought deep guilt upon themselves, as a result of their acts in the last twelve years, be subjected to severe punishment. Likewise, those who used their privileges as a member of the party or its organisations to their gain and to obtain other advantages, but also those who through defamation or denunciation have inflicted serious injury on their fellow men must be severely punished. The German national community does, however, have a right to retain the worthy people from amongst the party members in their midst, in order that they can continue their work undisturbed, and wishes them to be cleared of the stigma, which at present still sticks to them, of being a Nazi.

It is not my task to pass judgement on what might be an appropriate form of punishment. I would, however, just like to say that this must be graded according to the seriousness of the offence or crime, the site of the crime and the duration. As the least punishment, the withdrawal of an active and passive voting right within a specified period

of probation might perhaps be sufficient. In this way, it would be possible to effectively prevent disruption of the new political development by immature or unteachable elements, and consequently also enough would have been done to satisfy the popular instinct with regard to harmless nominal party members.

Denazification of the Universities

The author's own narrow sphere of activity lies, as can be readily appreciated, close to his heart. Much damage was done under the Nazi regime. Those who were completely unsuited to teach or carry out research forced their way into the universities and usurped power. These individuals, in many cases lecturers who had failed in their careers because of incompetence, divided the leadership positions in the NS-Dozentenbund (National Socialist Lecturers Association) amongst themselves and so had a substantial influence on new appointments, on which occasion they tried, if at all possible, to install additional 'old campaigners'. Apart from a few highly talented individuals, no-one was able to become a lecturer who did not comply by joining the party, the SA or similar organisations. The Reich leadership of the lecturers association in Munich also dominated the university department of the Ministry of Education, which itself often gave more careful consideration to the selection of suitable teachers. But, as a result of having been given a right of veto by Hitler, the Reich leadership was, however, able to prevent any appointment which was not acceptable to it. One can easily appreciate that all of those young applicants who were not able to renounce an academic career had to pay tribute to the party; mostly under enormous psychological pressure. Particular anxious individuals were prepared to get involved more than to a minimal extent and became block leaders¹⁵ or held similar positions, and now they have difficulties in making their non-Nazi convictions credible.

The universities must support the principle that all those young people who are valuable - because of their human, as well as their academic qualities - as researchers or teachers, who were not activists, can now be received graciously back again and not come to harm as a result of the fact that, in the last few years, they had no alternative but to follow the path of the party, which was completely merged with the state.

The whole new generation of the university teaching body depends on this decision.

I can very well understand that the English, who have been accustomed for many centuries to a democratic form of government, will have much trouble understanding such

¹⁵ Translator's note: in the NS a "block" was the smallest, unofficial unit of the Nazi party and was based on a block of houses.

a chain of thought. One has to have lived under a dictatorship in order to be able to fully comprehend this.”

Following this public declaration, which indeed drew attention to the misguided behaviour of the non-political Germans, Prandtl recommended, however, that the process of denazification should be reconsidered in accordance with the views he expressed. He now supported individual colleagues in achieving a fairer assessment of their past: those who had also been regarded as implicated by the military government simply because of their membership and who were accordingly convicted.

Prandtl again tried to explain to the British occupying power how differentially such membership should be judged. The following letter dated the 14th April 1946 to Mr. Bird illustrates this.

“I would like to mention the case of Professor Osenberg from the Technical University, Hanover. As you will know, during the last years of the war, his work as the director of the planning office of the Reich research institute was very successful. As a result of his efforts extending over many years, he was able to see to it that, despite the greatest opposition, important scientists were moved from the front and made available in a well-planned manner for research...

If there is a possibility of releasing him and other professors from internment ... this would be a very good action in the interests of humanity and would provide these academics with the chance to make use of their abilities.”

Another letter, dated the 13th January 1946, in which my father provided his support by acting as a mediator, relates to the case of Professor Schaefer. Prandtl sent a written confirmation for presentation during the denazification trial court proceedings against Professor H. Schaefer, Bad Nauheim, whose political past was being investigated.

“I personally came into contact with Professor Hans Schaefer in my capacity as chairman of the research committee in 1943. At that time, it was hoped to gain Professor Schaefer for a new position to be established at the Aeronautics Research Institute in Munich. At that time, he was being subjected to substantial pressure from the Frankfurt Gauleiter (leader of an

NSDAP district) who did everything in his power to remove him from Nauheim. I myself had the opportunity of holding a long discussion with him on the occasion of a visit to Göttingen. He also gave me a comprehensive account of the efforts of the Gauleiter to remove him from Nauheim.

From my report to the members of the research committee dated the 8th June 1943:

Professor Schaefer is making his way from Nauheim, because the Frankfurt Gauleiter does not like the fact that Schaefer is a practising catholic. The quite personal impression that Professor Schaefer made on me was that of a serious academic imbued with scientific ideas. I have no doubt that one can believe every word he says.”

In his biography entitled *Erkenntnisse und Bekenntnisse eines Wissenschaftlers* (The thoughts and beliefs of a scientist), the physiologist Professor Hans Schaefer himself gave an account of his visit to Göttingen [45].

“My attempt to take the easiest route to finding another position proved to be unsuccessful of course during the war, despite many attempts. I would like to tell you about one of these attempts, because it allows me to sing the praises of a great academic.

I had, in the meantime, made friends with Theo Benzinger. He was of the opinion that it would be possible to obtain the post of a governmental senior medical officer and had already smoothed all the paths to achieving this objective. The ultimate authoritative person in the matter was Professor Ludwig Prandtl, the great pioneer of research into fluid dynamics in Göttingen. I decided to visit him, in order to advance my plan to work at a biology institute, which had still to be founded, at the Aeronautics Research Institute in Munich, under the directorship of Benzinger. During my visit, which took place on the 7th June 1943, I found Prandtl to be very negative. He could not understand why I still wanted, even now, to go to the air-force and posed the question of whether I never read the newspapers. I told him that I had been forced by the Gauleiter to look for another position, that I was in a very difficult political position, and that changed the grumpy old man into a kind, fatherly adviser. His advice was to stick with Bad Nauheim. This advice was also given to me by my colleague Hermann Rein ... So, when the war came to an end, I was still in

Bad Nauheim. With the arrival of the American tanks in our small town, the greatest nightmare of my live had ended.”

Dr. Hans Schaefer wrote on the 17th November 1946,

“Dear Prof. Prandtl,

I have received your written confirmation regarding the matter related to me and would like to express my thanks to you. The letter will certainly have a convincing effect.”

26. The Immediate Post-War Period

Although the British occupation authority had forbidden the resumption of any kind of research work at individual institutes, nevertheless, the *Kaiser-Wilhelm-Gesellschaft* still continued to exist, for the time being, as the super-ordinate organisation. The General Secretary, Dr. Ernst Telschow, was successful in keeping this organisation in existence, following arduous discussions to reach an agreement, as a registered association. This farsighted man had already transferred part of the general administration from Berlin to Göttingen, which had remained undamaged, before the end of the war and so had provided a basis for further work.

Prandtl was also able to obtain a certificate of non-objection for Dr. Telschow, whose importance and effectiveness in subsequent years should certainly not be underestimated (letter dated 7.6.1946 from Prandtl to the occupying power).

Dr. Telschow carried out negotiations with the military authority in Hanover and reported there on his visits to the various institutes which were located in the American, the French and Russian zones.

But, still a unitary executive organ was lacking. When Max Planck arrived in Göttingen as a refugee, in order to find accommodation with relatives, the idea was put to him to support the continued existence of the research society (Kaiser Wilhelm Society). It was known that Planck was highly respected by the victorious powers, as a consequence of his clear, unassailable position in relation to Hitler. Despite his advanced years (he was 87 years old at the time), he was asked by a committee to accept the position of president of the Society. The society later bore his name: the *Max-Planck-Gesellschaft* (Max Planck Society). Planck accepted and declared that he would devote himself, to the best of his ability, to the task of reconstruction of this society, so that the responsibility for the many research institutes would once more be placed with a single authority.

Following Otto Hahn's release from imprisonment to Göttingen in April 1946, Planck was relieved of some of the administrative work. Hahn was then elected as the new president of the *Max-Planck-Gesellschaft*.

In this way, it was possible for the work of the Institute for Fluid Dynamics to be resumed, but not, however, that of the AVA, the *Aerodynamische Versuchsanstalt*. It was robbed of all of its equipment - the wind tunnels were partly destroyed or partly dismantled and transported to England. However, I cannot remember my father telling me about this. It must have caused him great pain to see that the research equipment, which had been planned over many years, broken up and his life's work destroyed by an act of dismantling. He was also no longer able to experience a magnificent project resulting in new wind tunnels being brought back, once more, into the old halls. My father once called himself a stoic: a declaration of belief in the philosophy of a basic ethical system which taught that one's behaviour should, in no way, be governed by emotion.

In contrast, in the area of science as a whole, a new start was being made; in particular, in the empty buildings of the AVA, it was possible to establish other institutes. W. Heisenberg had his *Kaiser-Wilhelm-Institut für Physik* (Kaiser Wilhelm Institute for Physics) transferred there and shared the space with C. F. von Weizsäcker and K. Wirtz who, for their part, established new departments. It is therefore not surprising that the first physics conference, after the end of war, took place in Göttingen, on the 4th October 1946. Although it was only possible to have a limited number of participants, because of the problems of providing board and food, nevertheless, approximately eighty physicists came to the conference. There was a sense of joy in getting back into the habit of being able to exchange scientific opinions and ideas, despite the pitiful conditions regarding provisions.

Prandtl now became quite consciously interested in politics. In view of the failings of the past, he felt he had a kind of duty to form his own view regarding recent political events and to draw conclusions based on these. After the parties re-established themselves in 1946, he became a member of the FDP (*Freie Demokratische Partei*; the German Liberal Party).

In the private sphere, in Calsowstraße, we experienced a new impetus as, in the winter of 1945, my sister returned to us in Göttingen. She lost everything during an air-raid in Munich and we were pleased to see her once more in good health. She herself, happy to be re-united with her family, immediately began to help with the housekeeping and it was very

dear to her heart to be able, to the best of her ability, to care for her father. Ensuring that there was enough food for a family was something that took up much time. In order to buy what little there was available on the market meant waiting in line; not just in front of one shop. In winter, we collected beech cones, to obtain a little oil from them, and gleaned vegetables from the potato fields, after they had been harvested, as potatoes - at that time the main staple food - could not be obtained in sufficient quantities. Sometimes, we were fortunate enough to be able to acquire valued foodstuffs for barter goods in the country. It was easier to cope in difficult circumstances by working together.

After his release from captivity, my cousin Hermann Föppl also wanted to study in Göttingen, and he was able to find accommodation with us. He remembered those evenings on which he sat together with his uncle at the large kitchen table and how the latter sat over his work until into the night. The consumption of electricity was rationed so that, in the evening, after 10 p.m., the electricity was completely switched off. But, in the kitchen, in addition to the electricity supply, we still had an old-fashioned gas light. The light which shone from our kitchen over to other houses that were shrouded in darkness may have been quite an astonishing phenomenon for many people living in Göttingen.

In April 1946, my husband, who had been a prisoner of war and was held by the Americans, was also released. He was still in good health. The provisions made available by the Americans were, in the end, adequate. Our little daughter, who was one and a half years old at the time, quickly made friends with her young father.

Now, we all lived in the same apartment, even though we were somewhat confined. But, it was possible to arrange for my father to keep two of his rooms for himself. The lack of rooms in Göttingen was a quite general problem, so that everyone had to get used to making do with less living space.

The meagre diet with which we had to somehow feed ourselves was always too little for a whole family. We still remember a pitiful meal consisting of only potatoes. In order to fry these, we put some cod liver oil in a pan. The product of our culinary skills was found by no-one to be palatable. The

reader can therefore certainly well understand the pleasure when, on the following day, we received a Care Package from America from Professor Courant, whose generous content we were able to use economically for a long time.

Later, other former colleagues who now lived in America thought of their teacher and friend Ludwig Prandtl, so that almost every month we received such precious packets from abroad. In this way, we were loaded with gifts and the anxious question of whether, on other days, we would be completely without supplies was no longer raised.

My father greatly enjoyed taking part in family life. His son-in-law who, above all, tended to bring human problems into the topics of conversation, sometimes gave a new stimulus to the discourse which was, of course, dominated by the natural sciences. This resulted in talks of a more general nature. Sometimes, my husband kept a record of these occasions, by taking notes about those things he considered to be of interest and importance.

One day he asked his father-in-law, in a certain light-hearted manner, whether he understood the theory of relativity, which to him, as a philologist, was simply a name. He replied, with a slight smile, by saying, "Yes, as a matter of fact. Indeed, it appealed to me straight away, so that I also became a relativist. As I read Einstein's first paper, I immediately felt convinced and said to myself, that's right!"

This reply was typical of Prandtl's attitude of making allowances for and having a helpful disposition towards those who were not acquainted with the natural sciences, which he nevertheless took seriously enough that he would pay attention to giving a worthy answer and one that the inquirer could understand. This attitude of always showing respect to others was also clear in a basic requirement of authors, which he formulated in the following way, "In order that he may better cope with an explanation, which may be partly difficult to understand, the reader must be treated in a courteous manner".

My husband often listened as his father-in-law sat at the piano to "prelude", as he called it. When, one day, he asked whether his music was partly produced as a kind of higher mathematics - driven like a sublime

game with proportions and numerical ratios - he replied, “No, not at all, certainly not, I just play by feeling, but when an unexpected chord slips in or an unintended harmony, this induces me then to consciously follow its direction. What underlies my playing is feeling and mood.” According to his own accounts, my father’s improvisations turned out best when they were associated with a particular occasion such as, for example, days to be commemorated or a farewell. (In fact, I can remember that he gave us the greatest pleasure when he played music at family celebrations, birthdays or baptisms, when he treated us to a masterful composition as a surprise.)

In a general discussion about external success, he said he had been especially favoured “in that the subject which was dear to my heart was also one in which there was a general interest at that time. One has to do one’s best to make the most of one’s talents. In addition, I also have my professional ethics, which allow me to endeavour to leave behind as perfect work as is possible and to acquire a circle of students who will continue that work”. I would like also to quote my father’s reply to a comment of a colleague of my husband about him. This man described my father as “a marvellous sort of man”. My father replied, “He was just surprised that someone whose scientific successes are talked about by all kinds of people shows no signs of conceit. I mean, I think I am able to say that, despite having received so many honours throughout the years, I have not become stuck up”. Then, after a short pause, he added, as it were, with conscious self-analysis, “But, when I say this, I do indeed show that I am conceited. I am, after all, proud of what I have done and achieved, but I do not take advantage of it”. On another occasion, he talked about his attitude to conflict situations. “People very often have to make apparent sacrifices by suppressing impassioned outbursts. I myself have the good fortune of reacting very slowly in such deliberations. By the time I have gained a clear view of the situation, everything has calmed down again to such an extent that I can view the matter with composure.”

This imperturbability was for him the embodiment of a basic attitude. In reply to the question of what enables him to cope with painful events, he again replied “Composure!” Following an operation, he went through a very difficult period. He was tormented by a lack of sleep and inner restlessness. His assessment of the situation was to say that he needed to regain his composure. Did he feel himself to be obliged to follow the stoic

ideal? “Yes, the teachings of stoicism have always appealed to me - not only the notion of expecting nothing in death, but also in life. I do not believe in immortality, but I do believe that one must lead a moral life. One does not need to reproach oneself, composure is bestowed on one. One should have sympathy and be good to others. One should help, but not expect anything; that is, one should adopt a certain stoic morality”. In reply to the question of whether his humanistic upbringing served as a preparation for this way of thinking, he replied, “Yes, it is quite possible. But, it requires a certain amount of strength to make this attitude one’s own”. This strength was also apparent in his calm attitude to death. In a discussion which also concerned the question of life after death, he said, “I expect nothing for myself. I know that, one day, my heart will cease beating and that my breathing will stop. I have had sufficient time to come to terms with this and reconcile myself with the fact that I will not live forever”. As a result of working in the field of natural sciences, he gradually distanced himself from catholic doctrine in which a belief in immortality is united with a belief in God. When the discussion moved in the direction of the notion of creation, he said, “A creator of the universe? Yes, how can I conceive such a thing? I never put the thought in my mind - neither do I have a need to do so”. In this sense, he expressly declared his support for the words of Goethe, “The greatest fortune that a thinking man can have is to have researched that which is explorable and to revere the unfathomable.”

In a discussion of the war, which had just come to an end, again the very serious foundation on which his attitude to life was based was clear, and also his strength to look discernible truth straight in the eye with relentless candour. “It is a wise old saying - the world is just a vale of tears”. My husband added his own comment on this observation, “It is a mark of Ludwig Prandtl’s deeply human nature that, with the firmest resolution of such an uncompromising realism in relation to the *conditio humana*, he was, nevertheless, tactful, and full of forbearance and goodness with regard to his fellowmen”.

In the winter semester of 1946, Prandtl became an emeritus professor and then, at the age of 72 years, he retired from his position as director of the institute. Professor Betz became his successor. However, it was considered necessary to create three departments as, in the meantime, it was no longer

possible for a single person to embrace such an extensive area. One continued to be headed by Ludwig Prandtl. Professor Tollmien, who had become Prandtl's successor at the university, and Professor Betz were likewise each responsible for one department. Close collaboration was guaranteed from the outset by having such an exceptional team as this one.

Now that my father had been freed from some of his duties, he was able to accept an invitation, in March 1947, to go to Switzerland. Thanks to the initiative of Professor Ackeret, in Zurich, the prerequisites were fulfilled for realising the plan for this trip.

Ackeret wrote to Prandtl on the 30th January 1947,

“Now, it really is time that I give you information about my efforts to enable you and one of your daughters to take a holiday in Switzerland.

Now, the main concern, namely, financing this and getting permission from the allies have been sorted out, there should no longer be any problems. Following inquiries, three companies, the public limited companies

Brown Boveri Cie., Baden,
Escher Wyss Maschinenfabriken
Gebrüder Sulzer, Winterthur

have agreed to jointly pay the costs of an approximately six-week stay for two persons. Now I would like to know if you have any special wishes regarding this stay.”

It is almost impossible to explain what it meant then, in 1947, suddenly to have the prospect of being able to travel in Switzerland, in circumstances in which there was a total lack of all kinds of goods. One had to fight to obtain even the most basic requirements, just in order to maintain existence. In our fantasy, we were now allowed to imagine the possibility of how we would live in a country untouched by war. At the beginning of March, my father set out on his journey and I was allowed to accompany him. In the period after the war, the trains did not run daily, but often only three times a week. But, finally, after many hours of travelling and staying overnight in Freiburg, in a bunker which had been adapted, on a make-shift basis, as lodgings, we arrived at the border station of Weil, where we were picked up. We then had to attend to a few formalities before we were able to board a train to Zurich, for the rest of our journey. We sat in our

shabby coats in a comfortable fast train amongst Swiss travellers who, in contrast to us, were well dressed and displayed a certain natural self-confidence which, understandably, did not characterise us. Some young people who were coming from cross-country skiing, with rosy cheeks and tanned, were making jokes in amongst cheerful conversation. The oppressive years of war and the subsequent general depression and difficulties had for us put all thoughts of such sportive pleasure into the unachievable distance.

In Zurich, we were generously given the opportunity to improve our wardrobe. We were given accommodation in a very nice hotel. In this way, we were able to enjoy exceptional, heavenly conditions, without any everyday worries, in intact Switzerland.

Professor Ackeret and his wife cared attentively for my father. Of course, a visit to his Institute of Aerodynamics was arranged. A visit to the factory belonging to the Sulzer brothers in Winterthur then took place, as well as a visit to the workshops and laboratories of the Escher Wyss factory. A personal appointment was also fixed with Dr. H. Gygi, whose chauffeur brought us to Wildegg, to his elegant house, where we had an especially enjoyable Sunday together with his family. The engineer Gygi, director of the machine factory Escher Wyss, was exceptionally interested in discussing specialist problems with my father. I noticed that though I was not able to precisely follow the exchange of ideas, Dr. Gygi gratefully agreed with the solutions proposed by my father.

During my stay in Zurich, I also had the opportunity, once more, of meeting my friend Lilli Misch, who had emigrated to Switzerland and was able to graduate in medicine during the period of Hitler's dictatorship. This reunion was a source of great pleasure for me. She and her husband, Dr. Walter Baum, invited my father and me to an unforgettable evening at the theatre in the Zurich playhouse. We saw the play "On borrowed time" by P. Osborne, with Albert Bassermann in the main role.

My father gave a lecture at the technical university about turbulence, in the context of a colloquium. On 15th March, we travelled to Ascona on the Lago Maggiore for a long stay. The three weeks spent there provided a real rest for my father. We were able to enjoy going for walks every day. The

view of the calm, overcast lake was, time and again, fascinating. New items on the programme had been planned for the return journey, however, which he unreservedly wanted to stick to. His interest in new projects, as well as new scientific publications, had in no way diminished.

He visited the research group of Professors Schardin and Sauer in Weil on the Rhine, who were about to set up a laboratory in the Alsatian. From there, he travelled to Karlsruhe to a meeting on applied mathematics and physics, and was able to listen to a substantial proportion of the numerous talks. He also participated in the subsequent discussion with colleagues. Having arrived back in Göttingen, he observed, “I was truly stimulated, but also tired out and squandered a great deal of my rest there, but I do not regret having taken part in this conference”.

On the 3rd July 1947, Professor Courant from the USA visited the long-familiar town of Göttingen. He noted in his diary, “7.30 a.m. I arrived in Göttingen in a somewhat nostalgic mood. Outwardly, there was hardly any damage to be seen. According to von Kármán, it was expressly excluded from the air attacks of the allies”. In the section of his notes devoted to Prandtl, he wrote, “The Institute of Aerodynamics had been converted into a true fortress. Prandtl was ill and depressed, but intellectually still active. He had been studying analogue computers, in detail, and with particular reference to meteorological calculations. The dimensions of the machines which he constructed were determined by the size of the ball-bearings which he found by accident amongst surplus war goods”.

For his summer vacation, my father was invited by his brother-in-law, Ludwig Föppl, to Ammerland. This provided him with the opportunity to relax in the familiar holiday home and, as the occasion demanded, the opportunity for scientific discussion. At the beginning of July, our second daughter Susanne was born and so, for the time being, we stayed in Göttingen.

The following brief text was probably written during my father’s vacation [36],

“On the subject of Mammatocumulus clouds

I have often observed this cloud form during holiday trips on the elevated Bavarian plain and relatively soon became aware, from experience of the

weather, that threatening clouds in which mammatocumulus clouds appear are followed by a quite normal, harmless weather course. I later observed particularly beautiful mammatocumulus clouds in a long mountain valley, which stretched from the end of the valley in the south-west to the north-east, which were formed from a large cloud with south-west flow and which drifted quickly down the valley. I was fully aware of the lability from the whole forms of movement - a certain similarity to the flow forms which become manifest in a liquid heated from below - and it did not require much reflection to discover that evidently a cloud air mass must lay over a transparent air mass and that the lability was caused by a sinking movement in which the cloud mass was warmed more slowly than the clear air mass. The fact that the flow took place in a direction down the valley also provided an explanation, in this case, for the sinking itself.”

This extract from the beginning of the text is sufficient to appreciate how, through observations of natural phenomena, Prandtl was inspired to engage in scientific thought.

From time to time, new technical personnel were recruited to the institute and all those who were appointed considered themselves to be very lucky to have got a job there.

When Frau von Stutterheim told me about how, in 1948, she obtained a job as a technical assistant to Dr. Reichardt, she also talked about her inner sympathy with ‘the nice old Professor Prandtl’, who often came into Dr. Reichardt’s office. Shortly after she took up her new job, she had to have an operation on her foot and so was only able to make her way to work with difficulty. Prof. Prandtl showed great sympathy because of her painful handicap. He tried to cheer her up by talking to her each day. Once, he said to her that he frequently counted the number of steps he took from home to the institute, in order to be able to determine whether, after a period of time, he took more steps than before. Evidently, he wanted to reliably control the ageing process, which he accepted in advance, in this way.

Similar thoughts were expressed in a letter to Dr. A. Baeumker, in Fairfield, USA, dated 14.02.1949.

“The work on my book is nowhere near finished. I might also add that I am very much aware of becoming old in many things that I do. But, ideas

are still plentiful, so that I cannot consider writing the memories of my life, as my daughters would gladly have me do. Mr. Sommerfeld is now over 80 years of age and is once more writing a book. By the time I reach that ripe old age, I hope I will have still retained my memories and, if not, it would nevertheless be no great shame. After all, I can see in the younger generation that what interested us is of no interest any more for young people. Only after a long period of time do such things become interesting once more.”

From a letter dated 1.6.1949

“I am afraid I must confess that I have understood very little indeed of your political essay and can only understand discourses on such matters when clear, direct words are used to explain what they are about.

I would like to add that I found it very interesting that my petition to Göring, in which I complained about the vile behaviour of some National Socialist, German physicists, has been read in Wrightfield.”

Prandtl now devoted his time exclusively to problems associated with meteorology. He collaborated with a meteorologist by the name of Dr. E. Kleinschmidt. In 1949, he published his thoughts and results in an offprint which was published by the Academy of Sciences. I would like to quote from the clearly understandable introduction. In the meantime, knowledge in this area has grown enormously, so that it appears worthwhile to make the reader aware of the first beginnings of scientific observations from that time using this introductory text.

Weather in the upper troposphere (presented at the meeting on 17th June 1949 [39])

“Previously, predicting areas of bad weather (barometric low-pressure areas) on the Atlantic coast of Europe had always been very difficult, as these low-pressure areas came on land from the sea with considerable speeds and, therefore - apart from the principal shipping lines, from which radio reports are received - could not be observed in due time before their arrival over land. With the introduction of radiosondes, which report weather conditions right up into the stratosphere to ground stations and which can also provide information about direction and strength of winds at these altitudes by taking double bearings, it has been possible to make substantial progress. It is apparent that, in the upper troposphere and also

in the lower stratosphere layers, a characteristic wind system with wind speeds of much more than 100 m/s arises which runs ahead of a new low-pressure area and, so to say, gives notice of this, such that the amount of speed also provides an indication of the magnitude of the low-pressure area.

One should also mention here a fundamental idea that provides a first prerequisite for the real calculations that, namely, the masses of air that move over the rotating earth drift together as a jointly rotating atmosphere.”

The collaboration with Dr. E. Kleinschmidt, the meteorologist, led Prandtl to new, unsolved problems which occupied him intensely and he discovered a few characteristic solutions as a consequence. Thanks to his wealth of creative ideas, he was also able to present important results for publication in the field of meteorology.

At the meeting of physicists, which was held on the 6th September 1948, at which Prandtl was elected to be an honorary member of the *Deutsche Physikalische Gesellschaft* (German Physical Society) in the British zone, he gave a short talk on his method of working. Later, he agreed to put down in writing the thoughts he had expressed in his informal talk, in order to make them accessible to a larger audience [31].

“I am particularly pleased to accede to Mr. B.’s request, because I have not, up until now, expressed my opinion in detail about the methods which have often allowed me to find a new approach to solving problems and especially also because I believe that with such remarks I am able to give useful advice to young colleagues, in particular.

Mr. Heisenberg claimed, in his kind remarks dedicated to me, amongst other things, that I have the ability to see which solutions there are to equations without carrying out a calculation. I must reply that I do not indeed have this ability, but that I do strive to achieve as detailed a view as possible of the matters underlying the tasks and try to understand the processes. The equations then come later, when I believe I have understood the matter. Their purpose is, on the one hand, to obtain quantitative propositions, which naturally cannot be achieved simply by intuition and, on the other hand, equations are a useful means of obtaining evidence for my conclusions which others are also ready to accept.”

My father's former student, Professor F. Schultz-Grunow, also referred to his special approach to scientific thinking in a lecture on the subject, given in October 1980, entitled "The intellectual legacy of Ludwig Prandtl" [46]:

"Prandtl endeavoured, in the first instance, to understand phenomena through intuition and thereby to acquire an insight into differential equations. Through his intuition, he discovered a number of overlapping influences. He knew how to identify the essential, separated this from the inessential, and saw that precisely this was blocking the way to finding a mathematical solution. A wonderful foundation of nature was revealed. Prandtl explained this approach himself, 'By systematically simplifying the approach, which can proceed to different extents depending on the task set, flexibility of methods will be achieved, which will be seen to be a great advantage compared to the strict but, indeed, also inflexible methods of exact theory'. In this way, he was able to achieve a new, eminently successful dimension of thought."

We can now turn once more to Prandtl's own speech,

"The way of thinking referred to earlier can certainly be learnt, as I have been able to prove with many students. ...

In old-fashioned mathematics lessons, which I received while at secondary school around 1890, there were no functions, simply concrete, individual examples. It therefore came as a great surprise to me during the first term of studies that there were 'variables' and 'functions' of a variable. With a true craving, at that time, I painted the course of the various functions of $y = x^n$ with positive and negative values of n on squared paper. ... Through examples taken from mechanics, I gradually became familiar with 'seeing' forces and accelerations in the equations and sketches or, by using my kinaesthetic sense, I was likewise able to feel the tensions within a solid body when subjected to load etc. ...

Streamlines for two-dimensional flow can be understood as contour lines of a 'stream function' and, consequently, can also be visualised as a spatial model of this function. In this way, there were a number of methods of painting pictures of the solutions which were being sought. Such 'pretend journeys' led me, amongst other things, to a nice relationship between the distribution of shear stress and soap films.

With regard to the particular tasks to which I have devoted my attention, I have on a number of occasions been motivated by published works which

have aroused my resistance. But, sometimes, my own lack of success has occasionally been the cause for me to seriously reflect.”

Here is an example. “In the period shortly before 1900, I stumbled on the claim, in many publications, that an escaping stream of compressed air cannot reach a higher speed than the speed of sound, although its energy is sufficient to achieve higher speeds. ... But, the matter can be easily straightened out. The Euler equations produce, with the continuity equation for a compressible medium, stationary waves with supersonic speed...” [34]

The scientific meeting of the *Gesellschaft für Angewandte Mathematik und Mechanik* (The Association of Applied Mathematics and Mechanics) took place in the British zone in 1948, between the 22nd and 24th September, in Göttingen. Prandtl, who had been its presiding chairman since its foundation in 1922, had successfully applied for renewed authorisation of the society by the occupation authorities. The British Scientific Adviser, Dr. R. Frazer, showed his interest. Prandtl included a lecture to be given by him in the programme: “Generating circulation by shaking vessels”. My father was also responsible for running the meeting. He encouraged a young participant, Julius Rotta¹⁶, to read a paper on a subject of his own choice. It was his first public lecture. An afternoon was set aside for a stroll through Nikolausberg (an area on the hillside of the outskirts of Göttingen), where there was also an opportunity for discussion over coffee and cake. I am told that Prandtl, who had now reached the age of seventy-three years, conversed in high spirits with the participants at the meeting and afterwards hurried on ahead on the way back with sprightly steps and led the participants to the most attractive vantage points.

As an emeritus professor, my father was still roped into his normal work rhythm. Apart from a preoccupation with questions related to meteorology, he set himself the task of editing a new edition of his textbook on the Essentials of Fluid Dynamics in order to bring his work up to date.

¹⁶ Dr. Julius Christian Rotta is the author of the book *Die Aerodynamische Versuchsanstalt in Göttingen, ein Werk Ludwig Prandtls. Ihre Geschichte von den Anfängen bis 1925* [43].

He was also still active in university affairs, which came up for discussion at the meetings of the academy. At a university celebration, which took place on the occasion of the hundredth birthday of the Göttingen scholar Felix Klein on the 7th May 1949, my father delivered an address [26] from which the following extract is taken.

“I may be allowed, as one of the ‘young people’ whose fate was entrusted to Felix Klein, to report on my experience under his guidance. It was a time in which the mammoth enterprise of compiling an encyclopaedia of mathematics was launched under his direction. The fact that it was possible to truly bring this project to an end in accordance with his original plan is entirely due to Klein who, through the infectious enthusiasm of his powerful personality, was able to spur on both the willing and the unwilling to achieve astounding results.”

I think it is fitting at this point to quote from a letter of Prandtl’s dated the 8th March 1949 to Professor Dr. A. Sommerfeld, concerning what a friend of Klein, Carl von Linde, who became very well known in relation to the industrial liquefaction of air, had advised him, when it became necessary to obtain money for the foundation of an Institute of Technical Physics, as well as also subsequently for a project of the model research testing facility, “Mr. Klein, if you simply intend to collect money from a number of industrialists, you will not collect very much. Such an enterprise must be realized by gaining the support of the richest of the industrialists and allowing him to collect money...”

Von Linde then introduced him to the commercial head of the Elberfeld paint factory, Henry Böttinger, who wished to develop a close relationship with the field of science. It was thanks to his interest in Klein’s ideas and his own unselfish, personal efforts for the great project that, in the end, so much money was collected that it was possible to substantially support technical research at the university. Without doubt, he made the decisive contribution to the realisation of these modern projects. Through under-secretary Althoff, in Berlin, who worked closely together with Klein, Böttinger received a hereditary title and a seat in the Prussian Upper Chamber.

1950 was a year in which a number of jubilees associated with Prandtl himself took place. He celebrated his seventy-fifth birthday, the golden jubilee of his doctorate, his fiftieth year of membership of the *Verein Deutscher Ingenieure* (The Association of German Engineers) and, in July, the twenty-five year history of the institute was commemorated, from the opening of the Institute for Fluid Dynamics through to the post-war period.

In the journal *Forschungen und Fortschritte*, Professor Tollmien published an article on the occasion of the seventy-fifth birthday of Ludwig Prandtl [49]. My father's career will, by now, be sufficiently well known to the reader, so I would just like to include the first and last paragraph of the article in my account. Tollmien began in the following way, "Epochs in the history of an important man are not measured according to a round number of years, such outstanding data serve only to remind those around us to ascertain the merits of the person who is the subject of the celebration and to preserve what has been accomplished!" He concluded his article with these words, "With this brief overview of the works of Prandtl, up until now, one should not overlook his significant influence as a scientific educator. In addition to the many PhD students who gained their degree under his supervision, there were also numerous co-workers who were recruited, with the continued expansion of the Göttingen institute, who were blessed by receiving his encouragement. When he became an emeritus professor in 1946, Prandtl gave up lecturing voluntarily, but continued to participate, with his unsurpassed wealth of knowledge and with his own resolute temperament, in the discussions of the colloquium about questions of applied mathematics and mechanics. At the *Max-Planck-Institut für Strömungsforschung* (Max Planck Institute for Fluid Dynamics), he carried out research in his own department. When one views his publications from the final years, of which only few can be mentioned at this point, one becomes aware that he did not need to play the role of the 'historical figure', but that, even in old age, he found himself at the centre of a blessed, highly engaging, creative period of activity.

May we, Prandtl's students and friends, as well as his colleagues throughout the world, be granted the good fortune to continue to see this venerable man active in our midst for a very long time to come."

There were also many congratulations sent by his former students from abroad.

27. The Last Years of his Life

In order that I may give the reader an account of the last years of my father's life, I have drawn on correspondence between my father and former colleagues who were now engaged in new fields of activity in England, America and also Russia. I have limited this account to communications which say something personal about my father.

At the same time, they reflect the amiable relationship of personal trust which existed between him and his students. They contain accounts of his work and reflections of various kinds.

In a letter dated 1st March 1950, Prandtl replied to a letter from Professor Bock in Moscow, from whom he had received a copy of his circular letter. Prof. G. Bock who, since 1936, had held a senior position in the research institute Adlershof in Berlin, was arrested at the end of the war and taken to the USSR. After experiencing hard times in the Lubjanka prison, he was allowed to work in Moscow, as a scientist, at the Central Institute of Aero-Hydrodynamics. He suffered greatly from being separated from his family.

The following passage is quoted from Prandtl's reply.

"The circular gives quite a graphic description of the conditions under which you are living. Sadly, you also say that you have become lonelier as a result of the departure of one study group. If there is no change for the better in the immediate future, then at least you will have the comfort of knowing that your wife and children are still there, even though far away, and that she is looking after them.

As for me, I lost my wife a little less than ten years ago. Although I have two daughters, one of whom does not have children and is also a war widow and the other who has two lively little daughters aged 5 and 2 1/2 years old and is married to a cheerful young man, this is still no substitute for the wife with whom I shared both joy and sorrow for 31 years and whom I have dearly missed in the years following her death. The adage 'Habit is given from on high and is a substitute for fortune' also applies to me. The way things are at present in Germany where, as a result of the destruction of houses and apartments and the migration of Germans expelled from eastern countries, accommodation is being occupied by twice the number of people, my daughters live in my house and manage

the household together. And so fortune is a thing of the past which has become replaced by habit.

For a man who is 75 years old, I consider myself to be in a fine state of health for my age.

Compared to earlier times, the direction taken by the work of the institute has, of course, had to be substantially re-oriented. This process has not yet been completed. I myself also have taken part in this, to the best of my ability, and have reverted to a hobbyhorse and earlier passion of mine - dynamic meteorology. The science of meteorology has, especially in America, but also in Norway, Sweden and England, already reached an advanced stage and there seems to be a desire to make up for lost time. New research methods have also been introduced, to some extent - such as radar - with whose aid one can track the speed of the wind, even at great heights. One now knows a great deal about the atmosphere up to a height of 20 km, so that it has really become worthwhile to track things dynamically.

So, once again, I have thrown myself, be it somewhat late in life, into research in a young science and investigating things which have not been explored in an area that really gives me pleasure. If one considers this aspect of my work, once more I have truly had good luck in relation to science!"

Even in his formal correspondence, my father placed great value on giving a very personal reply.

Letter dated 16.12.1949, to the Indian Mathematical Society, Madras

"The Indian Mathematical Society has been so kind as to notify me that it would be holding this year's meeting on the 26th to the 29th December at the University in Madras. In its letter of invitation, it referred to me as an 'eminent mathematician'. I truly cannot make a claim to this title. I am an engineer and, if you like, a theoretician in the field of engineering, and in a number of instances I have made use of mathematics in solving my problems. But, I have never advanced mathematical science through any contribution on my part. I would most cordially thank you for your good intentions and wish you much success for your meeting."

In April 1950, our third daughter Ruth was born and, of course, her grandfather was delighted once more to see another granddaughter grow

up in his home. But, this also meant that, from that time on, I had little time to chat undisturbed with my father in the evening. However, my sister cared for his well-being.

A celebration took place on the 15th July 1950 in Göttingen. The occasion was the foundation of the Kaiser Wilhelm Institute for Fluid Dynamics 25 years ago. In the meantime, it had been renamed the Max Planck Institute for Fluid Dynamics. For the first time after the war, many former collaborators and students of Prandtl came together, from both Germany and abroad, to join in the festive event. At the same time, it was the last time that he was able to gather his former colleagues around him in a large number.

In the late autumn, on the 19th November 1950, which was a Saturday and also my sister's birthday, my father went, as was customary, for a walk in the woods. He suddenly succumbed to cerebral apoplexy, as he stooped towards some fresh green ivy. He wanted to pick this attractive decoration from amongst the now somewhat monotonous winter woods to take home with him, as a table decoration.

I would like to quote from his account of this incident. "I became aware of something happening in my head but, in my typical obstinacy, nevertheless, continued to pick the ivy." He hobbled home. The doctor, whom we called immediately, diagnosed paralysis of a leg and arm, and prescribed absolute quiet rest at home. My father remained our patient for some weeks. He sat very patiently in a broad armchair; nevertheless, very sad that he had to neglect his work at the institute. He got encouragement and was cheered up by visitors, who knew how to keep him entertained and who kept him up to date about the institute. From a letter addressed to Dr. Rotta and dated 27th November, he declared that, despite his weak condition, he was still grappling with scientific problems.

"I have received a piece of work from S... for evaluation. I have read this from beginning to end. If you have informed yourself about the work of Szablewski, I would welcome a visit from you in my sick-room."

He was now able to turn his attention to some of the items of correspondence which had been put to one side. Amongst these was one which was particularly urgent.

Prandtl addressed a letter dated the 29th November 1950 to the catholic parish council with a statement that he intended to leave the church. In that year, Pope Pius XII had raised the ascension of Mary to formal dogma. My father wrote the following.

“Somewhat delayed, because of the pressures of work and then illness, I would like to now herewith declare that I intend to leave the Catholic Church.

I have come to learn from the newspapers that the earthly remains of Mary, mother of Christ, have been transposed to heaven. For someone like me, with training in the natural sciences, this is quite an incomprehensible notion and, accordingly, for a person who earnestly carries out scientific research, this cannot be dictated as dogma. I would also like to note that since 1905 already, a time at which everything revolved around the anti-modernist oath, I had already inwardly broken from the church.

Nevertheless, outwardly I remained faithful to it, as many valuable recollections of my youth maintained a bond between me and the church. Whereas, at that time, the subject in question was the suppression of the freedom of thought of catholic priests which, to me, appeared to be hardly wise, now however, the focus is on me and my attitude.

I would appear dishonest if, by remaining in the Catholic Church, I were to give my formal agreement to the new dogma which itself will probably do very great harm to the church.

At the same time, I would like to note that it will prove to be a failure, if the church continues to ignore the ideas of natural science ... ”

Visits to the sick-room were always greatly welcomed. Once, the artist Wolfgang Willrich visited him. As my father learnt from him, in the course of the conversation, that he also played the piano and that he had the habit of improvising on this instrument, my father asked him to open the piano and play something for him. The resonant melody of the artist's own composition at once filled the sick-room. My father was greatly moved. I saw tears of emotion in his eyes. The originality of this kind of music

making delighted him. Yet, the thought that he himself had now, for many days not been able to generate musical inspiration on the piano may, at the same time, have possibly been consciously painful for him.

It had always been a great source of pleasure to my father to be able to express his inner life through playing. My father thanked his guest with many words of appreciation for playing and praised his guest's talent in being able to render such a fascinating musical theme so well and compared this with his present failure.

However, the words of comfort expressed by Mr. Willrich that he should not give up hope of an improvement sounded quite consoling to my father. An improvement did indeed come after some days of waiting patiently. As a result of gradual resorption, the paralysis diminished. As soon as he was able to, he went to the institute. Initially, he was picked up by the official car of the AVA institute, but soon he preferred to be independent by walking to the institute, as he had always done. He felt an urge to progress with the new edition of 'Essentials of Fluid Dynamics'. However, his capacity for work had become noticeably reduced and he became tired much more quickly than he had previously.

He wrote the following to Professor Grammel on the 7th January 1951, "The paralysis in my right leg has, in the meantime, become much less. Certainly I still limp a little, but I have already started once more to go for short walks on the Göttingen Hainberg."

To Professor Busemann on the 19th January 1951, "In the meantime, I have been able to look through the material for the new edition of my book and I take an interest in important events taking place in the world."

In the same year, he wrote on the 2nd March to Professor Grammel, "I have come to realise that one cannot reach the age of 76 years without being penalized and, regarding retirement, one has to put this off until the future."

In the summer of the same year, on the 14th June 1951, my father wrote to Professor G. Bock,

“The main reason why I am only now able to write to you today is because I have been putting much work into a new edition of my book the Essentials of Fluid Mechanics. The pace at which this discipline has developed, mainly as a result of American publications, has become so great that one cannot even think of gaining a true overview of the individual branches of the subject. My capacity to work has become really much less than it was previously and, above all, I am not able at all today to really follow the specialist literature. If I had foreseen this, I would perhaps have planned something more modest. After all, one expects from a ‘guide-book’, which the book is intended to be, that all important subjects are included and are given consideration. Of course, I have now accepted the help of former students, otherwise the whole enterprise would be hopeless. For me, it is a true blessing that I am not able to understand Russian, otherwise the amount of referencing would be still greater ... If the Russians want to change the situation in which their work is not well known to the wider scientific community, they will have to prepare translations into a western language themselves and then their work would become more well-known.”

In the spring of 1951, my husband bought a small car. Although it was a two-seater, it was possible for four people to travel in it. We were able to take my father out for short excursions, which he enjoyed just as much as we did. On one occasion, when we made a trip to the Harz (a forest area to the north of Göttingen), we were taken by surprise by a rain shower. My husband became aware of how a great amount of water rose up on the left edge of the windscreen, instead of running off slowly. My husband drew the attention of my father to this phenomenon. He looked at the water and uttered emphatically, “That’s right!” At the same time, a gentle smile on his face indicated a certain detachment as, with these words, he gave expression to a satisfaction that this damp element was governed by the laws which the science of fluid dynamics “stipulated” to it.

My father had planned to include a long holiday in the summer of 1951, in order to take a really good rest. My sister accompanied him on the journey to Bavaria. It was to be his last summer holiday.

Once again, a celebration took place in Göttingen, this time on the occasion of the two hundredth anniversary of the founding of the Göttingen Academy of Sciences. The ceremony was held on the 10th November 1951. The academy came into being in 1751, fourteen years after the founding of the George August University, in Göttingen. It was intended, from this time on, that teaching and research should mutually stimulate and enrich one another. And, as me was told, the “Göttingen manner” certainly contributed to the form of modern universities at other locations.

On this occasion, the Federal President of Germany, Theodor Heuss, came to Göttingen, which was a source of joy to the whole town. The President of the Academy of Sciences at that time, Professor Werner Heisenberg, presided over the special celebration. The ceremony took place in the great hall of the university on the 10th November with the widest participation of scholars, both from Germany and abroad.

On the day before, Heuss met with the President of the Max Planck Society, Otto Hahn, and honoured the Max Planck Institute for Fluid Dynamics by a visit. During the celebration, the Federal President of Germany awarded Prandtl the *Bundesverdienstkreuz* (Federal Cross of Merit).

I would like to quote a sentence from an address given by Heuss at the end of his visit, in the town hall, “Göttingen is a small town, but one through which the currents of the world flow.”

As a permanent memory of his visit, the Federal President of Germany planted a young lime tree, in the presence of the whole staff of the institute, in a circular flower bed near the entrance gate. In the meantime, it has become a magnificent tree and is still called the “Heuss lime tree” by the initiated.

What remains for me to write in this account of my father’s last years of life before he once more suffered a stroke, at the beginning of August 1952, are again personal communications - about his condition - which he took the trouble to add to the specialist content of letters which he wrote to those colleagues who were also friends.

From a letter dated the 22nd April 1952 to Professor Blenk, “My own powers have unfortunately declined quite substantially recently, so that not much active participation can be expected of me in this direction anymore” (he was nominated to be a member of the newly founded WGL).

Another letter, dated 18th March 1952, to Professor Tietjens in Bangalore, “I myself will go this time with my daughter Hilde to Bad Gastein in order to transform all kinds of signs of old age there into a milder form.”

So, on the 1st May 1952, he travelled in the company of my sister for three weeks to Bad Gastein. They were accommodated there, in the best manner possible, in the house of the retired colleague Pröll. However, the course of treatment proved to be too much of a strain and, on returning home, he did not feel recuperated. It troubled him that he had not been able to regain his former energy and stamina.

Letter dated 30th June 1952 to Dipl.-Ing. R. Langer, a former colleague, “I cannot say that, in all respects, things are going well for me. Following very positive accounts of the experience of colleagues, I decided to go to the health resort at Bad Gastein. But, the course of treatment at the spa did not suit, so that afterwards I had to recuperate from the Gastein cure. People in Gastein say that the true benefit of treatment appears half a year later. Well, I am hoping for the best!”

My father no longer showed signs of recovery from the stroke which he had suffered at the beginning of August. The renewed weakness resulted in a long period of being confined to bed. We engaged a nurse in our house. “Sister Lenchen” was particularly aware of her duty and took care of her patient in a conscientious and loving manner. She stayed with us until my father died. How often I heard her say, “The professor is so patient and undemanding. He asks for nothing and makes no requests, is always content with everything, and grateful for every form of assistance. He is always considerate. Indeed, he even thinks about how the smallest item of work can be made easier for me. I have never looked after such a modest and meek patient.”

The only difficulty which he caused us at the beginning was his headstrong attempts, despite his weakness, to make his way, now as ever, to the institute. On arriving there, he was completely unable to concentrate his thoughts. He could not hide his exhaustion and he was brought home. The *Aerodynamische Versuchsanstalt* AVA had, throughout the years, been the true centre of his life, from which he could now only hesitatingly separate himself and he set about doing this with a saddened heart.

His medical condition became worse and he knew that he would now no longer recover. Without complaining, he resigned himself to the inevitable. On the 15th August 1953, he died. He remained to the last moment in his familiar surroundings.

There were difficulties in arranging his funeral ceremony, as the university's theologians refused to say a Christian laudatory speech for the colleague who recently left the church. Despite this, the priest from the reform church, Pastor Th. Kamlah, gave the funeral oration. I would like to quote from this.

20th August 1953

“He settled the last, most profound questions of life with himself and did not care to talk about these. But, it was one of the most precious moments of my professional life when he came to me on the occasion of his wife's death and, deeply moved, he granted me an insight into his fine soul.”

In his introduction to *Ludwig Prandtl's gesammelte Abhandlungen* (Ludwig Prandtl's Collected Papers), his former student and later successor Professor Walter Tollmien [50] wrote,

“It was in November 1950 that he was struck by a mild stroke from which, not least due to his great willpower, he soon recovered. However, those around him noticed with concern, a few months later, that his strength was constantly declining. In August 1952, the dreaded breakdown occurred, which resulted in him no longer being able to express his thoughts in an orderly manner. Even then, his great kindness still gleamed in his demeanour. I was reminded of the great Immanuel Kant who died in a similar manner.

During my last visit to Prandtl, he was only able to express himself with his eyes, until he said his last words on shaking hands with me for the last

time, 'We thank you'. I know that I am acting as the deceased would have wished me to when I pass on these words of thanks to all his colleagues, to all those who helped with his work, and to his friends in the scientific community."

28. Final Comments

In order to pay tribute to Ludwig Prandtl and in memory of his pioneering work in aerodynamics, an award was created four years after his death. The aim was both to honour the work of future specialists in aerodynamics and to preserve his name. It was decided to adopt, as a symbol, a golden ring bearing his name in letters that stood out: the LUDWIG PRANDTL Ring. The figure of an eagle was carved in the large stone made of rock crystal, which was intended to symbolise the freedom of the intellect.

The 4th February, my father's birthday, was chosen as the date for presenting the award for the first time in 1957. *The Wissenschaftliche Gesellschaft für Luftfahrt* (The Scientific Aeronautical Society) decided to award the highest honour to a researcher in aerodynamics to Theodore von Kármán. As he was unable to be personally present in Göttingen to accept the reward, he wrote a letter which was read at the ceremony. "I consider it to be a great honour that the Ludwig Prandtl Ring has been awarded to me on the first occasion of its being awarded. ... Prandtl's influence was decisive for my scientific development and I constantly remember him with gratitude and admiration."

Since then, the Ludwig Prandtl Ring has been awarded to many deserving researchers in the field of aerodynamics who once worked alongside him as his students. These are scientists of a special class, who advanced science and gave it a new impulse.

After Ludwig Prandtl's birthday had been celebrated for the 100th time, on the 4th February 1975, a commemoration took place, on the 3rd April, in the municipal hall of Göttingen, in the setting of the annual scientific meeting of The Association of Applied Mathematics and Mechanics [9]. My father had been its president for more than 20 years. The Ludwig Prandtl lecture was given at the meeting, on this occasion for the eighteenth time, by Fritz Schultz-Grunow. In the same year, the Max Planck Institute for Fluid Dynamics issued a commemorative publication on the occasion of fifty years of its existence [18].

Appendix

Prof. Dr. L. Prandtl

Enclosure to the letter dated 28th April 1941 – pp. 314/41 –
addressed to Reichsmarschall Hermann Göring

I. On the subject of theoretical physics

It is the task of theoretical physics to present a logical edifice of theories that is free from inconsistencies and which can impose an order on the facts observed of such a kind that even findings which are widely disparate can be explained jointly and, at the same time, as precisely as possible. The laws deriving from this work can then, in turn, serve to predict the results of new experiments. One must expect that a theory is free from intrinsic logical contradictions and that it takes into account all of the facts it is called upon to explain. Depending on the hypotheses on which the theory is based, the very same group of facts can produce several permissible theories. If a new fact is observed which is consistent with one of these theories, but not with one of the others, this other theory must be abandoned. This case occurred at the turn of the century as a result of the experimental discoveries generated by the so-called Michelson interference experiment. Because of the Newtonian notion of space and time which, up until this time, was considered to be irrefutably correct, this experiment would have had to have established a statement about the relative velocity of the earth in relation to the world ether. But, despite a number of more refined repetitions, it always produced negative results (instead of a displacement of the fringes, there was no displacement). In this way, the Newtonian notion of space and time was proven to be basically wrong. The variations for all terrestrial processes are, however, so small that one is able to continue to use this old notion of space and time practically. H. A. Lorentz in Leiden was able to show, at that time, that the Maxwell equations of electrodynamics do not contradict the results of new research. This means that an inconsistency does not arise if one interprets the physical world as consisting of electro-dynamic processes. From a precise standpoint, what was now needed was a clear formulation of a way of looking at space and time that would take into account the new findings with complete exactness. One such formulation was produced for the first

time by Albert Einstein. His system is devoid of any internal contradictions but, at the same time, as I have already said, was naturally not the only possible solution, but certainly the simplest.

Confronted by this state of affairs, the Lenard group still has its head buried in the sand like an ostrich and adheres to the Newtonian view of space and time, even today, although this conception has long been crushed as a result of Michelson's experiment. The Einstein notion of space and time, which is now accepted by clearly thinking physicists throughout the world as being the best solution, at present, and which has long been a foundation for the further development of physics and that cannot be lost, is simply not true, in the view of the Lenard group, because its originator was a Jew. All far-reaching experiments which have been carried out since then by Aryans with the aid of the new instrument constitute, in the opinion of those who support Lenard, "Jewish physics".

The situation regarding quantum theory, which also had its origin at the beginning of this century, is something quite different. Human understanding of the physical world developed in relation to the visible environment. According to our present knowledge, this consists of small particles (atoms) which, in turn, are composed of still smaller particles. All visible processes, even those restricted to the smallest space, involve extremely great numbers of such particles and it was believed that all such processes reflect a strict law of cause and effect, from which a "causality principle" could be inferred. The whole of the older theoretical physics is based on such causal connections between individual quantities with one another. Nowadays, since research has long been able to penetrate the inside of the atom and one can, so to say, investigate the prime constituents of matter (with the help of certain methods, these individual objects are separately discernible), it has been shown that the concept of causality fails at this level and that it has to be replaced by a concept of statistical probability. (In the case of decaying atoms of radium, for example, one can in no way specify when a particular radium atom will decay. One can, however, specify the average number that will decay in an hour or a year from a particular amount of radium. Such things are not restricted to radium, but play a role in all atomic processes.) The old principle of causality is therefore seen to be simply a "law of large numbers" as one which is operative in all kinds of questions of statistical wholes. The larger the number is, the smaller are the random deviations from that expected in the case of "causality". The energy transformations

in the atoms, about which one has no detailed knowledge when and where they will occur, in particular cases, additionally have the property that, depending on the type of transformation, quite specific quanta of energy are always transformed (hence the name quantum theory). With such notions, one was able to draw together an abundance of old and new observational findings in a logically unified system. But, for the supporters of Lenard, this was also considered to be “Jewish physics”, perhaps according to the principle which I occasionally have heard, “That which I do not understand I consider to be Jewish”. There were naturally also contributions from Jews to this part of scientific development, but the greatest contribution was made by men such as Planck and Sommerfeld, Heisenberg and Schrödinger.

II. Details of the Lenard circle

1. Lenard himself deservedly established a good name for himself as a result of experimental investigations in which he would probably have also discovered x-rays, if Röntgen had not beat him to it. However, he never considered mathematical theory to be important and things would have been fine if he had not begun to argue about questions of mathematics. In his old age, he wrote a textbook in several volumes, to which he gave the title “German Physics”. This was lacking in the necessary clarity and rigour already in relation to the simple lawfulness of conventional mechanics. But, though it might pass as a textbook for the lower grades, it was certainly not satisfactory for the higher ones.
2. Another exponent of the group is Johannes Stark, the past president of the *Physikalisch-Technische Reichsanstalt* (Physical Technical German Reich Institute). I know Mr. Stark from the time when he was a *Privatdozent* (university lecturer) in Göttingen to be a rather passionate and unusual man. At the same time, he is a quite magnificent experimenter and has made two first-class discoveries of which one - referred to by specialists as the “Stark effect” - has made his name immortal. He never concerned himself with theory, as far as I know, but this did not prevent him, in unbelievably malicious articles of which one appeared a number of years ago in the *Schwarze Korps* (Black Corps), from insulting Planck and Heisenberg without restraint.
3. The group had a number of followers who were essentially engaged in experiments and who, in their way, carried out creditable work. In

contrast, there were also a substantial number of people who considered themselves to be unrecognized geniuses, but who, because of their inadequate achievements in the past, were unable to make great headway and, of course, since the upheaval brought about by National Socialism, had seen a ray of hope. Of these, some were active in reforming the philosophical bases of physics - especially the notion of space and time - but, however, for all of these individuals, the Michelson experiment played no role at all, or to put it another way, they remained, just as before, rooted in the Newtonian view of space and time¹⁷.

4. A particular concern is that of the successor to the Munich theoretician Sommerfeld, who is known throughout the world, to whom gratitude is due for, in addition to many other things, a clear ordering of the laws of spectral lines. His successor, named Wilhelm Müller, was first assistant and later professor of technical mechanics, the former in Hanover and the latter in Prague and Aachen, and who has, up until now, concerned himself with fluid mechanics and aeromechanics, and also written textbooks about branches of this academic discipline. With regard to theoretical physics, however, he has produced nothing, absolutely nothing. Instead of those topics which physicists need for their education, such as electrodynamics, electron theory, optics and radiation, thermodynamics, mathematical statistics and partial differential equations in physics, he teaches - according to his own accounts - aeromechanics and other aspects of engineering mechanics. It cannot be denied that it is useful for university students to learn something about these subjects but, when a substantial part of physics is withheld from them because of this, a state of affairs is produced which one can only describe as sabotaging required teaching. In the November/December 1940 issue of the journal *Zeitschrift für die gesamte Naturwissenschaft* (Journal of Natural Sciences) pages 281-298, Mr. Müller gave an extensive account of his programme. In this article, with

¹⁷ cf. diverse, partly venomous articles by Kubach, Thüring, Dingler, amongst others, in the *Zeitschrift für die gesamte Naturwissenschaft*, which is referred to, in a subtitle, as “The organ of the Reich specialist group natural science of the Reich student leadership”. (On the inside of the cover, there is a list of the members of the editorial colloquium).

the title “The state of theoretical physics at the universities”, he did not neglect to say many unfriendly things about the representatives of theoretical physics. Incidentally, there is an abundant expression of the statement of belief regarding physics on the part of the Lenard group: one can read there that, on the part of the theoreticians, “a mysterious group of authorities”.... compel “in almost a magical way, a commitment to a particular programme” which “threatens everyone who ventures to voice his own opinion, independent of the crowd”. (I must add here that the “mysterious authorities” are nothing more than experimental facts and that the threat of those who think otherwise is nothing more than the legitimate rejection of wrongheaded persons who do not wish to see the facts). The Heling publishing company, Leipzig, is currently publicising a brochure by Stark and Müller with the title “Jewish and German Physics” in which the harshest challenge is made “with regard to a dogmatism still rooted in the Jewish spirit, which neither serves truth nor knowledge but, instead strives to violate nature and tends to degrade it (nature) to a mere servant of formulae”. Moreover, in the brochure “the fundamental difference between this Jewish or Jewish-influenced theoretical arbitrariness and German pragmatic theory” is to be set out using examples and it will make clear that the German pragmatic theory “does not try to explain the given order on the basis of the simplest, clearly comprehensible system of causal laws”.

I think that these specimens of text are enough in order to sufficiently characterise the views of the Lenard circle.

L. Prandtl



Ludwig Prandtl
at his desk

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When Ludwig Prandtl took up the Chair of Applied Mechanics at Göttingen University in 1904, the small university town became the cradle of modern fluid mechanics and aerodynamics. Not only did Prandtl found two research institutions of world-wide renown, the Aerodynamische Versuchsanstalt (AVA) and the Kaiser-Wilhelm-Institut für Strömungsforschung, but with the so-called 'Göttingen School' he also established an exceptionally fertile line of scientific thinking, unique for its special balance of intuition for physics and mathematical precision. The scientific methods developed by Prandtl and his pupils are manifested in numerous dissertations, monographs and textbooks that now rate as classics and hence belong to the fundamental works on fluid mechanics. Yet many of these publications have long been out of print and inaccessible for study. The series Göttinger Klassiker der Strömungsmechanik is thus making available selected publications that emerged from Ludwig Prandtl's 'Göttingen School' or stand in a particular historical relationship to it.

This highly personal biography of Ludwig Prandtl compiled by his daughter, Johanna Vogel-Prandtl, is complemented by numerous photographs depicting Prandtl's working and private life. It completes the picture of the founding father of modern fluid mechanics whose scientific importance continues to resonate to this day.



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