

Ludwig Prandtl

A Biographical Sketch, Remembrances and Documents

German original by

Johanna Vogel-Prandtl

English translation by

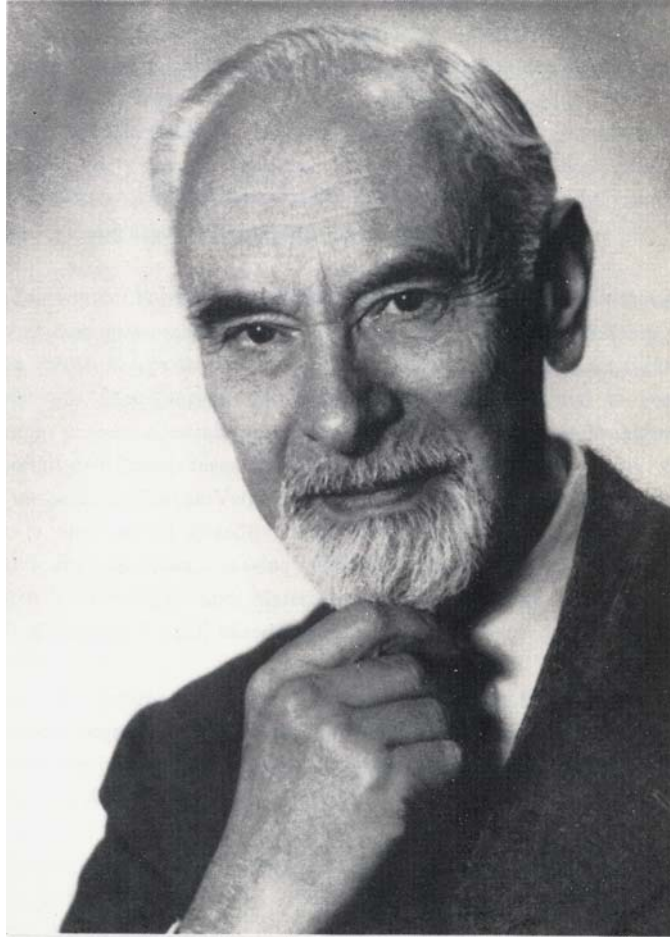
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on the occasion of the 100th anniversary of the publication in 1904
of Prandtl's paper on the boundary layer theory

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Ludwig Prandtl
4.2.1875 – 15.8.1953

A few words about the translation

Ever since I received from Professor Ernst Mueller, now more than ten years ago, a copy of Ludwig Prandtl's biography, authored in German by his daughter Mrs. Johanna Vogel-Prandtl, I wanted to have the text translated to English. Prandtl was clearly one of the greatest fluid dynamicists ever, but his later life seemed to me to be somewhat tragic for reasons that the readers will soon see. I was especially keen that the contents of Prandtl's letter of 1941 to Hermann Goering, decrying the outbursts against "Jewish Science", which had evolved into a political movement in Nazi Germany, should be made public. It must have taken some courage and concern on Prandtl's part to note that "they [the antagonists of "Jewish Physics"] have poisoned the air with ... disdain for the past..." See also Chapter 21 of this book. This aspect of Prandtl's personality was counter to the notion that was in circulation after the second world-war---that he was a naïve man who had buried his head in the sand. I immediately made some inquiries for translation and publication of the book but the project stalled for a number of reasons, including finances. Both Ernst Mueller and the biographer, with whom he was in contact about the possibility of the translation, passed away sometime thereafter, which slowed the project even further.

The occasion of the 100th anniversary of Prandtl's 1904 paper on boundary layers revived the idea in my mind and I was fortunate that Dr. V. Vasanta Ram readily agreed to translate the biography. For him, as for me, it has been a labor of love. As one of Professor Hermann Schlichting's Ph.D. students, Vasanta Ram belongs to Prandtl's academic family, is knowledgeable about both German and English, and thus an ideal person to have undertaken the task. He has worked hard on the translation despite his physical handicap and other hurdles that he and I faced during the exercise. He commands my unstinted praise and gratitude. I also wish to thank Professor Roddam Narasimha for being a steady source of encouragement.

It is my hope to be able to soon place the translation as a book published by an international publisher. This version is complete but various improvements are possible. It seemed important to use the occasion of the IUTAM meeting to distribute the material in the present form on the CD that you currently have in your possession. I hope that you will find its reading as much of an occasion as I did for reflecting on the vicissitudes of life.

One obvious aspect requires specific mention: the author of the German original was not a professionally trained scientific biographer. This book is thus an intimate account of the person she loved and admired. The translator has kept alive the same informal spirit and style everywhere. I have reviewed the translation numerous times but none of my modifications has attempted to alter this feature.

Katepalli R. Sreenivasan
Trieste, 21 July 2004

Author's foreword by Johanna Vogel-Prandtl

Translator's preface by V. Vasanta Ram

Chapter 1. Introduction

Chapter 2. Childhood

Chapter 3. As a student, and an employee at *MAN*

Chapter 4. Engagement and marriage

Chapter 5. 1911-1918, daily routine

Chapter 6. A day at home

Chapter 7. Gliding

Chapter 8. 'Call' to Munich

Chapter 9. Building up of the Institute and new projects

Chapter 10. The new *Kaiser-Wilhelm-Institut*

Chapter 11. Journey to London

Chapter 12. Journey to Japan

Chapter 13. A day at home again

Chapter 14. Journeys on vacation

Chapter 15. The year 1933

Chapter 16. Honorary doctorates at Cambridge and Trondheim

Chapter 17. The house in the mountains

Chapter 18. Pleading for W. Heisenberg

Chapter 19. Voices on the situation at that time

Chapter 20. Congress in America

Chapter 21. Physicists' dispute

Chapter 22. Journey to Romania

Chapter 23. The last war years

Chapter 24. The end of the war

Chapter 25. New beginning at the university

Chapter 26. The first post-war years

Chapter 27. The last years of life

Chapter 28. Concluding remarks

Appendix

Literature cited

Glossary

Author's foreword

By Johanna Vogel-Prandtl

In the course of the last few years, I have felt more and more impelled to sketch a biographical study of the personality of my father, Ludwig Prandtl. As his daughter, I could, after all, use many personal memories as a basis for preparing a sketch that would do justice to the different facets of his personality. Scenes that took place within the innermost circle of the family should not be absent from such a sketch---scenes reflecting Prandtl's nature that I, as the last member of his family, would like to put on record, at least for the sake of my children and of those who knew Prandtl either personally or by name.

I must mention that my uncle, Professor Ludwig Föppl, brought up the subject of writing memoirs again and again in conversations with his brother-in-law, trying to impress on him the importance of doing it on reaching the age he had, just as his father August Föppl had done earlier. Prandtl always put him off, saying with a smile: "Probably later, I still have many other important things to do!" But I knew Father well enough to realize that he had no intention whatever of reflecting upon his own life and writing about it, then or later.

When Father died in 1953, my uncle, Ludwig Föppl, approached me saying: "Now you should write about him!"

In any case, this first suggestion set me thinking on how I could possibly succeed in such an undertaking. One shortcoming would certainly not escape notice. I would certainly not be in a position to give professionally competent interpretations of his scientific work, and could therefore speak only in very general terms on it. But his scientific output has been extensively documented in his Collected Works (*Gesammelte Abhandlungen* [50]), and this is accessible to the reader. Besides, there are numerous further references given, which facilitate the interested reader in continuing his or her study of Ludwig Prandtl's work.

When I finally began sorting out papers to write this biography, it turned out that I could fall back on many published material in these matters that had appeared in journals, articles and letters. These are often quoted here. It is quite possible that aerodynamicists and readers interested in science would find my commentaries on particular works of Prandtl inadequate. My objective here has only been to make at least a reference to all the work that obviously occupied such a central position in his life.

My more important purpose in this book, however, is to describe the "human being" in Ludwig Prandtl. This venture owes much to his letters and articles, and to letters by his pupils, so that my account can for the most part claim a certain authenticity.

Finally I wish to thank my husband for going through the text and for making corrections.

Special thanks are due to Herr Dr. Julius Rotta, whose close participation in my work made him contribute several supplements. He added scientific articles to the book and examined many quotations for their authenticity. The extensive bibliography of Ludwig Prandtl's writings, prepared by him, has added special value to this book. I wish to extend particular thanks to Herr Dr. Julius Rotta also for proof-reading the work.

I feel I owe a debt of thanks also to Herr Dr. Walter Tillmann, the administrator of the *MPI*-Archives, for his obliging help and competent assistance at the stage of the book going into print.

Translator's preface

By V. Vasanta Ram

It is perhaps no exaggeration to state that it is unlikely to find a fluid dynamicist today who is not in some way influenced by works of Prandtl, of which his 1904 paper on boundary layers is seminal. The Translator is no exception. Later, when he was a research student at Prof. Schlichting's *Institut für Strömungsmechanik* in Braunschweig, he had the occasion to come in contact with people who had worked with Prandtl. During this period and later, he obtained glimpses of Prandtl's personality through occasional and informal narratives of people who knew him in person. These accounts, together with what the Translator had read about Prandtl in published literature, generated in him a keen interest in wishing to learn more about Prandtl's personality. This interest remained unfulfilled for a long time, until Johanna Vogel-Prandtl's biographical sketch of her father, "Ludwig Prandtl---*Ein Lebensbild, Erinnerungen, Dokumente*", appeared as a report of MPI in 1993, in German. This publication, while meeting the immediate needs of the present Translator, made him feel that its contents ought to be made known to the community of fluid dynamicists in the world as a whole, many of whom today may not be conversant with German. This feeling would have, most probably, merely stayed as an intention within the Translator's person, had his long-standing friend, Professor K.R. Sreenivasan, not given him the impetus for undertaking the translation into English. The Translator then consulted Dr. J.C. Rotta on his thinking about this proposal. Dr. Rotta had worked with Prandtl and his assistance in the preparation of the biography had been acknowledged by its author. Dr. Rotta warmly welcomed the proposal and introduced the Translator to Herr Vogel, with recommendations. Herr Vogel was very receptive to the idea. The response on the whole was encouraging to the Translator to undertake the task, and the result is the document that is in your hands presently.

Early during the course of the translation, it became clear that, in order to preserve the spirit of the original, it would be necessary to take over many German words unchanged into English. Some of the reasons are the following:

Firstly, the differences between the way research work is organized and conducted in German universities---with the *Instituts* headed by an *Ordinarius* who is provided with *Assistents* and other *Mitarbeiter*---and in universities in the English-speaking world, are indeed very wide. Therefore, there is often no counterpart to certain positions in the German set-up. Literal translation of the designations would be misleading, so the Translator has opted to keep the German word unchanged.

Secondly, the Translator regards it as a sign of respect for the other culture that their proper names, in particular of their towns and cities, should be written as closely as possible to the pronunciation in the other tongue. So the city of *Hannover* is spelt with a double-n, and the city where Prandtl was first employed as *Nürnberg*, instead of as 'Nurenberg'. An exception, however, is made in writing Munich instead of *München*, since the former has firmly established itself in all English-speaking countries.

Thirdly, when following an established course in translating a certain word, a distortion of meaning could occur. A particularly outstanding example for such a distortion is when the word *arisch* is translated as 'aryan', although this is found to be common in many translations. In short, the *NAZI* use of the word *arisch* is almost exactly opposite to the meaning of the word 'aryan' (see Glossary). Therefore, the Translator has kept the word *arisch* unchanged to convey the meaning assigned by the *NAZIs* in their context.

German words taken over unchanged in the translation have been denoted in *italics*. They have been put together in the Glossary at the end, which, although incomplete, attempts to provide a brief explanation of the terms.

The Translator prepared a draft of the translation and sent the same to Herr Vogel for his comments, who then suggested improvements in the draft. Some of these changes have already been made in the current version, but there has not been sufficient time to incorporate all of them. It is hoped that it will be possible to do this soon. The draft, after making these corrections, was sent in an electronically readable form to Professor K. R. Sreenivasan, who has personally attended to the work of lay-out and editing.

First and foremost, thanks are due to Herr Vogel and to Dr. Rotta for their encouragement and support to the Translator to undertake this work.

The Translator owes a deep debt of gratitude to Mr. Arun Prasad, Professor Roddam Narasimha and Professor K.R. Sreenivasan, who went through the draft in detail, pointed out to the shortcomings of an earlier version, and suggested improvements. Without their active support, the translation would not have reached its present stage.

The Translator wishes his work to be regarded as a sign of his thanks to the culture that has nurtured him for so many years, although he comes from an entirely different background. He would also see its purpose fulfilled if his translation contributes towards mutual understanding of cultures, which, he believes, is more the need of the hour than ever before. This outlook is a product of his experiences in life taken as a whole, and reflects a certain philosophy that has evolved therefrom. Although it is hard to trace with precision the origin of a particular trait of this *Weltanschauung*, some personalities, with whom the Translator had constantly been in touch---in person, through correspondence, and through their literary/scientific/other works---have left an indelible impression on him. He wishes to acknowledge the support he enjoyed of these personalities:

Masti Venkatesa Iyengar, author of literary works in the (South-) Indian language, Kannada, and in English, India;
Prof. Hermann Schlichting, Germany;
Prof. Joseph Kestin, USA;
Prof. Keith Stewartson, UK;
Prof. Itiro Tani, Japan; and
Hephzibah Menuhin and Lord Yehudi Menuhin, UK

1. Introduction

What memories do I have of my father? His benevolent nature and inner harmony are still present with me just as his calm and thoughtful manner, which was wholly undeterred by the mostly impatient fervor of his surroundings. I see him in front of my eyes, customarily handling things around him with care. When he raised the weight to wind up the wall-clock, which was, by the way, always well regulated, he did so with his hand supporting the weight and paused for a moment to listen attentively to the regular beat of the pendulum before gently closing the glass door of the clock.

He had a very pronounced liking for keeping and preserving things. Our simple style of life at home remained unchanged over the years. At home, the attention to utilitarian considerations took precedence over modernization. The force of this habit dictated what existed to continue almost without any change. I really do not remember my father ever expressing any material desires. In fact, his tremendous modesty and simplicity enabled him, in fact, to be grateful and contented with small gifts during the post-war years of severe hardship.

He would have been surprised if he came to know of my aspirations to put the past on record, and he would have probably objected by saying that his life, of which I am writing now, had not been very important.

2. Childhood

Unfortunately, that my attempt now to narrate my father's childhood can only be fragmentary, by giving a disjointed account since there is none left who could have helped me unearth all the memories. I will therefore be content with relating details that I have partly taken from my grandfather's mnemonic notes, in which he faithfully, even though only sketchily, recorded the development of his only son, and from stories our father told us from his memory. I have taken out the facts about the family history from the genealogical records gathered together by two cousins of my father, Professor Wilhelm Prandtl and *Ministerialrat* Carl Prandtl.

Ludwig, the first child of Alexander Prandtl, Professor at the Weihenstephan Agricultural College near the town of Freising, and his wife Magdalena (nee Ostermann), was born on Thursday 4 February 1875 at quarter to seven in the evening on the third floor of the house of his widowed grandmother Maria Ostermann, whose husband was a merchant by profession.

At that time, the house of his birth in Freising, at Hauptstrasse 64, was in the possession of the Ostermann family for over one hundred years. The founder of the family was Ludwig Ostermann who had moved in from Austria to settle there in 1760. Together with his brother Franz, who was working as a glass painter, he had left his hometown Kranebitten near Kiefersfelden to build up a new existence in Freising. Their newly founded grocer's shop was adjacent to one of the city gates known as "Veitstor". However, this gate had to be pulled down in 1875 due to its dilapidated state, which in turn required some changes to be made in the house of the merchant, too. To the west of the house, there were horse stables and flat cots that belonged to a pub. The rear windows allowed a view on medieval gables and small back-yard houses.

In 1869, when he took up his position as a professor at the Weihenstephan Central School of Agriculture in Freising at the age of 29, Alexander Prandtl rented a room in the merchant's house from the widow Maria Ostermann. He came there from Munich where he had completed his studies at school and university. After attending the Munich Polytechnical School, from which he had graduated as a *Kulturingenieur* (Cultural Engineer) and assumed a position of a civil servant in Lower Bavaria. He had now been called to take up the position of a Professor of Applied Mathematics and Soil Improvement/Melioration (*Meliorationskunde*). The following subjects were also taught at Weihenstephan: agricultural chemistry, drawing of agricultural implements and plants, anatomy and physiology of domestic animals, forestry, meteorology and others. The associated brewery served for practical training. Alexander was working there as a scientist in the laboratory of the experimental dairy station. From 1870 to 1875, he primarily worked on the design of a continuously operating milk centrifuge. The idea to deal with the problem of fat extraction from milk through the centrifugal force came from his brother Antonin, who had written a paper on this subject in the Polytechnical Journal eleven years ago, approaching the practical task of increasing the concentration of milk from a chemical point of view. Alexander succeeded in making substantial improvements to his brother's design, and showed his new fat extraction machine at the 1875 World

Exhibition in Frankfurt on the Main. The world's first continuously operating milk centrifuge attracted considerable attention as an exhibit and provided inspiration for further development. Later on, the same model was exhibited in the Dairy Division of the *Deutsche Museum* (in Munich). In the following years, he developed a new machine, a milk separator that enabled the milk to be separated into its individual components without getting creamed. Alexander also published several scientific/technical articles in the *Weihenstephaner Milchzeitung* (Weihenstephan Milk Journal) which I want to list here for the sake of completeness. An article from 1877 was "*Über den theoretisch zu erwartenden Effekt der Aufrahmung durch Zentrifugalkraft*" (On the effect of creaming from centrifugal force that may be expected on theoretical grounds), and in 1879 it was "*Über den Einfluß der durch Erwärmung oder Abkühlung der Milch verursachten Strömung*" (On the influence of the flow caused by heating or cooling of milk).

The family Prandtl or Präntl, as it was also written earlier, had been resident in Munich for several generations since the beginning of the 18th century. However, when tracing back the line, the forefathers are found in the Tegernsee region (a lake in Bavaria). One of these forefathers is the carpenter Bartholomäus Präntl, whose eldest daughter Maria is mentioned in the chronicles in Egern since she founded the Marian Association (*Marianische Bund*) in her home-town. On 19 January 1770 she died after a godly life, and the following lines were added to the death register of Egern:

"Huius nomen, benigne lector, non leviter praetereas, illius Maria 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. ab 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."

"Her name, dear reader, should not be ignored, as it is the name of that Maria who taught countless souls by word and example to follow the Blessed Virgin in the virtue of chastity, as far as this is possible. She was the founder and supporter of the so called *Marianische Bund* in Egern and really a real benefactor, who dedicated all that she earned in the sweat of her face to the poor and to the Blessed Virgin. Draw your conclusion, dear reader, as to the kind of a death she had after leading such a pious life. She was obsessed by an evil demon. However, believe (me), that it was no misery to her but a torture to the demon, to the demon, I say, who was certainly very irritated on having to see all those outstanding devotional deeds she did day by day. On 19th January, she was relieved from both the uninvited guest and of the bonds of flesh in order to eternally dwell in heaven with Christ, who was her only love and whom she had often received in deep devotion to God in the holy sacraments before she departed this world.

Maria's brother Wolfgang Präntl, a carpenter by profession like his father, was the first, who moved to Munich, where he found a job at the Anger monastery. It would go too far to list all the family members over generations. So I will skip to the grandfather of Ludwig Prandtl, Antonin Prandtl, who was born in 1795. As a young man, he was a soldier by profession before he chose a career in the civil service, where he rose to the position of an actuary (*Aktuar*) and tax liquidator (*Steuerliquidator*). At the age of 40 and occupying 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, came from a famous artists' family that is mentioned in Franz Bienback's "History of the *Cisterziener Stift Waldsassen*". Different members of his family created wood carvings for the monastery church in Waldsassen. Court sculptor Michael supplied his artwork for the chambers of King Maximilian I in the old *Residenz* that were destroyed by a fire. Moreover, he created decorations in the royal box of the court theatre. Later on, he devoted himself to making carvings from ivory, alabaster and nacre. Some pieces of this ivory cabinet are displayed in the Bavarian National Museum. Some small works he created at the beginning of the 19th century passed into our possession. These works are very fine woodcarvings that are also museum pieces. In 1868, Michael died in Munich at the age of 96.

Antonin Prandtl and his wife had bought a garden plot in Untergiesing, where they had set up a small coffee house. Their guests were only young people, most of them artists, who ventured into the "strange" suburb. The generous and liberal atmosphere of life there with many stimulating ideas from the guests probably brought pleasure into the life of Antonin's growing children - they were three boys and one girl - and certainly also stimulated their intellectual development. Their parents enabled them to go to a secondary school and to pass a qualified vocational training. Carl attended Justus Liebig's chemistry lectures, then went over to study fermentation chemistry and exclusively devoted himself to the subject of brewery. He was appointed as *Assistent* for chemistry and technology at the Weihenstephan Agricultural College. In this specific field, he provided several scientific works and contributions. He invented the Prandtl filter press and the Prandtl yeast press, and became the general representative for these brewery machines. Mention has already been made of the intellectual achievements of the younger Antonin. After not being granted the possibility to put his ideas in dairy technology into practice, he addressed himself to the field of brewery. He worked as a master brewer in Switzerland, spent many years in Hamburg, and returned to Munich in 1884, where he and his brother Carl bought the Giesing Brewery. A decade later, when electrification entered the breweries, they could not keep pace with this change in their small plant and went insolvent. However, thanks to their scientific knowledge they could still act as experts in this field. The youngest child, Anna, married a district judge (*Amtsrichter*). Alexander, the father of Ludwig Prandtl, has already been mentioned above.

The living conditions at the Ostermanns' in Freising, where Alexander had rented an accommodation, were much more modest and less spacious than those of the Prandtl family in Untergiesing. Of course, life in the suburb of Munich, actually connected with the *Residenzstadt* (Munich) through a horse-drawn tram, was freer and more exciting

than in the small town on the left banks of the Isar river at the mouth of the tributary stream Mosach. At the time, when Alexander settled in Mosach City, as the town is often called, the number of inhabitants amounted to 7000. The spires of four ancient churches towered up among the old houses. On a hill within eyesight known as the Domberg, there was a basilica with adjoining monastery buildings in which a seminary was housed. The widow Maria Ostermann, nee Döbl, was the daughter of a master baker from Freising. The trade merchant Ludwig Ostermann - as he is designated in the records of the Freising church register - was 22 years older than his wife. He died when the children were still very young so that Maria Ostermann alone had to bear the burden and the responsibility for the growing children. Her four children, Magdalena, Ludwig, Leopold and Maria were brought up from their very roots in strict obedience to Catholic conventions, whatever the reason for this might have been, whether the close proximity of their living site to the holy centre, or the attachment to tradition. She saw to it that they attended the monastery school and went to church regularly since she had complete confidence in the authority of the church that was supposed to help her in her difficult task. When Alexander met his wife-to-be, she was just 14 years old and had not yet finished school. Right from the beginning, he had a special affection for this little, gentle girl, who conscientiously took on her domestic and school duties in a touching manner. Many exercise-books of Magdalena are still preserved. They are full of pious words and maxims, written in her flowing and flawless handwriting. My father, Ludwig Prandtl, also kept a few prize books of hers containing lines of appreciation, such as: "1st prize from the general yearly passing batch for Magdalena Ostermann, student at the Freising High School for Girls. All these gift books were first prizes. Alexander became more and more attached to this serious-minded and shy girl. He and Leni celebrated their engagement on 18 September 1872.

He married the 18 years old girl on 19 March 1874 at the parish church in Freising. Both were Catholic, but Alexander was not firmly rooted in the church any more. In 1909, Ludwig Prandtl wrote in a letter to his wife-to-be: "Until a short while ago, I was a strict Catholic - probably the heritage from my pious mother." He asked Gertrud Föppl about her attitude to religion and went on to write: "If two have to harmonise with each other, their religious belief is a very important point. Unfortunately, I noticed with my parents, who were good souls, but harmonised with each other very poorly, whether in matters of religion or in the education of children or something else. Apart from the gloom that was caused later by the sad ill-health, I consider the married life of my parents as a typical example for a couple that married for mutual love, but did not get happy due to a lack of understanding for each other".

When Ludwig Prandtl was born in 1875 his mother was only 19 years of age, his father 35. Here are some excerpts from his diary: "The ceremony of baptism was held on 11 February. On 4 May we all went to the shooting grounds to plant 12 fir trees in order to keep Ludwig's birth in memory. On 16 December, Ludwig fell from the cradle with no visible signs of being hurt. The child was weighed and its growth measured on every birthday. Entry on 4 February 1879: "Ludwig can count objects up to 10 and precisely repeat pitches sung to him."

In the meantime, the young family had moved into an apartment of its own which was also on the *Hauptstrasse* at number 41. The entry on 30 April '79: "Ludwig can be sent as a messenger to (his) grandmother." During these errands, he made many observations on his own. Full of curiosity, he peeped into the openings of the drains dug up by the road workers and was coming home late. He told me what follows from his very early memory: As it often used to, the lonely and dreamy child was engaged in playing on the street in front of the house when suddenly a downpour came down from the dark clouds. Instead of hurrying into the house, the child stayed out in the rain since it was full of excitement to watch the gutter collecting more and more water, draining off the leaves and paper clippings. At that time, a woman hurried past him with her dress tied around like an apron and with the seam of her wide skirt thrown over her head like a hood. Little Ludwig then made the unexpected discovery that there were legs hidden behind the skirts of women that looked the same as those of men. The fashion of those days with skirts reaching down to the feet and the prudery at that time had kept this a secret from him. Another anecdote that happened later took place at the railway station. His father took him there to pick up relatives from the train. After having welcomed the visitors, they all slowly went along in the crowd trying to reach the gates. However, suddenly the father notices that Ludwig is not by his side and not seen anywhere. A little excited, the father runs along the platform. There he sees his little son lying on his belly at the edge of the platform, directly in front of the locomotive, inspecting and watching the same from the bottom. As he fetches him, the parent is not spare with harsh words. When relating this story my father assured me that he was not aware of any wrongdoing; understandably he was bored listening to the conversation and so he went pursuing his own interests.

Another anecdote related to Easter comes into memory: The painted Easter eggs had been hidden in the garden for the little boy Ludwig to find. With thoroughness he went about searching for them and deposited his collected bounties in a basket that his mother kept ready for him. But what a disappointment there was on his face when he took charge of the basket. He had seen at a glance that not all of the eggs he had found actually were in the basket. He started to thoroughly examine and count the eggs, and to his parents' surprise, he had stored in his memory the number of Easter eggs of each kind he had gathered, which did by no means tallied anywhere near the number in the basket. The reason was that his father, in order to extend the joy, had repeatedly taken the eggs already found from the basket and had hidden them again, apparently believing that a small boy could be cheated this way. He then had to confide to his son the whole truth of what he had done, lest he should be blamed for deceit and fondness for sweets.

1880: "Ludwig begins reading printed matter". 1881: "Although Ludwig is lean he looks healthy. He wants to be a gymnastics teacher." He entered school in the fall of 1881. 1882:" Ludwig ranks first among 82 children!" He also remained at the top in the following years at primary school. In September 1885 he was admitted to the Latin School that is situated on the Domberg Hill near Freising. On 4 April 1886, Ludwig went to his Holy Communion, and the confirmation was celebrated on 15 May.

The domestic conditions were quite strained during these years due to frequent illness of his mother. Her delicate health had been shaken by severe strokes of fate, and she was

shattered both physically and mentally. In April 1877 she had given birth to her second son, who unexpectedly died one week later. A third child, a little girl, was born in January 1879, but suffered from jaundice, of which she died two weeks later. In summer, Magdalena Prandtl went alone to Altötting to derive comfort from her prayers. In 1881, she delivered a stillborn child in its sixth month, and the same misfortune recurred in 1883. She has further two miscarriages after which she is completely exhausted. In the language of present medical knowledge it was obviously a case of "Rhesus negative". Preventive measures could not be taken at that time, since there was only insufficient knowledge in this field.

Magdalena Prandtl often suffered from angina pectoris. In 1888 the depression turned into a nervous disorder, and she could no longer stay at home. The doctor suggested to the father to admit her to a psychiatric institution in Munich. When she returned home half a year later she was still confined to bed. Since her state of health showed no improvement she was brought to a nursing home in Neufriedheim.

His mother's sufferings cast a mournful shadow on Ludwig's boyhood years, although his father took care of him even more. Magdalena's sister Marie, who was not married, kept the household for her brother-in-law during those difficult times and looked after her nephew with much care. She played on the piano with Ludwig and sang with him folk songs and *lieder*. However, Ludwig's experiences made in his childhood centered around Alexander's personality, whereas his mother's influence waned more and more due to her ill health. The father encouraged his son's early interest in physical sciences; he gave him his books and explained to him the function of the machines and instruments described therein. He also encouraged him to observe nature, which happened very often during the hiking tours (*Wanderungen*) they made together in their mountainous home region. His father's very broad knowledge of nature satisfied the boy's intellectual demands, which found expression in many questions. To substantiate his private lessons in nature study, his father one day brought home a box with two white mice that was kept on the balcony. Soon, the first baby mice were born and needed care and attention. This became a lively occupation for the lonely boy. However, within a few months the mice family had grown to assume fearsome proportions so that the decision had to be taken to stop the successful mice breeding.

Moreover Alexander was concerned with educational problems. He was vexed that Ludwig often was dreamy and negligent in doing his homework. This taxed his patience to the utmost so that sometimes he took to very stern measures to cure him of these weaknesses. In this way, he formed the boy, whose development was so close to his heart. He meticulously noted down details of Ludwig's development in his diary, including certificates, illnesses and travels. Alexander's brother and sister, Carl and Anna, and of course also Carl's children, who were of the same age as Ludwig, often came for a visit. They also met quite often at Munich, the old hometown. My father had very pleasant memories of the days and weeks he spent in Dingolfing visiting his aunt Anna, his father's sister. Anna, who had remained childless in her marriage, used to invite several of her nephews and nieces to stay with her during their holidays, and at no time did she find their light and cheerful ways in the garden and within the house unbearable.

Ludwig was at ease and felt very much at home with this aunt, who was the wife of *Oberamtsrichter* Kastner. Among his cousins, he forgot his unhappiness over his own circumstances. His relatives of the same age were his best playfellows and could substitute the lack of any siblings at least in part. Ludwig was attached to them for his whole life. One of them wrote her cousin Ludwig in 1944: "I was thinking of how you used to ponder over equilibrium and statics. Do you remember your after-dinner experiments with bottles, plates, forks and knives that mostly reached fearful heights?"

At that time, also the grandmother Anna Charlotte Prandtl was living at her daughter's in Dingolfing and was very happy to see her growing grandson visiting her often.

The travels he did with the father during the school holidays were also a kind of experience he later recalled with pleasure. These vacations, "*Vakanzreisen*" as Alexander noted in his diary, took him either to the lake area around Munich or, via Innsbruck, to the valleys of the Austrian mountains, or sometimes even to South Tirol, to Bozen and Meran. When they stayed in one place a little longer during the holidays, Ludwig spent his time making drawings of the landscape paying attention to details. His hometown Freising often was also an object of his eagerness to draw. The enthusiasm, with which he worked on the details, is an evidence for his talent at that age and his patience at work.

Alexander attached importance to the development of musical talents of his son. At the age of nine Ludwig got his first piano lessons by Professor Durmayer. The father himself liked to play the piano and used to give music performances for evening entertainment with a teacher in Freising. He had also achieved certain virtuosity in the art of playing the horn, just like his brother Carl. Once Alexander and Carl gave a public performance with horn duets in which the programme lasted almost two hours. The occupation with music probably fulfilled Alexander's inward needs, as his religion did not provide him with the necessary refreshment. His attitude towards the church was more and more determined by denial. He could not reconcile the dogmas of the Catholic belief with his scientific and critical thinking. In particular, the dogma of the Pope's infallibility that was proclaimed in 1870 later appeared to him as being unacceptable. Probably, he was under the influence of the group of Munich professors, who protested together against the dogma (*Altkatholiken*). In 1886, Alexander left the church for ever.

In Ludwig's life, the father's influence in religious matters cannot be overlooked. The responsibility the father had to bear for the care and welfare of his child needed considerable time due to the ill-health of his wife, which however he could not afford, since his job required frequent travels. In the fall of 1888, he therefore decided to admit Ludwig to the *Ludwigs-Gymnasium* (Grammar School) in Munich, an education institution under royal patronage, and spoke with the Director Willy von Coulon. Ludwig was put up in the boarding home Hollandem and went home only during the holidays. Sometimes my father spoke of these times as difficult ones for him. His experiences in living together with other schoolboys were not pleasant, since he often was teased and domineered by stronger and defter schoolmates. Inwardly, he was helpless against these insolences and suffered silently. At the end of the school year, his father took him back to Freising, as his mother had slightly recovered from her illness. However, as mentioned,

earlier the recovery was only temporary, her health taking a turn for the worse soon. For the following two years, Ludwig attended the Latin grammar school at Freising. Thereafter, when his mother had to retreat from all family life, the boy was sent on the Munich *Gymnasium* again. This time, he was better able to assert his position and found friends. One of these friends, Oskar Winsauer, who had become the City Priest at the Heilig-Kreuz Church in Munich-Forstenried in 1940, remembers these days at the hostel and the school:

"6. April 1941.

Lieber Studienkollege!

Und jetzt schreibe ich doch! Oft schon wollte ich mich hinsetzen, um meinen lieben Koäven und Mitzögling vom Hollandeum zu schreiben und zu gratulieren, besonders damals, als im 'Neuen Münchener Tageblatt' Dein Bild erschien samt der Mitteilung, dass Dir eine hohe staatliche Auszeichnung zuteil geworden ist - aber immer hielt mich der Gedanke zurück, was wird der berühmte Wissenschaftler um einen einfachen Pfarrer scheren. Nun habe ich Klotz und Reiter getroffen, die mir mitteilten, dass Du ihnen freundlichst ein Lebenszeichen gegeben habest. So möchte ich Dir auch ein Lebenszeichen geben und Dir einliegend eine Urkunde aus dem vorigen Jahrhundert übermitteln. Armer Leidenskollege! Aber, was musst Du auch Deine Karte beschmieren? Übrigens wird das kaum der einzige Pultarrest gewesen sein, den wir erhalten haben. Ich wenigstens brachte deren 60 pro Jahr zusammen - weil ich mir erlaubte 'mit Tinte ins Buch zu schreiben' oder 'wegen geräuschvollen Niesens' und dergleichen mehr - meist aber wegen Unaufmerksamkeit.

Solltest Du einmal wieder während Deiner Ferien nach München kommen, würde ich Dich herzlich bitten, mich anzurufen."

"6 April 1941

Dear Fellow Students!

After all, I am writing you now! I often wanted to sit down to write and congratulate my *Koaeve* (chum) and fellow pupil at the Hollandeum, in particular at that time when your photograph appeared in the *Neues Münchner Tageblatt* together with the announcement that you have been granted a national honour T¹---but one thought always held me off: What would the famous scientist care for a simple priest? Now I met Klotz and Reiter, who told me that you have been kind enough to give them a "sign of life". I wish to give you a "sign of life", too, and I am enclosing a document from the last century. Oh, poor companion in misfortune! But why did you have to smutch your card? By the way, that would hardly have been the only punishment (*Pultarrest*) we got. For me, the total came

¹Possibly it is: *Freistaat Bayern, Goldener Ehrenring mit dem Bayerischen Staatswappen, München, 7.5.1926* (Free State of Bavaria, Golden Ring of Honour with the Bavarian Coat of Arms, 7 May 1926)

up to 60 per year---since I permitted myself to 'write with ink in the book' or to 'sneeze aloud' and some things more alike---but mostly due to poor attention.

If you happen to come to Munich again during the holidays I would request you from the bottom of my heart to call me on the phone."

In all these years, Ludwig's performance in the scientific subjects was far above average and after some time, this intellectual superiority did earn him the respect of his classmates.

In 1894, he could start studying at a university and he stayed in Munich. For four years he was a student attending lectures at the *Technische Hochschule* in Munich.

In the meantime, the home in Freising had been broken up completely. Alexander, who was suffering from heart weakness, retired at the age of 52 and moved over to his sister Anna at Dingolfing with the burden of fate resting heavily on him. He died there on 17 March 1896. In 1898, after much suffering, his wife Magdalena was relieved of further suffering by death. Ludwig stood alone in life now. He was completely absorbed in his science, which led him to success after a few years only. I am deeply touched to say that it is very sad, indeed, that his parents did not live to see this joyful development.

3. Years of study---*MAN*-appointment

Ludwig Prandtl's interests focussed on physical and technical subjects, so the decision on the subject of study at the university posed no difficulties. He chose to study mechanical engineering. Following the advice of his caring father he began in August 94 itself, - he had completed school in July---a three-month period of practical training at a workshop. This apprenticeship, which had to be passed before taking up the study at a university, took him to the mechanical engineering company *MAN* at Nürnberg where he had applied for an employment. There he worked in the foundry as well as in the pattern shop. After this period of practical training, in autumn 94, he took up his studies of the theoretical parts at the *Königliche Technische Hochschule* (Royal Technical College) in Munich.

His teachers in the most important subjects were: Professor of Mechanics, August Föppl; Professor of Mathematics, S. Finsterwalder; Professor of Physics, L. Sohnke; Professor of Theory of Machines, M. Schröter.

He used the time during the holidays he used for further practical work, partly again in Nürnberg. In 1898 he graduated from the *Technische Hochschule* as a mechanical engineer.

It is certain that these years of study in Munich widened his horizon substantially. He became a member of a student fraternity called *Münchner Gesangverein* by name, which brought together mostly students oriented towards music. My father had a beautiful bass voice, and he liked singing in a choir for several voices. Just as his father once did, he too picked up a wind-instrument and learned to blow on the waldhorn (French horn). A member of the fraternity, who wrote him 40 years later, referred to this in his letter of 5 May 1939. Hermann Peckert wrote the following: "I presume you still remember me; although perhaps not as clearly as I remember *Trompetenprandtl* (trumpet Prandtl) with his full black beard and his cheerful temperament that was always unshakeable. In all likelihood, this has not changed. Possibly you have given up trumpet blowing after you did enough studies of the *Luftwirbel* it generated" However, the piano remained his favourite instrument. After six years of practice, he had reached a level of respectable proficiency. He played sonatas of Beethoven, Haydn, and Mozart. He sang Schubert's *lieder* to his own accompaniment on the pianoforte.

The students (members of the fraternity) also went on hiking tours in the surroundings. In one or the other small village church, he climbed up the steps to the organ, examined the bellows and played preludes in all registers, one following the other. He felt a special kind of love for this versatile music instrument.

Much later, when his *Institut* at Göttingen was expanded, he even toyed with the idea of having an organ installed in one of the halls.

There were several occasions of social gathering. My father told me of a "laundry festivity" in the carnival period, which was celebrated with much colourful imagination. Most of the women, dressed in the costumes of Dutch women, brought laundry baskets

with them. Clotheslines were put up everywhere in the hall on which everyone could hang up her own clothing. The decent custom was of course respected--no piece of clothing that could not be named in public! But towels, serviettes and pillowcases hung very soon on the clotheslines all in a tumble. And, in these surroundings that resembled a drying loft, dancing went on merrily.

He was a frequent guest at the house of his uncle Carl Prandtl, who then lived in Munich. He made preparations for hiking through the mountains with his cousin Carl or he accompanied his cousin Clara on her walks along the Isar or through the Nymphenburg Park.

When Prandtl passed the final examination in 1898 with the grade "*sehr gut*" ("very good"), Professor Föppl offered him the job of a *Hilfsassistent*, which he gladly accepted. The post, which was meant for one aspiring to earn a doctor's degree, was assigned for one year only. Now, after completion of his studies, Prandtl should be conscripted for military service. For this reason, Professor August Föppl wrote the following letter of request to the Commando of the Royal Pioneer Detachment:

"In the beginning of the new academic year in autumn of this year, we plan to start tutorials in the mechanical-engineering laboratory of the *Königliche Technische Hochschule*, of which I am the director, and for this purpose, we intend to employ another assistant. Since this branch of study is being newly founded, it is crucial to fill this position with a properly trained engineer. Herr Ludwig Prandtl, who will be leaving the *Hochschule* at the end of the semester and is due to enter (military) service, is especially qualified for this post. If it is permissible to postpone Prandtl's conscription for military service by one year, I would earnestly request the *Königliche Commando* (The Royal Command) to do so. Thereby, this would render an important service to the education at the *Königliche (Royal) Technische Hochschule*. Hoping that my request would be granted I remain your most devoted,

Dr. A. Föppl, Royal Professor."

The request was allowed. The period when Prandtl worked with August Föppl in his mechanical engineering laboratory can be dated exactly: from 1 October 1898 to 30 November 1899. Besides attending to the duties of a teaching assistant at the courses, he worked on various experimental and theoretical problems on strength of materials and elasticity. One of them was worked out and submitted as his doctoral dissertation (*Doktorarbeit*).

It was customary in those days for an *Assistent* to be invited by his professor to his home also. This custom was an attempt to instil in the young student a feeling of security in matters of human relationships. As first and foremost of course, the invited young man had to drive in by cab on a Sunday, present his visiting card to the house-maid and, removing the white gloves from his hand, to be greeted by the professor and his wife in the drawing room. The Föppl family did not stick very closely to this etiquette, so Prandtl could feel at ease with them. When he was invited to this family for the first time, he also

got to know the children. At that time, my mother, the family's eldest daughter, was 16 years old then, a shy blonde. They also had two sons, both going to the *Gymnasium*, and a little sister at the age of six. When my grandmother learned that the new *Assistent* had recently lost both of his parents, she often invited him for lunch or dinner with their family.

One of the two sons, Professor Ludwig Föppl, Prandtl's future brother-in-law, has given me a small note he made for himself under the heading "Memories of Ludwig Prandtl". His description of the personality and efficacy of his brother-in-law would add to my account in many respects. It begins with memories of those days:

"The first meeting with Ludwig Prandtl that the author of this note still remembers could have been in the year 1898 when the twenty-three year old Prandtl was an *Assistent* of my father August Föppl, and was invited now and then by my parents for Sunday lunch. He was glad to stay on with us for coffee after lunch, especially since my mother treated him with motherly affection. This practical woman with a kind heart felt that this young man, who was so lonely and was exposed to life without any womanly help, should occasionally be taken under her wings. She gave him advice in some practical matters, which certainly helped him to master his daily life. Once, when she saw that the hanger of his overcoat was torn off, she sewed it on, and when Prandtl took leave of us, he was not just a little surprised that brownies had been at work in the meantime and put his overcoat back in order. During one of such visits by Prandtl, in the Christmas season---I was eleven years old, my father suggested to me after lunch to play a Christmas carol on my violin for the visitor. I was hesitant and my playing was only a modest success. I do not have that fine ear that Prandtl had, and I can imagine today that it was far from a pleasure for him to have to listen to me. After I finished playing, he remarked that the violin seemed to be a little out of tune. I noticed with what care he expressed his criticism in order not to hurt me.

When he was my father's *Assistent*, Prandtl worked on his doctoral thesis. The subject of his thesis that he chose all by himself was "*Kipperscheinungen an belasteten Staeben*" ("lateral deflection of loaded bars").

Since this first work of his, which he carried out entirely on his own, already shows the characteristic signature of the later Prandtl, it is appropriate to go briefly into the problem and the way it was handled by Prandtl. Consider a T square kept horizontally, clamped at the T end, and the other end (the vertical longer edge of its cross section) loaded by an incremental weight. In this configuration, a proportionately small weight causes a lateral deflection of the loaded end. Prandtl introduced the term *Auskippen* ("deflecting away") for this movement, which has been generally adopted since then for such phenomena in loaded structures and has a great practical significance in building design/construction.

Although an explanation for this "deflecting away" had been sought several times before, it was left to the young Prandtl to succeed in completely explaining the observed phenomenon. Following his line of thoughts that led him to the solution of the problem in the dissertation, the close proximity of the mathematical approach to the observed

geometry, as the loaded structure tilts away laterally, is striking as particularly characteristic. His extraordinary skill at capturing the essential elements of an observed phenomenon through a suitable mathematical-physical ansatz is already manifested by his first scientific work.

With this dissertation completed in 1899, Prandtl could not get a doctor's degree at the *Technische Hochschule München* (this institution was given the right to award doctor's degrees only in 1900) , so that he submitted the work to the university. The *Philosophische Fakultät* of the Munich University appointed the renowned mathematician Ferdinand Lindemann as the referee. The examiner in the main subject was Professor Leo Graetz. The viva voce took place on 29 January 1900. Since the finding in the dissertation was that the key differential equation for lateral torsional buckling belongs to the type of Bessel's differential equation and since the numerical evaluation of the Bessel's function of a certain order was done for the first time in this dissertation, the mathematician was interested in the work, and Prandtl passed the doctoral examination with a good grade." (Quote from Ludwig Föppl)

The title of the dissertation was: *Kipperscheinungen, ein Fall vom instabilem elastischem Gleichgewicht* (Lateral torsional buckling: A case of unstable elastic equilibrium). Its publication was a slightly long drawn affair; the dissertation appeared in Nürnberg in 1901[28].

Of course, the printed dissertation was immediately sent to August Föppl. He replied with his letter dated 21 February 1901:

"Dear Herr Prandtl:

I have been very happy with the fine piece of work that you sent me, and I went through it immediately from beginning to end. I was especially very pleasantly surprised at the detailed and circumspect discussion of all the different cases connected with lateral torsional buckling (*Kipperscheinungen*). I had not known before that your work would cover such a large orbit of phenomena. It is for the first time that I have come across such an excellently accomplished piece of work from one of my students, which, therefore, makes me all the more happy."

By now the period of study in Munich was completed, and the professional career began. He wrote to the government building officer, *Baurat* Anton Rieppel (known as the builder of the *Müngsten* bridge, the highest railway bridge in Germany) in Nürnberg in reply to a letter from him: "In the matter regarding your valued offer I would be very glad to take over the set-up of the laboratory, and I am ready to enter into an employment with you on 1 January. Once everything is running smoothly in the laboratory, it will perhaps be possible for me to change over to the office of either gas or steam engines. But these things are only in the future, which need not be discussed here now.

I have also taken the liberty of enclosing a copy of the testimonial given to me by Herr Professor Föppl, at the time of termination of my work with him.

I am looking forward to your favourable decision and, if need be, am willing to come over and talk with you in Nürnberg at any time you desire."

On 1 January 1900 he joined *Maschinenbaugesellschaft* in Nürnberg as an engineer. At that time, the company merged with *Maschinenfabrik Augsburg* to become *MAN*. Here, in the plant that was already familiar to him, his work was that of a *Mitarbeiter* in the design office. There were plans for a new works building, and drawings had to be made ready for installation of the machinery. Among other things, the young engineer had, the assignment to make improvements to a defective plant for pneumatic suction of the shavings in the new wagon division. This was urgently called for, since work in the carpentry was hampered by shavings that were accumulating in bulk. It also turned out that the dust and the fine wooden shavings, falling off from the woodworking machines, were causing much suffering to the workmen in the carpentry. Because of the resulting air pollution, some of them came down with lung ailments. The suction line was supposed to extend over several barracks. This was how Prandtl's attention was drawn for the first time to the problems in fluid flow. On going through the literature on this problem that was available to him, he could only verify that there was little known for certain in this area. He therefore set out to obtain clarity on several open issues through experiments conducted with relatively rough methods to start with. Based on the results of these studies, the shavings suction plant was entirely rebuilt. The problem was solved successfully by the design of a unit incorporating a cyclone separator, and very soon it was realised that it was possible to reduce the power to be installed to a third of its former value by the choice of better shapes and proper sizes of the piping, and to achieve uninterrupted operation. From that time on, the factory took up production of Prandtl's shavings suction plant in its manufacturing program, and soon received many orders.

During the vacations he regularly went to his relatives in Dingolfing or to Munich, and never missed to meet there his respected university teacher August Föppl, who was interested in following up Prandtl's career.

In the year 1901, a successor was to be appointed to the professor's chair for mechanics in Hannover that had become vacant. August Föppl, who was consulted in this matter, suggested among others the young engineer from Nürnberg, whose doctoral dissertation had proved him to have great talent. Early in August, Prandtl was informed by a letter from the Prussian Ministry for Education that he, among others, had been proposed for the appointment as professor to the chair of mechanics in Hannover, and that he should come to Berlin for a discussion if he intended to accept this teaching position in the event of his selection. A few weeks later, he was informed that he had been chosen. Prof. Carl Runge, who had been holding the chair for mathematics at the *Technische Hochschule Hannover* since 1886, must have exercised a decisive influence on getting the vacant post offered to the young engineer. On 21 August, the appointment order was signed:

"Wir Wilhelm, von Gottes Gnaden, König von Preußen thun kund und fügen hiermit zu wissen, daß Wir Allergnädigst geruht haben, den bisherigen Ingenieur Dr. Ludwig

Prandtl in Nürnberg zum etatmäßigen Professor an der Technischen Hochschule in Hannover zu ernennen."

"We, Wilhelm, King of Prussia, by God's grace, are pleased to announce and hereby make known that We appoint, the engineer Dr. Ludwig Prandtl, till now in Nürnberg, to the professor's chair at the *Technische Hochschule* in Hannover."

On 30 September, after giving up his engineer's position in Nürnberg, he travelled to Hannover as a Prussian civil servant. Being 26 years old, he was the youngest professor in Prussia. He gave lectures in mechanics in the Division of Mechanical Engineering and held tutorials in graphic statics. The examinations that he had to hold in a semester were large in number, and were an additional duty. However, he did find enough time to pursue his own research on fluid flow phenomena. The Nürnberg experiences on the laws of fluid motion had left many of its details unanswered. For example, the question was still open as to why the air stream in a conically expanding pipe does not follow the walls of the pipe, but almost flows as a free jet in the middle of the pipe.

He wrote of his impressions of his move to his relatives at his Bavarian home. The frequent letters, which were conceived as circulars, went to his father's brother and sister, both of whom were now living in Munich, and to the family Ostermann in Freising.

Letter of 26 October 1901: "For the time being I have left my furniture with my Nürnberg landlord and landlady. Since I happen to be in Nürnberg just now, I also wish to tell how my farewell went off there. Of course, I was at several farewell parties, once at the Nürnberg Philister Union, where I had the opportunity to throw a beer party. Then an exchange of views with the men's choral society. A farewell song with horn solo (he blew the horn part himself) '*Behüt dich Gott*' (may God protect you). The next day at seven in the morning, I steamed off into fog. At the *Hochschule* in Hannover almost all *Gaus* of Germany are represented, we have Bavarians, Swabians, Badenians, Kurhesses, Austrians, and, of course, a pride of Prussians. (I have not yet taken my oath of office, so for the time being I am permitted to feel as a non-Prussian.)

A little more about my search for living accommodation: I received 60 offers in response to my advertisement, but I did not find the right one among them. A colleague got me the same, and I am quite happy." (He moved to Nienburgerstrasse 12.) "The location is somewhat like *Königinstrasse* in Munich, with the only difference that here, I am better entertained by an electrical streetcar/tram rattling along, that I see, hear and feel. Apart from this, the location is very beautiful. Just opposite to it, there is a park, behind it you sometimes see a sunset, which is, however, mostly not to be seen due to fog.

Letter of 3 January 1902: "By the way, I wanted to tell you about my life and doings in Hannover. First the language: it is said that the purest and best German is spoken in Hannover, i.e. by the people. Now, listen! My first discovery was that I could understand the waiter at the hotel only with difficulty, and the same happened with the shopkeepers. But then, I soon made the big discovery that the local language could have been derived from German when certain rules of pronunciation are observed. (After all, the dialect of

the old language cannot be described that easily, couldn't it?) The pointed "*Stein*" is meant literally, the '*ei*' being pronounced like 'A' in *Kas* at your place. Once these rules of pronunciation are learned, you will find that the people here speak written German quite well.

Even otherwise, Hannover has various peculiarities: a streetcar driven by accumulators (there are no overhead lines in the heart of the city). The streetcar network is the largest in Germany after Berlin. Streetcars go to every nook and corner out into the Lüneburg Heide, as if those in Munich would go to Freising, Dachau, Starnberg, Wolfpatshausen, Sauerlach and Grafing.

I was assured that Hannover lies on seven hills. But I have not yet found all of them. One, I discovered without any help. That is the Schneiderberg which I cross every day to go to the *Hochschule*. It is so high that the even the tallest man cannot look over it (that is the way it is expressed here). The weather here changes between being foggy, wet or windy, for a change wet and foggy or wet and windy. This climate could be the reason, why windows open here outwards so that there is no place for a winter window in the front.

Something I miss here is our good home bread less salt and no spices. Over here, the bread is eaten only with butter (even beggars do not accept it in another way)."

Letter of 1 July 1902:

"One day at the beginning of May, I took part in a geological excursion to the Harz where we saw, in rain, the beauty of the mountains and the stone formations, and despite the bad weather---these were very beautiful, indeed; the Harz is an excellent mountain, the Bavarian Woods cannot be compared with it, at least not as I remember them. The parks of Herrenhausen are now splendid, everywhere the lilacs are blossoming, the nightingales are singing and the frogs are croaking. Even at the *Hochschule*, May has not passed by without leaving its trace: A colleague, until then my daily companion at the table, is engaged. I think I am the only one among the younger *Dozents*, who is not engaged. In spite of this, the girls of Hannover have no chance of capturing me in their basket for the time being. I still think the one for me should be able to cook *Knödel* and *Nockerl* and not derive a sense of pleasure in adding raisins to spinach."

His attachment to his Bavarian home made it difficult for him in several respects to develop an intimate relationship with the Hannover life style.

Even in matters of socialising at the *Hochschule*, there were differences in interpretations. Formality was emphasised in all matters. Once, my father was asked to participate in a small stage performance. A Bavarian group of singers was supposed to come on the stage and the men were to appear dressed in leather shorts. When the young *Dozents* came to the rehearsal in the traditional Bavarian costume, flesh-coloured tricots were distributed to them to be worn underneath the leather shorts, since it was considered beyond the limits of permissible decency for the society ladies to be shown men's bare knees.

On the other hand, a very deep and friendly relationship developed between Professor Carl Runge, a man from Bremen by birth, and Ludwig Prandtl, 19 years younger in age. My father revered his witty and versed colleague, and spent many happy hours in his house in Kirchrode. In her reflections on Carl Runge's life, his daughter Iris [44] writes: "Those days, Runge often brought with him a young friend Ludwig Prandtl with whom he liked to talk over scientific matters. Carl Runge had also exerted his influence to get Prandtl called for the appointment to this post. Very soon it became evident that this new friend had a good understanding of music and a beautiful bass voice." (The Runge family attempted to perform Bach's St. Matthew Passion (*Matthäuspassion*)). With his sonorous voice in bass, the father Runge in tenor and the daughters in soprano and alto, the full timbre of all voices could be achieved, although the untrained voices needed many trials to achieve a tolerable result."

Letter of 30 January 1904 to the relatives:

"On Christmas Day, I spent the evening with my colleague and fellow *Philister* Runge (4 girls and 2 boys, therefore a house full of life). I go there quite often now, we have many common scientific interests, music is created diligently (mixed quartette)."

There were several other colleagues who soon became his friends. One of these was Dr. van Hanstein, a *Privatdozent* for literature, who often invited him to his home. In 1903, Prandtl happened to move into an apartment situated diagonally opposite to his friend's home so that they lived in immediate vicinity.

3 January 1903 - he had moved to Militärstrasse:

"The last quarter was full of work for me, so much, that I do not wish for it again. What forced me most to work was that I had begun to hand out autographed notes to all my lectures in which the most important points were put together. I was forced to work out my lecture material with such a care that I could use it over several years. I have made significant progress at my research work."

He had built for himself a small experimental facility with a water tunnel. The water that was set flowing with a paddle-like mechanism was first mixed with glittering leaf-like particles (iron glitter) in order to visualise the motion in the flow resulting from different experimental configurations. Once he told his student Dr. W. Tillmann how he got these iron glitter by chance: One day, when Prandtl was working with *MAN* in Nürnberg,, construction workers came to him. They brought with them reddish coloured chunks from an excavation pit and thought they had stroked soil containing copper. On slurring the material in water, he discovered tiny imbricated particles with which a flow could be made visible. Under the influence of a shear, these suspended particles assume a preferred orientation. Light reflected by the particles then convey an image of the flow. Chemically, these glittering iron filing particles were made of iron oxide. By slurring of the discovered material in a large number of self-made cardboard saucers, he had obtained a large quantity of iron glitter suitable for flow visualisation. A similarly well

suited raw material has not been discovered again. The stock of iron glitter travelled with him to Hannover and Göttingen when he was called to accept chairs in these places. With thrifty use, the collected stock was sufficient to last for fifty years before it was finally replaced by a synthetic pearlescent pigment.

Prandtl worked late into the night, drawing and doing calculations in search of laws. His experience then taught him the lesson that eagerness at work taken too far can lead to excessive strain, and thereafter he consciously exercised moderateness in pace of work despite urgent problems.

Letter of 23 January 1903:

"Suddenly, I have had too much work in February, and it is still affecting me, i.e. I get tired from work very soon. As a diversion I have started to take photos."

However, even thereafter, his daily work routine ran into many more hours than usual, and it is to be supposed that in those days he worked throughout the night. He led a somewhat retreated life, and over the Whitsun/Pentecost holidays, he went on a longer hiking tour through the *Wesergebirge* (the hilly country on the Weser River) which brought him enough rest. He included small sketches in his travelogues to illustrate his hiking route and his impressions of the landscape.

Letter of 23 June 1903:

"By train to Coppenbrügge, hiking through the Ith hills, luncheon in Lauenstein, keep moving along the crest, rest on the Hammerslust rock, in the evening to Escherhausen. Next morning via Homburg (old castle in ruins on the high mountain) to Stadtoldendorf, from there on the Ebersnacken and the Königszinnen. Going aboard at Bodenwerder and on the Weser up to Hameln. Sightseeing of the town, swimming in the Weser. Next day in Ohrberg (nice park), swimming in the Weser, back home in the evening. The tallest mountain that I saw was 495 m high!"

Letter of 30 January 1904:

"I start with my bidding farewell to the beautiful land of Bavaria last September. As you may know, I went to the meeting of scientists and doctors (*Naturforscher- und Ärzteversammlung*) to Kassel, at that time. I do not repent having participated in this meeting. I came to establish many valuable contacts there, particularly with mathematicians and physicists. My own lectures were somewhat afflicted with the fact that both were scheduled for the afternoon of the last day. One was received with approval, the other (on vectors) met, as expected, with differences of opinion. At the end of the conference, a number of mathematicians and physicists followed an invitation to Göttingen that offers extraordinarily interesting things and personalities. The hospitality there is great. I was put up at the astronomer Schwarzschild's, had my afternoon lunch at Professor Nernst's the chemist, and Mr. Ramsay the English chemist, was seated two seats next to mine. Soon after my return to Hannover, a business of a different kind

started in full swing: holding examinations in the forenoon, holding examinations again in the afternoon, and so on for 4 weeks. Lectures have started in the meantime, then there were again examinations besides the lectures, and so did the time pass until Christmas. Since 5 January, the lectures are going on again. Moreover, there was lot of other work: extended publications of my lectures, a few other publications are in preparation, and then the committees, so there is no lack of work for me. In spite of this, recently, on the Emperor's birthday, I allowed myself the pleasure of doing nothing the whole day long. I went skating and on a walk."

Then he got back to his diversified work.

In spring, an inquiry came in from *Geheimrat* Felix Klein from Göttingen whether Prandtl would be willing to take over the Institute for Technical Physics that had been headed by Professor H. Lorenz. This institute that involves the position of an *ausserordentlicher Professor* was founded upon the initiative of Felix Klein, the creative mathematician and organiser of mathematical-physical-technical education, when funds were made available for this purpose by the *Göttinger Vereinigung zur Förderung der angewandten Physik und Mathematik* ("Göttingen Society for the Promotion of Applied Physics and Mathematics") under the chairmanship of Henry Th. Böttinger and F. Klein. In a letter to Klein, Prandtl's earlier boss at *MAN*, *Baurat* Rieppel, expressed his opinion on this proposal for filling this post: "7 March: I hold the opinion that your idea to primarily consider Herr Dr. Prandtl for this post is very fortunate. Herr Prandtl is an extraordinarily talented person and, at the same time, very diligent. His amiable character is a guarantee for a pleasant working atmosphere..."

Runge from Hannover expressed himself as follows: "I hold a very high opinion of his talent and will do everything within my powers to keep him at our university. . . "

On 22 April, Karl Schwarzschild wrote to Klein in the same matter: "I got a letter from Runge on Prandtl---Dismal prospects!"

On 4 May, Prandtl sent a provisional reply to this offer to Klein.

"Letter of 4 May, Hannover
To Prof. Felix Klein

Respected Colleague:

As promised, I would like to inform you about my considerations regarding the professor's post in mechanical engineering in Göttingen. On the one hand, I am attracted by having my own laboratory and more of leisure time, and last but not least the nice scientific interaction in Göttingen. On the other hand, my work in Hannover during the period of almost three years of my stay here has become very dear to me. I would probably be exchanging my large sphere of activity here with a much smaller one. I would not attach much value to my not having a seat (with voting rights) at the *Fakultät* in Göttingen, being an *a.o.* Professor, whereas I am a regular member (with full rights) in

the department here. My most serious misgivings come from my feeling of belonging to engineering. For a long time, I have been toying with the idea of putting my efforts in enhancing the scientific content of teaching at technical universities (*Technische Hochschule*). From this standpoint, my change over a university only appears justifiable, as this position---which, I think, will not be my final one---will give me the extraordinary opportunity of elevating my scientific level and prepare myself for tasks in the future. Furthermore, the exchange of thoughts with theoreticians will help to solve many of the problems which are close to practical application."

The salary of 6500 Marks per annum that he asked for was the same as his pay at the *Technische Hochschule Hannover*.

The decision on the matter was supposed to be taken by the ministry in Berlin. Klein had forwarded the recommendations with a personal letter and had made the following points regarding Prandtl: "Prandtl's works stand out for his sound knowledge and mastery of mathematical tools in combination with the power of intuition and great originality of thoughts. In addition, Prandtl has a particularly deep interest in pedagogics."

Since the ministry did not approve of the pay demand, Henry von Böttinger (the commercial head of the company *Farbenfabriken*, and formerly, the Bayer company in Elberfeld) wanted to provide the sum falling short of the 6500 Marks from private funds,. So, as far as the matter of pay was concerned, the offer for the appointment to Göttingen was to be given serious consideration. Prandtl travelled to Berlin for negotiations and asked for some time to think it over.

In a letter of 25 June to Professor Klein, everything was still in suspense.

"Hannover, 25 June 1904

Respected Herr *Geheimrat*!

The decision has not yet been taken, I do not yet have the call in writing. The reason for the delay is that the Hannover colleagues have put in vast efforts with the ministry to retain me here. I also wish to take this opportunity to inform you that I had to struggle with myself to cut all the links that hold me here, and much effort has really been put in keeping me here. The Civil Engineering Department is setting up a new and beautiful Solid Mechanics Laboratory (*Festigkeitslaboratorium*), which is to be completed shortly, and a few members of this department have offered to leave the same to me for my discretionary use, and so on! After weighing the pros and cons of one against the other for long, I finally tend to Göttingen."

On 1 July, the decision was taken in favour of Göttingen.

However, the negotiations with the ministry were not yet concluded. Finally, on 1 July, they had reached their goal, and Prandtl was in a position to give his final assent. On a postcard to Klein, he wrote: "Respected Herr *Geheimrat*! After having just received a

letter from Herr (*Ministerialrat*) Naumann I have decided to accept the Göttingen offer of appointment."

Although it is unusual to choose to take a retrograde step in the academic career, i.e. giving up the position of an *ordentlicher Professor* to take up one of an *ausserordentlicher Professor*, Prandtl considered this an opportunity to devote himself to his scientific research. His *Doktorvater*, August Föppl, had strongly advised him not to accept such an offer. It goes against all reason to degrade oneself professionally. But Prandtl's creative spirit placed the accents differently. He was attracted to the prospect of having much more freedom in the new place for pursuing his problems and research ideas. He was also convinced that he would later have an opportunity to regain the position of an *ordentlicher Professor* again.

Prandtl cherished a great admiration for the mathematician Klein, by whom he also felt personally attracted, and whose protectorate held the promise of a good working atmosphere.

Klein had special goals for teaching in the branches of mathematics and science. To the students, whose aspirations were often to take up a profession of a more practical nature, e.g.. working in a factory or teaching at a school, he wanted to impart an education that should be related more closely to this purpose. In those days, German universities had little connection to engineering or industry. The American universities served as an example. He was a superb organiser, and his activities were widely recognized. Thanks to his initiative, a number of chairs and institutes were set up in Göttingen that were designed to serve practical applications in the field of science. In Prandtl, he had found a teacher who, as an engineer, could develop his subject matters entirely from the practical point of view. Felix Klein became his trusted friend, who participated in all his plans and always supported him through professional discussions in his scientific field.

On 12 August 1904, just before moving to Göttingen, he travelled to a conference in Heidelberg. It was the III International Mathematicians' Congress (*der III. Internationale Mathematiker-Kongress*), where he lectured on his new scientific theory called the boundary-layer theory [35] (*Grenzschichttheorie*). It was the result of his experimental and theoretical studies mentioned earlier. This talk caused a sensation among the participating mathematicians, who followed his new ideas on flow phenomena with great interest. A fundamental step in knowledge had been taken that would be significant for the development of aeronautics. Now, he had become famous in scientific circles.

In his memoirs, Professor Ludwig Föppl comments on Prandtl's boundary-layer theory:

"In view of the importance of this work, I would like to point out to its essentials. By that time, there had been no theoretical explanation for the drag experienced by a body in a flowing liquid or in the air. The same applies to the lift on an airplane. Classical mechanics was either based on frictionless flow, or, when friction was taken into account, mathematical difficulties were so enormous that hitherto, no practicable solution had been found. Prandtl's idea that led out of this bottleneck was the assumption that a

frictionless flow was everywhere with the exception of the region along solid boundaries. Prandtl showed that friction, however small, had to be taken into account in a thin layer along solid walls. Since that time, this layer has been known as Prandtl's boundary layer. With these simplifying assumptions, the mathematical difficulties just mentioned, that show up in classical fluid mechanics of a flow with friction, could be overcome in a number of practical cases. Prandtl could prove theoretically and experimentally that the boundary layer can separate from the surface of a body immersed in a flowing fluid at suitable points, to roll up and leave the body as an isolated vortex.

At the Mathematicians' Congress in Heidelberg then, Sommerfeld then heard Felix Klein saying to Prandtl: "Your talk was the most beautiful one of the whole congress."

It is characteristic for the plenty of ingenious ideas Prandtl had at that time that, in addition to the boundary-layer theory just mentioned, he presented a paper at the same Mathematicians' Congress that dealt with the area of the theory of elasticity. Since that time, this paper is known to every theoretician in elasticity as Prandtl's analogy between the torsion of a prismatic bar and the curvature of a soap film, which is formed on a hole of the same cross section as the bar under pressure from one side. This equivalence has often been used for the solution of torsion problems in experiments."

On the latter problem, two articles have been published in print [24, 40].

The letter of appointment for the post of professor at Göttingen was already in Prandtl's hands, when the Heidelberg Congress took place. Its exact wording is on record:

"The Minister for Education in Spiritual Matters and Medicine, Berlin, 31 July.

In pursuance of the negotiations conducted with you upon my commission, I herewith appoint you with the most supreme authorisation of His Majesty the Emperor and the King, from the 1st of September of this year onwards, to the post of *ausserordentlicher Professor* in the Faculty of Philosophy at the University in Göttingen, and bestow you with the duties of giving lectures and tutorials in technical physics and agricultural machines that were hitherto held by Professor Lorenz within the purview of the *Extraordnariat*. Concurrently, I transfer to you the directorship of the Division of Technical Physics belonging to the Institute of Physics. I request you to take over your new position before the beginning of the next semester, and send to the Dean of the Faculty by return of post the list of lectures to be announced for the next semester. Instead of your present service pay, I approve from 1 September of this year, an annual salary of

4000 M(arks)

to be paid to you and an annual housing allowance of

540 M(arks)"

For the month of September, Prandtl, arranged for his deputation, On 1 October, he took over the work of his new appointment at the university. For the same autumn semester 1904, Felix Klein had also asserted the appointment of Carl Runge to a position in Göttingen. Just like Prandtl, he was eagerly looking forward to this move. In June 1904, Felix Klein had personally asked Carl Runge, if he would also like to come over to Göttingen. When Runge talked to *Ministerialdirektor* Althoff in Berlin about this subject, all his demands were met to his joy. The new position was upgraded to the post of an *ordentlicher professor* with corresponding increase in salary. Runge had received calls for positions in other places, such as Marburg, Danzig, and Aachen, but none of these universities could offer the pay he asked for. His chair, designated as "Chair for Applied Mathematics" (*Lehrstuhl für angewandte Mathematik*), was the first in Germany for this subject. Prandtl had been appointed Professor for Applied Mechanics. Both of them moved into an old venerable institute building on the Prinzenstrasse, into the so-called Michaelishaus, in which Karl Friedrich Gauss and Wilhelm Eduard Weber formerly had made their first experiments with electromagnetic telegraphy.

Iris Runge writes [44]: "The rather small angular rooms, the worn out floor in the hall entrance and stairs reminded you of the age of the building that dated back to the 18th century. Yet, everything was bright and new, although furnished in a simple and functional manner.

When Runge came to Göttingen, Klein asked him and Prandtl to conduct a joint seminar on problems in electrical engineering.

At the time of registration, the science students were given a study guide prepared by Klein that had the title: "Suggestions and explanations for students of mathematics and physics". Its aim was to lead the young people to the important tasks without any detour. Anyway, these years saw a unique collaboration of all those who were involved as teachers in the vast structure of the knowledge of nature. All parties involved were cooperating, starting from those representing practical applications, the group to which Prandtl and his mechanical engineering laboratory belonged - his subject was named by some colleagues as *Fakultät Schmieröl* ("Faculty of Lubricating Oil")- right up to the guardians of the pure heights of mathematical theory."

The most renowned professor among the mathematicians was David Hilbert. Klein had been successful in his efforts to bring him (Hilbert) to Göttingen, where he stayed until the end of his life, and rejected an offer from Berlin in 1902. Klein's suggestion to extend the science division of the *Philosophische Fakultät* (Faculty of Philosophy) was in line with Hilbert's thinking, and provided a broad base for students from all over the world.

Runge and Prandtl, whose friendship had its roots already in their time at Hannover, were particularly close to each other. In Göttingen, they moved even closer to each other both in spatial and professional respect, which was a very fortunate constellation. But it was the free atmosphere at work in Göttingen that brought Prandtl's originality in engineering mathematics into full bloom. The union of Prandtl's and Runge's institutes often provided

the opportunity for stimulating discussions, which was conducive for the origin and development of new ideas.

Prandtl, looking for further insights in his special field of research in fluid flows, now mainly dealt with the area of gas flow. He got good chances for research work in his institute. Already in 1898, Klein had founded the *Göttinger Vereinigung zur Förderung der angewandten Mathematik und Physik* (The Göttingen Society for Promotion of Applied Mathematics and Physics) together with interested industrial magnates and some professors from Göttingen. Substantial financial aid from the industrial magnates had enabled him to take up new institute projects, e.g., the *Physikalisches Institut* on Bunsenstrasse in 1905. This offered more space in the old *Physikalisches Institut* on the Prinzenstrasse for the new *Dozents*, and Prandtl could extend the existing facilities through a closed-circuit water tunnel for flow visualization.

As explained in the preceding text, I wish to emphasise at this stage that Prandtl went ahead with his research in fluid flows as a purely scientific piece of work. After he had solved the practical problem for *MAN*, he continued research in this area in his own interest and for the sake of gaining knowledge. In the beginning, he had no idea that his science would have a bright future.

In 1906, again with the cooperation of *Ministerialdirektor* Althoff, a new society was founded: the *Motorluftschiff-Studiengesellschaft* (Society for the Study of Powered Airships) with the essential goal to promote the development of the Parseval airship. Prandtl was chosen as a member of the technical committee. Klein suggested drawing plans for a laboratory for model studies in order to establish a superb scientific working atmosphere for conducting tests and preliminary studies. He commissioned Prandtl with this task. Thus, the impulse for a development that corresponded to his inclinations and wishes came in a certain sense from outside. Soon, the building plan blue prints were ready and the preliminary work started in the beginning of 1907. By the way, Prandtl received an offer for an appointment to the *TH* Stuttgart. In a letter to *Ministerialdirektor* Althoff, he described his situation in respect to his teaching duties and disclosed to him his standpoint towards the offer.

"30 March 1907

To His Excellency Herr *Ministerialdirektor*
Dr. Althoff, Berlin, Ministry for Education

I have the honor to inform Your Excellency that, yesterday, I received a letter dated 26 March from the Württemberg Ministry of Education in which an offer of the position of an *Ordentlicher Professor* for Technical Mechanics at the *TH* Stuttgart has been made to me.

Although this offer is very attractive to me, there are reasons for me to give serious consideration to remain in Göttingen. Of course, I am not without wishes. I am quite happy with my *Institut* except for the very stringent budget that has not been raised up to

now. But thanks to the aid of the *Göttinger Vereinigung* (Göttingen Society), which has kept the *Institut* from drowning, this does not cause me much concern.

I am less happy with my present teaching activities, as despite all my efforts, it has not been possible for me to get a larger circle of students interested in my efforts. The reason, partly, is that the subject is put aside as an unnecessary minor subject, since it is handled only by an *Extraordinariat*, that has little or no participation in conducting examinations.

Therefore, my wishes primarily concern the measures to elevate the standing of my subject.

One request that I address especially to your Excellency, is to upgrade my teaching position to an *Ordinariat*, or, if this is not possible, to grant me the position of a personal *Ordinariat*. My personal position in this matter remains the same as 3 years ago, I gave up the chair of an *Ordinariat* in Hannover gladly, and even now, I do not ask for a position with voting rights in the *Fakultät*. However, I think I owe it to the standing of the chair that I am holding, to raise this request.

A second measure to reach this goal of being taken as a member of the examination commission for Applied Mathematics (examination for teachers' qualification) has already been initiated. Moreover, I intend to place a third, which refer to the changes on the award of a Doctor's degree (*Promotion*) in physics before the *Fakultät* in Göttingen.

Besides these things, there is another request on my mind: I am needed in Göttingen to handle heterogeneous matters, among which the subject of agricultural machinery is very remote from my scientific interests. Transferring the subject of agricultural machinery to a suitable *Dozent*, as I once reported to the minister, would relieve me of the burden of the Division of Agriculture and at the same time be a scientific gain to me.

Since the Württemberg Ministry has informed me that that the matter is urgent, may I kindly ask for your early reply.

Devoted L. Prandtl"

Prandtl rejected the offer for the post in Stuttgart, since his demands for Göttingen were met and his professor's post was upgraded to that of a personal *Ordinariat*. They planned a laboratory for him there. In autumn 1907, a closed circuit wind tunnel was built according to Prandtl's specifications at the east of the *Leinekanal* on *Hildebrandstrasse*. The cross-sectional dimensions of its test section were two metres by two metres. It was equipped with a powerful blower for wind generation, and later on, this type was copied and built abroad as the Göttingen-type wind tunnel. Independent of this, the engineer Alexandre Gustave Eiffel had built an open-circuit wind tunnel in Paris almost at the same time. This design was also developed further. Eiffel's experimental facility was primarily to serve a special goal, viz. to measure the wind pressure on the tower he had built.

Professor Ludwig Föppl writes: "Almost at the same time as the German wind tunnels were built in Göttingen, the builder of the Eiffel Tower put up a similar wind tunnel in Paris and got drag measurements conducted there. Therefore, it was possible to compare the results of measurements obtained in Göttingen and Paris with each other. There was a good agreement between the two for most of the models. In contrast, for some models, the results of the two measurements differed from each other significantly. Although the measurements were repeated with great care both in Göttingen and in Paris, the differences in the drag coefficient remained the same."

After different conjectures on the physical reason for the discrepancies were put forth, Prandtl succeeded in explaining the same in a surprisingly simple manner with the help of his boundary-layer theory. The reason was that the airflow in the wind tunnels at Göttingen and Paris was not identical. After the inclusion of a contraction, the airflow available for measurements in the Göttingen wind tunnel was turbulence free, whereas it was more turbulent in the Paris wind tunnel. Through carefully conceived experiments with spheres, in which in one case vortices (characteristic of turbulence) were generated by a mesh in the flow and in the other a tripping wire ring soldered onto the surface of the sphere disturbed the smooth flow, he could eliminate the discrepancy, and thus, conclusively prove his thoughts [22].

"Prandtl was awarded the Benett prize for this impressive explanation of the controversial question."

It was surprising again and again how many sided the problems were that he addressed. At that time, with an agreement by the *Motorluftschiff-Studiengesellschaft* ("The Powered Airship-Study Society"), he was also engaged in the design of a flying kite. The insights he gained in his wind-tunnel studies, which provided results that enabled a drastic reduction of the large energy losses incurred in flying in those days, promoted the development of flying objects. Models of airplanes, navigable airships, and wing profiles were suspended in the wind tunnel and their drag was measured at different wind speeds. The scientific evaluation of the precise measurements led to the development of the streamline shape and form.

The switching on of the blower could be heard well in the surrounding neighbourhood; it could not be kept a secret that unusual things were happening there on the *Hildebrandstrasse*; but the new "Home of the Wind" ("*Windheim*") belonged to the progressive side of Göttingen. Considering that Otto Lilienthal, with his own design of a glider resembling a flying bird, started as the first flying human being in 1891, and that in 1903, the American Wright Brothers ventured their first powered flight with their twin-deck airplane, whose flight characteristics were only tested sparingly, it has to be accepted that the science of flight research with its results taken for granted today, was totally new at that time and attracted much public attention.

Moreover, the flight with airships brought much attention and appreciation, since it was clear that a vehicle lighter than air had to prove itself in flight.

On 2 July 1900, when Graf Zeppelin succeeded in his maiden voyage on the Lake of Constance (*Bodensee*) with his manoeuvrable airship, a reporter Eugen Wolf, wrote the following enthusiastic article in the periodical, *Die Woche*,: "Christoph(er) Columbus could not have experienced more intensely the feeling of being blessed when the cry "Land" fell on his ears than all those who were possessed by the dashing cavalry general Graf (Count) Zeppelin, when finally, the majestic sleek air vehicle, that lent a feeling of safety in all its parts, obeyed a light pressure on the lever by its pilot, raised itself slowly and silently from its parking place, and took a course through the air like a celestial apparition."

As against this, the very first trials of the Wright brothers to overcome earth's gravity by motor power bore a closer resemblance, not to the weightless flight of a migratory bird, but to a hen fluttering her wings. At its first flight, the powered airplane glided for 12 seconds over the ground before its skids touched the ground after 50 metres. The spectators who had assembled together for this demonstration did not stare into the sky, but had to crouch onto the ground in order to be a witness to the first powered flight. This was the only stance that permitted them to judge whether the airplane had taken off the ground. After persistent repeated trials these two aircraft technicians did succeed in flying higher and more often.

In 1908, Orville and Wilbur Wright carried out several times in France, Germany and England successful demonstrations of their flying machines that had been improved in the meantime. Airspace had thus been conquered. It was now the task of the aerodynamicist to achieve stability and flightworthiness for the flying machines (objects). Soon, scientific workers (*wissenschaftliche Mitarbeiter*) came together in the laboratory. A few names are known to me: I wish to mention Th. von Karman first. His path of studies led him to Göttingen as early as 1906. In 1907, Dipl.-Ing. Georg Fuhrmann was hired, who then worked in building up the laboratory. Dipl.-Ing. Otto Föppl joined in 1909. In 1911 and 1912, two further helping hands came in: Dipl.-Ing. A. Betz and Dr.-Ing. C. Wieselsberger.

The Hungarian mechanical engineer Theodore von Karman wrote to Prandtl in 1906 asking if he could work with him as a doctoral candidate in the field of mechanics.

"8 September 1906, Budapest

Respected Herr Professor!

According to the instructions of the local *Technische Hochschule* I intend to spend the next semester at the University in Göttingen and work during my stay in the areas of technical mechanics and heat. My task is to gain deeper scientific insight into these mathematical subjects that serve in technical education, and in particular, in the training of mechanical engineers, as a preparation and foundation for the purely technical disciplines. . . .

I am convinced I can fulfil the task best, if I place myself completely under your guidance.

Your devoted Theodor Karman"

Karman was a highly successful student of Prandtl (he got his doctor's degree working with Prandtl in 1908) and became a professor at the *Technische Hochschule* in Aachen in 1913. Under his direction, a wind tunnel according to the well-known design in Göttingen was built as early as in the beginning of 1914. In 1929 he accepted an offer from America to be the director of a research laboratory in aeronautics in Pasadena. He was unsettled by the political development in Germany and could foresee where the ideas of the *NAZIs* (*Nationalsozialisten*) would lead to, which would hit him especially hard as a Jew. In America he found the very best conditions for work. Through his innovative spirit, he helped American aeronautical research to attain lofty heights for which generous financial support was available.

Karman did not let his connections with his former teacher in Göttingen snap, as long as he stayed in Germany. Both the scientists did research on turbulent flows and exchanged their results.

In his biography "The Wind and Beyond" Karman writes [15]: "In my opinion Prandtl unraveled the puzzle of some natural phenomena of tremendous basic importance and was deserving of a Nobel Prize."

Prandtl had settled down well in Göttingen. He regularly met for lunch with a group of cheerful young *Dozents* who were still bachelors. Members of this group were: Karl Schwarzschild, astronomer, Professor Max Pohlenz, philologist of old languages, and the philologist Jakob Wackernagel. The intellectual exchange of thoughts was many-sided. Soon, the bonds of friendship between him and the two years older Karl Schwarzschild, a very amiable person, became closer. His observatory often served as the social meeting place for many of his friends including Carl Runge. His almost playful ways to deal with mathematics inspired him to entertain his friends with amusing experiments.

Just like Prandtl, Schwarzschild was also enthusiastic about the balloon flights that were within reach. The *Niedersächsische Verein für Luftfahrt* (Lower Saxony Society for Aeronautics) that had been founded enabled its members to arrange for a balloon flight in Göttingen. The balloon, which was made in a balloon factory in Augsburg from "double Perkal" material, had a diameter of 14 metres when filled. It was called *Segler* (sailor).

The balloon was anchored in a field near the gas works, filled with gas until it took a spherical shape, and was then ready for its journey in the air. Later, as a child, I have once been a witness to such a balloon take-off. There was much waiting time going along with it, but the excitement grew in the very moment when its anchors could be loosened and the balloon levitated, remaining within sight for a long time.

The Board of Governors of the Society had laid down regulations for those aspiring to obtain a licence for flying balloons. It had joined the *Deutscher Luftschiffverband* (German Airship Society) as a corporate member and followed the guidelines set out by the society, e.g., the certificate of proficiency in reading instruments and judging atmospheric conditions (weather, solar radiation, and cloud formation). Another requirement was: "The Board of Governors conducts an examination through an especially constituted committee as to whether the aspirant can supervise the preparation and filling of the balloon without the help of an expert and is capable of doing the needful operations by himself." The payment conditions for accompanying persons were also laid down.

A note in the newspaper *Göttinger Tageblatt* of 10 January 1908 indicates that Prandtl travelled as a passenger in a balloon:

"In the balloon from Göttingen to Berlin

As reported earlier, four *Dozents* of the Göttingen University, Herr Professor Prandtl and Drs. Linke, Pütter and Bestelmeyer, recently flew in a balloon to Berlin. They took off in the balloon *Segler* at nine in the morning and landed, after a seven-hour flight without untoward incidents, at four in the afternoon on the shores of the *Müggel* Lake, not far from Rahnsdorf. The airship was piloted by Dr. Linke. The balloon *Segler* is a vehicle with an air capacity of 1400 cubic metres. The *Verein für Luftschiffahrt* (Airship Society) held its annual general meeting on the same day in Berlin. When the gentlemen took off, the wind direction raised hope for a punctual landing in Berlin enabling them to participate in the meeting. However, since they had only a free balloon at their disposal and not a manoeuvrable airship, these hopes stood on rather shaky ground. Therefore, the four scholars were all the more proud that they could be at the meeting in time."

After a few short trial flights under instruction, Prandtl obtained a licence for piloting a balloon all by himself. On 15 August 1909, he wrote to his fiancée Gertrud: "You may congratulate a newly baked balloon pilot, I passed the examination yesterday."

He undertook several flights as a balloon pilot that made him extraordinarily happy. The opportunity to observe the natural wind currents and feel the same as a fundamental force when flying, was a unique experience. He derived great pleasure from being able to observe with keen attention the cloud formation and the landscape spreading out below him. On his balloon flights, Schwarzschild conducted astronomical position determination with a surveying sextant. The creative imagination of the scientists was stimulated by these undertakings again and again.

In 1909, Schwarzschild got an offer from Potsdam and became the Director of the local Astrophysical Observatory. He left the familiar Göttingen with all his good friends.

In contrast, Prandtl's steady rise took place within the Göttingen framework.

On 11 January 1909 he got the following order from the Ministry: "In addition to the commission to teach that you already have I authorise you (*Euer Hochwohlgeboren!?*), from the next semester onwards, to represent the entire field of scientific aeronautics also in lectures and tutorials. ..."

There was the following announcement as a news item in a newspaper: "The Minister of Education has granted Dr. Prandtl of Göttingen a commission to teach aerodynamics. As far as we are informed, this may be the first professor for aeronautics."

His course of lectures was divided into six sections:

1. Aerostatics: On the equilibrium of the entire atmosphere and the fundamentals of dynamic meteorology
2. Aerodynamics: General laws of fluid motion
3. Equilibrium of flying kites and gliders
4. Propulsion by airscrews
5. Stability of balloons and flying machines
6. On navigation - terrestrial and astronomical determination of position, radius of action under wind influence.

In its issue of 15 April 1909, the periodical *Berliner Illustrierte Zeitung* approached Prandtl with the following request:

We read in the newspapers that you will shortly be heading the first college of aeronautics at the University in Göttingen and plan to combine your lectures (*Vorfuehrungen!! sind gemeint Vorlesungen??*) with practical demonstrations. We request you to please allow our draughtsman to draw such a lecture in which experiments are conducted with models, and hope for your agreement."

Even the French press reported about the new chair, and in the English Times of 7 April 1909, the aerodynamicist F.W. Lanchester published an article on the problems of airship transport from which I quote a paragraph:

"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 the Göttingen University in addition to his more recent appointment.

The aerodynamics laboratory at Göttingen had already been built and equipped by private enterprise before the new chair was founded, and it is probably the best thing of its kind in the world."

4. Engagement and marriage

During all these years Prandtl's relationship with the Föppl family was very active. They repeatedly met each other during the holiday season, since Prandtl did not miss paying a visit to his respected teacher whenever he was in Munich. There might have been a secret attraction for him to pay these visits---that is the chance to meet the meanwhile grown up daughter Gertrud at the Föppls, who modestly withdrew as soon as the father came to be engaged in conversation with the visitor.

The exchange of thoughts and opinions between the older and the much younger colleague was very stimulating. They discussed scientific subjects that could be thought out afresh again and again; while this brought their intellectual world closer together, the mutual trust between them kept growing. They also wanted to talk over matters concerning personnel and new appointments to positions at technical universities. Besides communications on family matters, many of August Föppl's letters contain suggestions regarding calls to chairs and scientific work that cannot be given a place in the text I am writing now. I wish to include excerpts from private communications only.

From the letters of August Föppl:

19 November 1903:

"All of us are well. Recently, my daughter" (Gertrud) "was on a visit to Hannover for a few weeks and she saw you from a distance, from a gallery at a *Commerse*."

1 January 1906:

My wife and I would be delighted if you came down to lunch with us at 12.45 on Thursday 4 January (entirely within the family, so please come in travel suit). On 3 January, I start my lectures again; so you would meet me also on 3, 4, 5 January after the lecture at 10 o'clock in the laboratory."

In 1908, August Föppl wrote to Prandtl with a personal request:

22 July 1908:

My younger son Ludwig has studied mechanical engineering for two years and has now reached the stage of *Vorprüfung* (preliminary examination). There is no doubt that he will pass the examination with the best grades. However, it has become clear now that he is indeed talented in the mathematical subjects and is very happy doing them, but does not want to know much about machine design. I intend to put him through studying mathematics provisionally for one year, and that in Göttingen. When the year is over, he can decide for himself, whether he wants to pursue engineering studies or entirely change over to mathematics.

My request to you is to draw up a time-table for my son. You will know the lectures in Göttingen that are especially worthy of recommendation to a young diligent and talented man.

Thanking you very much in anticipation for the information (if it is not conveyed orally in person which I would prefer),

your much devoted August Föppl."

In this summer, they also met during the holidays which Prandtl always spent in South Germany. Since 1894, the Föppl family had owned a holiday home on the lake Starnberger See so that guests could be comfortably accommodated there in the countryside during the holiday season. As he would often do, Prandtl took a short trip from Munich to Starnberger See, met the family in Ammerland, and had the opportunity to advise Ludwig at length on changing the subject of study.

With the beginning of the autumn semester of 1908, the student from Munich (Ludwig Föppl) started attending the mathematics lectures in Göttingen. He attended the colleges of David Hilbert and Felix Klein, whose fame attracted many students from elsewhere. It was an advantage for him that he could also participate in that seminar on mechanics that was referred to earlier and held by Klein, Prandtl, and Runge together.

Thus there grew a new closer relationship between the Föppl family and Ludwig Prandtl. The professor in Göttingen also took personal care of the student son of his former teacher.

Moreover, Prandtl always asked him, how the other members of the family in Munich were doing. When Ludwig Föppl informed him in December 1908 that his sister Gertrud would be engaged soon, the young scholar could not hide a certain excitement. My uncle Ludwig told me later that Prandtl stared very sadly into space, when he heard this news.

On 31 December 1908, he sent his colleague Föppl his best wishes for the New Year together with a congratulatory message on the engagement of *Fräulein* Gertrud.

3 January 1909, letter from August Föppl:

"Many thanks for your kind letter for the New Year. One of the greetings contained therein, however, has missed its objective. The engagement of my daughter Gertrud was broken after a short period of life." (It is reasonable to suppose that Prandtl did not take the news of the turn of events indifferently.)

August Föppl then continued: "I thank you very much for the kind acceptance and support you have given to my son Ludwig. Now you will get my son Otto to Göttingen, too! In the beginning, I did not like it very much that he wanted to quit his post in Gotha so soon. I value continuity and perseverance in leading one's life. I hope that he will come up to your expectations."

Engineer Otto Föppl, the elder son, also came to Prandtl to Göttingen. He was an *Assistant* to the young aerodynamicist in the *Modellversuchsanstalt*.

Soon, even for the daughter Gertrud the town of Göttingen was destined to gain special significance in a more eventful manner than for her brothers. And we will now relate how Gertrud's path in life led her from Munich to this town.

On Easter 1909, Prandtl made up his mind to ask Gertrud to marry him.

In his memoirs, Ludwig Föppl has noted down the following: "Prandtl had planned a vacation trip to the lake Gardasee and Bozen over the Easter holidays. As he often used to do on such occasions, he stopped over in Munich to visit us and conversed with my elder sister Gertrud. Soon thereafter, she got a proposal of marriage from Prandtl in a letter he sent from Riva:

"Riva, 20 April 1909

Respected *Fräulein!* In the solitude of the mountains, my decision has matured to ask you a question I have been carrying along with me for long.

This news set off a feeling of great joy in me, since I knew my sister would not be in better hands with any other man. My parents also thought likewise. Gertrud's decision to accept the proposal of marriage was not long to come and she wrote her decision to Prandtl. Since he had planned to travel on to Bozen, he had requested her to send him her reply by *poste restante*. He had also told her, how long he intended to stay in Riva, but due to some absent-mindedness, he had not indicated the name of the hotel, where he was staying. Since Gertrud replied without any delay, she sent the same to Riva to be held *poste restante*. Meanwhile, Prandtl thought that her letter would reach him at the hotel, if the reply was to follow without delay. After his arrival in Bozen, he waited in vain for the *poste restante* reply from Munich.

For Gertrud, it was a week of anxiety during which there was no news from Prandtl. When I had to return to Göttingen at the end of April in order to be there in time for the beginning of the summer semester, a reply to Gertrud's letter had not yet arrived. I comforted her saying that I would ask immediately after my arrival in Göttingen, if Prandtl had already returned from his trip. I was told he had not yet returned, but was expected soon. I immediately informed Gertrud accordingly. After finding out the date of his return, I went to his home at the address *Kirchweg 1a* in the evening and, after an exchange of courtesies, I hesitatingly asked him, if he had not received the letter that my sister had sent to him *poste restante* to Riva. Totally surprised, it came out of him: 'To Riva? Every day, I inquired about a letter from her at the post office in Bozen and, finally, I had to return to Göttingen.' After this error was explained, there was joy on all sides and we greeted each other as brothers-in-law. The same night, I sent a telegram to Gertrud assuring her that everything was in order, and on the day following, I wrote her in a letter what had happened."

The parents Föppl welcomed the alliance whole heartedly.

August Föppl on 10 May 1909:

"Dear Colleague!

I am very happy that you and my daughter have agreed to enter into the bond of marriage. I give you my blessings from the bottom of my heart. I have always highly admired you, not only as a scholar but also as a human being, and I do not know of anyone, whom would be more welcome to me as a son-in-law. Since we will come closer as yet, the rules of grammar demand that we address each other as "*Du*" in the future, and I use it straightaway. Gertrud has always been a good and loving daughter to me. I will miss her very much. We hope to see you here with our other sons over Pentecost (Whit Sunday). We can come to an agreement on all details then.

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

Frau Emilie Föppl wrote:

"Like my husband, I also want to introduce straightaway the familiar form "*Du*" by heartily welcoming you as my dear son. I am very happy about this alliance. For many years, I have had a special affection for you and I believe devoutly that my child will find her happiness in life with you. Since Gertrud has been brought up to seek that profound happiness in faithful fulfillment of duties at home, I hope she will be a partner of the kind you wish.

May the blessing of God be with you on your way together

Hearty greetings! Your faithful mother E. Föppl."²

From Prandtl's letters during the engagement period:

5 May 1909:

My youth was bleary due to the misfortune that befell my parents. But my equanimity helped me tide over even the saddest times without my entirely losing my vitality. Later on, I was extraordinarily lucky, indeed. If, by a grant of destiny, we find ourselves in happy accord with each other concurring harmoniously without break, it will then have also brought me much more than what it could have ever taken away from me."

9 May 1909:

Unfortunately, we men can almost never return to our wives what they give us in devotional love. The wife totally dedicates herself to domestic matters for the sake of her husband---in contrast, she has to share him with his professional interests.

²It should be mentioned in this context that the account on the story of Prandtl's marriage given as incidental by Professor Th. von Karman in his book "The Wind and Beyond" (in German "Die Wirbelstrasse", Hoffmann und Kampe Verlag, Hamburg, 1968) does not correspond to this account.

With me, things are particularly bad: You will have to compete with two rivals. One of them is a dignified lady, who keeps, however, her devotees stick to her path with an almost divine power. The other, although still young as a bud, casts her net with seductive attraction on anyone susceptible to fall for her beauty. Shall I name these? One is science, and the other is the motion of airships.

In this semester, I am more up to my ears in work than before! There is the setting up of my *Modellversuchsanstalt* (Laboratory for Model Experiments), which was already the subject of a debate in the English Parliament, the lecture course on airship motion for which, of course, I have to work out new material, and different lectures that I have agreed to give. One lecture is to be given at the General Meeting of the *Verein Deutscher Ingenieure* (VDI, German Society of Engineers), another at the Frankfurt fair (*ILA - Internationale Luftfahrtausstellung* - International Aeronautics Fair). In the latter, I will participate in two capacities, as an exhibitor on the one hand, and as the head of the prize contestants on the other.

If I knew, where I could get the time, I would also like to work on building a flying machine. But for various reasons I will keep away from this plan for the present.

You ask me what I normally do on Sundays. The answer: writing letters, going through literature. After lunch at '*Englischer Hof*' together with a group young *Dozents*, we mostly take a walk in their company that may range from a simple coffee stroll to a neighboring village up to a trip to somewhere in the *Mittelgebirge*, depending upon mood and weather. Today, for instance, we walked through the beautiful valleys with blossoming cherry trees all the way up to the proud *Burg Hanstein*. You will certainly like this very much in Göttingen. You are close to nature everywhere so that you can live, as if you were in the countryside, since the new districts of the city have been laid out as a garden city."

2 July 1909 - Prandtl sends his bride suggestions for an apartment to live in: "1. Prinz-Albrechtstrasse 20, first floor, preferred pretty location. Bordering at the back with the plot of the observatory" (his friend Schwarzschild was working there at that time)--- "twelve minutes to the *Institut*, nine to the market."

He also mentions an apartment situated farther away and includes the following balance sheet: "Covering the distance to the *Institut* twice a day means 40 minutes more to walk, with 288 working days per year that would amount to eight full days and nights. When I weigh the pros and the cons against each other, I come to no conclusion, because the advantages and the disadvantages balance each other. I hope things are better with you and you clearly tend to one of these."

Obviously, Gertrud made her choice from a distance and decided in favor of the apartment on Prinz-Albrecht-Strasse.

10 July 1909:

"Today, I sent the sketches of the furniture. I do not like any of the different buffets I found, so I sat down and made a design myself."

The drawing is still there, and I unmistakably recognized the same as the buffet that was in my parents' dining room

All these letters show, how much he invested in errands, writing and thoughts on these private matters in spite of the heavy load of work. After all, this was important for him.

Prandtl's description of moving into the new apartment: "Moving in went on as follows: Getting up at half past five - from six to eight I had one filling of the balloon (unpowered balloon)---the packer came at nine---I helped him until eleven. From eleven to one, I had to hold a seminar. Lunch - loading of the furniture from two to half past three, transportation from half past three to four, arranging in the new apartment from four to half past five. Now a pause for rest. At nine, for a finish, one meeting of the seminar board of directors."

The marriage was waiting just around the corner. An agreement had been reached in respect of religion that Prandtl would remain in the Catholic church but Gertrud's protestant ancestry would prescribe the formalities for the marriage. On 11 September 1909, Ludwig Prandtl and Gertrud Föppl married in Munich according to evangelical formalities. The marriage festivities were held at the Föppls' house, Hess-Strasse 10.

My aunt, the ten years younger sister, told me in her old age that she could come down to Gertrud's wedding in spite of staying at a Swiss boarding home, where she was learning French. Contrary to her grown up brothers, she considered the new brother-in-law as a member of her father's generation, since they had moved with each other as colleagues.

The nature of the relationship between the two scientists, however, changed slowly. The father-in-law kept himself more to talking about family matters---he was rarely inclined to engage in discussion about technical subjects.

Three weeks later, there was a second marriage celebrated within the Föppl family. The elder son Otto married the daughter of a colleague in Munich. This young couple also moved to Göttingen. Otto Föppl, who had submitted part of his work done in Göttingen on the subject "Forces due to wind on plane and cambered plates" as a dissertation [8], later became a professor for strength of materials in Braunschweig.

When my mother came to Göttingen at the end of September 1909, she was enchanted by the life in this small town and she experienced no difficulty in feeling at home here soon.

They returned from their honeymoon which had taken them to the lake Gardasee. At the railway station in Göttingen, they boarded an open coach that moved on at a leisurely pace through the town and brought them to Prinz-Albrecht-Strasse (today renamed as Keplerstrasse). On the way, my father showed his young wife some important buildings, like the *Physikalische Institut* looking over the river Leine and the university library. At

this point, the bend to the Hauptstrasse had already been reached and the route followed Weender Strasse over a certain stretch in the direction of Quentins Eck. The lady from Munich was very amused that this short distance from the Auditorium to the Markt was Göttingen's main thoroughfare. My father also gave some suggestions for shopping here and there. In passing, they saw the *Rathaus* (town hall) and the *Gänselieselbrunnen* (the well-known fountain in the town of Göttingen). At the *Markt*, the small steed drew the light carriage around the corner and went up along the *Lange Geismarstrasse* and the *Kurze Geismarstrasse* through the *Geismartor* (Geismar gate), from where the mighty stone lions looked down in a sphinx-like manner. Shortly thereafter, the ride ended, Prinz-Albrecht-Strasse 20 being the end-point of the long journey. The next move was into the six-room house that my father had rented in the meantime. He had followed the advice of relatives and had hired the services of a housemaid, who received them and helped unpacking.

The next morning, my mother wanted to look around the town and do some shopping. When she entered a shop on Weender Strasse, she was served with extraordinary attention. And then she heard the shop assistant say: "Yes, please, Frau Professor, may we send you these things to your apartment?" She (my mother) could only reply quickly by asking: "How do you know me?" "Yes, we did see you yesterday afternoon going along here in the coach with Herr Professor." To some extent, my mother felt enchanted and at the same time amused. In this town thorough which she had just passed as a stranger, she was already known. In Munich, she had walked through the streets without drawing attention. Here, in this small university town, she was already expected and was paid the attention accorded to a Frau Professor. Without a foreboding, the couple in the coach had probably drawn the attention of many eyes.

My father, brown-haired, with a full black beard, looked serious and mature. Next to him, my mother with her blond hair pinned up, looked very young and tender. At that time, she was 27 years old.

Very soon, she got used to her new role that was assigned to her rather suddenly through the marriage. When she was awakened in the morning by a knock on the door with the words: "Frau Professor, hot water is ready", she had to think once and establish with astonishment: "That is me, this Frau Professor!"

Once she said to me: "It is certainly very nice, if you share the experience of success with your husband all the way, help him here and there and having the joy to rise with him up step by step. I had experienced things that were undeservingly kind." She was given a position commensurate with the high esteem her husband enjoyed and was always treated as a respected person.

Although she had spent a few months looking forward to this new world that she thought she knew a little from the accounts related by her brothers and her fiance, everything actually was surprisingly different. She was soon stretched to the full in the new sphere of life. Since her husband did not have a secretary of his own, it turned out that she took over the work of typing for him. Both had learned the same shorthand, the *Gabelsberger*,

which eased their cooperation. This gave her an opportunity to gain some access to his intellectual world and, above all, an insight into his circle of people. Her clear and decisive way often was a fortunate supplement to his nature, since problems arose for him, as he was thinking over and over again even on trivial details, carefully weighing their pros and cons against each other. As far as day-to-day matters were concerned, his thoroughness, with which he always patiently explained to us his point of view and reflected aloud on the various alternatives, had something of a touching nature. In contrast, my mother found it easy to come to a quick decision and it was comforting when decisions on matters arising in day-to-day life could be taken without procrastination. A scene that is deeply engrained in my memory due to its repeated occurrence, illustrates this point. He opened the day's mail at breakfast and got absorbed in reading them. Then he suddenly stood up, now in a hurry. Yet he looked out of the windows on different sides of our apartment to observe the sky, read the temperature from the external thermometer, and deliberated on the question, which overcoat to put on. The decision was even more difficult, if suspicious looking clouds covered the sky: Should he take an umbrella with him? He asked for my mother's advice. She replied with no hesitation. Without casting even a quick glance through the window, she said with cheerful optimism: "You will not need an umbrella." The reply was: "That's fine, it is your responsibility", and the black object was left back hanging on its hook at home.

The couple loved to take long walks. On Saturday afternoons as well as on Sundays, they walked through the near woods, sometimes going as far as the neighboring villages.

There is a note indicating that a first social get-together at the Prinz-Albrecht-Strasse was held on 7 December 1910. The young wife had to prove herself at hosting after they had been invited one after the other by the families of their colleagues during their first year of marriage. My father was very happy to be able to receive his colleagues at his own home after so many years in Göttingen as a bachelor. The Hilbert couple, *Geheimrat* Klein and his wife, Professor Runge, Professor Wiechert, Professor Simon, and others, all came for dinner. To judge from the expressions of content by my father, it must have been a nice evening.

But my mother understood very well that very frequent get-togethers in the evening would rob her husband of the hours he normally used for work at night. Therefore, they generally avoided entering into large-scale social commitments. In contrast, Gertrud's brothers often came to their home for a snug Sunday lunch.

For the rest, the couple enjoyed being together all by themselves at home. One of the rooms was furnished as a music salon. On its window side, there stood a Bechstein piano that my father had bought when moving in. Hardly did a day pass without the piano being brought to sound. Even in his old days, he felt the urgent need to sit at the piano at least once a day to get absorbed in the world of tones. Without needing the help of any score in front of him, he then played on the keys, drawing energetically from the rich well of his creative imagination. His sources of inspiration were the (musical) ideas of Bach or Mozart, Beethoven and Brahms, which he changed and developed into his own structures. All of his improvisations probably resembled each other in style, but his

musical ideas were so rich that they sounded new and original, never being repeated. Once, when we expressed our admiration, he only replied: "Oh, I have stolen the theme from Haydn, it is not mine." But, of course, he could come up with his own theme that he developed in the form of a fugue. He seemed to have an endless number of ways in mind to express himself musically, to reflect his mood.

His piano playing meant a lot to us. We felt how much his music was an expression of his entire personality. When he returned home late in the afternoon from his *Institut* and sat at the piano, he sought relaxation in playing (the piano) and his imaginations spread out an atmosphere of harmony, and the joy of life passed through a filter of art.

Later, when we had a little more understanding of music, we asked him among other things to try to compose a fugue with three voices. He pondered for a while and then, to our astonishment, soon played a short composition with the usual interlacing of repeating themes. It was a wonderful surprise to recognize the sovereignty with which his ability, which we had put to test, had proven successful. Now it was our turn to think out a theme for ourselves. For him, this was a new game again, and he did the task set in a cheerful spirit.

I wish to relate here another occurrence that I remember from my mother's narrations. Once, when my parents were visiting colleagues, who also had a piano at their home, the lady of the house related how sorry she felt that one of the keys of their piano had lost its sound for some time; otherwise, she would have been glad to ask my father to play the piano. He started playing and very soon he had to make the discovery that despite energetic playing the key remained without generating any sound. While everyone had gathered in the adjoining room and engaged in lively conversation, my father went to the other room, unnoticed by anyone, to look into the piano. He opened it with care and soon found out the reason for the key remaining silent. A thimble had fallen between the strings jamming the same. After gently removing the thimble, he sat at the piano and started playing powerfully from the low bass all the way up in rich harmonies. When the lady of the house opened the connecting door, he told her that she must have erred. All keys were in order, he had just tried them out all. She looked at him unbelievably and wanted to show him the particular key, and lo and behold, the key sounded correctly. The lady now started protesting, saying that just the day before the key was without any sound. Then my father said he had found something that he wanted to give her, and handed over the thimble to the amusement of the rest who had gathered there. He was now requested to play again. The happy appreciation of the small gathering was a sufficient gesture of thanks for him.

Once in a while, my mother traveled to visit her parents, followed by trips to the mountains for rest. The letters they wrote each other show how close they were to each other.

Ludwig to Gertrud on 4 August 1912:

Now it is the end of the semester. I celebrated the same by sleeping long. My only positive performance is this letter to you, while at least a dozen letters are waiting for an answer! Monday 9 to 11 Sommerfeld, 11 to 1 a double lecture squeezed in, afternoon gymnastics, then dinner with Ludwig Föppl at our home. Karman joined us, they stayed up to 11 o'clock and worked on an article. Otherwise, I would have written yesterday. Yesterday was a big day here. The Zeppelin boat "*Hansa*" flew a round over Göttingen (the city civic administration and the *Verein für Luftfahrt*---Society for Aeronautics---paid for the round flight). The entire Göttingen population was either on its feet or on the roofs. We were on the veranda roof and saw it in its full magnificence. The bells were ringing, flags were hoisted on the towers, and jubilation was all around. It is a pity that you weren't here!"

A letter of Gertrud of 15 August 1912 ends as follows:

"May you be well, my good, good husband. When I walk through the woods alone, I am usually in conversation with you.

A thousand greetings. Yours Gertrud."

Ludwig Föppl writes about these times:

"After the teachers' examination in Munich, I went again at the start of the winter semester of 1910 to Göttingen to work for my doctor's degree. The four and a half years that followed gave me an opportunity to come in contact often with the newly married couple Prandtl. I had a standing invitation to the Prandtls for lunch on Sundays. It is with pleasure that I recall these Sundays that passed by in harmony. Prandtl was no one who despised a good meal.

He obviously enjoyed attending the Sunday barbeque and during the meal, he vented his imagination of the possible tastes of the dishes on the table in different combinations. After lunch that was followed by a short rest he sat at the piano, a beautiful Bechtstein, and played improvising. I enjoyed listening to him, sunk in a sofa, and admired his gift to lend musical expression to his mood of the moment without a score in front of him. Of course, occasionally, the piano also had to serve experimental purposes, as for instance when he placed a newspaper on or under the strings and examined the effect of the same on the sound. Since he had an ear for absolute pitch, he was able to tune the piano by himself. Prandtl could be so deeply absorbed in his piano playing that he forgets everything else. Piano playing was a source of spiritual regeneration for him.

An integral part of my Sunday visits to the Prandtls was a walk taken together in the afternoon walk. Usually, we took the route going up the Hainberg hill to the Kaiser-Wilhelm-Park or to the *Kehr* where we had coffee. Prandtl's extremely alert mind took detailed note of changes, developments, and happenings in the surroundings on our way. In spring, he could derive childlike pleasure from the blossoming of the flowers and listened intently to the birds' singing. He followed the wind and the weather changes with apt attention. With his comments, he gave further interesting explanations on his

observations, so the walks were always very stimulating. I also came to know of his strong playing instinct. I remember that once in a cafe, he started building a tower from the crockery after finishing the coffee in order to examine the stability of the structure. But it also happened now and then that one of the pieces broke, for which he then paid the waitress with profuse apologies. These Sunday walks did all of us a lot of good. Prandtl felt a strong need to take a brisk walk at least once a week. For him, it was a counterbalance to his normal way of life. This did also apply to the gymnastics with the professors, in which he took part every Saturday in the late afternoon.”

So, the precious years passed, during which Prandtl's esteem steadily grew, thanks to his diligence and imaginative ideas.

Since in these years my own inclination to the subject of mechanics was clearly manifested with both my doctor's dissertation and the *Habilitation* dealing with problems in mechanics, frequent meetings with Prandtl and being with him were extraordinarily fruitful for me in scientific respect. When I was stuck with some difficulty or the other, a talk with Prandtl often sufficed to help me tide over the same. He gave his help not only to me as a brother-in-law, but also to all young people, who approached him with similar requests. His benevolence and humane nature knew no limits. Therefore, he was very much liked by all, his students, *Assistents* and colleagues. Of course it also happened occasionally that his benevolence was ripped off.

Also during the summer holidays, I often met Ludwig Prandtl, since we spent a few weeks together in our parents' country house on the lake Starnberger See. He then took with him a file containing outstanding work and unanswered letters, which nailed him down to his desk during bad weather. When the weather was good, he enjoyed spending time in our company in the garden, the charming landscape, and bathing in the lake. We often stood together in the garden at a point with a beautiful view over the lake and the whole Bavarian mountain chain, and Prandtl saw around, noted all details with attention and liked to express himself in words over the same. In particular, the very impressive atmosphere of the evening hours could make Prandtl react with much enthusiasm. Often, when he saw the sky colored with extraordinary beauty, he called all of us and drew our attention to the different coloring shades. One desire that always had a special meaning to him was the weather observations. From our viewing point in the garden, the development of the weather could be seen well in advance. Prandtl often observed the approach of thunderstorms and followed the origin and growth of cloud patterns with their own peculiar characteristics. He often stayed there until the first rain drops fell. One summer, when a newly planted pine-tree hedge just in front of our viewing point had grown so tall that it obstructed the view into the distance, which had been possible so far, we decided to build a small mound of gravel to provide an elevated platform for viewing. We moved many wheelbarrow loads of gravel from a stone pit to the site. Prandtl helped like a comrade at this physically strenuous work, although it was more difficult for him than for us, the younger. He took part in all our enterprises, enjoyed every jest, and often contributed to new ones. He readily adjusted himself to every situation and never spoiled a sport, even if we sometimes made jokes about his clumsiness at physical work. In these situations, you could not notice the learned and renowned professor he was. He always

remained friendly and modest, as modesty actually is a sign of a high level of culture and education. He also played tennis with us on our tennis court, although he had no practice in that game and fast reaction was not in his prudent nature. But we were always happy, when he played with us. There was much to laugh, for instance after a faulty stroke, when he wanted to give a deep analysis of the stroke and we drew his attention to the difference between theory and practice.

It is with very pleasant memories that I associate my walks with Prandtl in the *Ammerland* region and its surroundings. His company at walks was always lovable and interesting. Every puddle we passed by inspired him for experiments and he had to throw at least one stone to study the spreading of the waves. Once I went along the lake with him, when there was a strong west wind, and we observed the group velocity of waves of different height. After drawing my attention to this phenomenon that was unknown to me before, we sat on a bench, and he began instructing me through a few formulas that he wrote on a piece of paper. He derived the interference of two waves of almost the same frequency, from which the relation follows that the group velocity is half the velocity of the single wave train. He, thus, coupled in his head his observations with the physical law underlying the same.

This was precisely the surprising gift that he had: intellectual assimilation of observations with the help of the basic laws of physics. Since this way of thinking had become an integral part of his person ever since his youth and he used it instinctively at every step, it made no particularly taxing demands of intellectual effort on him. The habit was engrained so deeply in him that even at work it appeared, as if it were a product obtained with the same ease as in play. To me, it often appeared, as if he were in possession of an infinite spring of knowledge in physics, from which he could draw with ease at any time so that he could contribute to the problem under discussion. This would explain the huge volume of his achievements in science as well as the broad span of his interests in all branches of science. Whether it was a problem in physics or engineering, or in astronomy, geology, or mechanics, he always sprang a surprise through his depth of knowledge, often conversancy with details of special nature, and novel conclusions. Repeatedly, he was engaged in conversations with different faculty colleagues on their subjects without needing any special explanations.

I had the fortune of having very close family ties with the two leading representatives in the field of mechanics in Germany, my father August Föppl and my brother-in-law Ludwig Prandtl. I have learned a lot from both, in science as well as at a humane level. Although I stood only in the shadow of these two great men, I believe to be in a second-to-none position to judge on the work and the way of their lives. Over the years, I realised to my surprise the generosity, with which mother nature distributes her gifts; although the two men worked in the same area of science, there was nothing common in their nature. Of course, the two were of the same character in respect of excellence and reliability. It is also superfluous to point out to their diligence, which ran as an unending stream through the course of their lives, since it is indispensable for success, even in science. However, they were different in their temperament and their way of work right from the very roots. Even in their way of life, they were individuals cast in two entirely different moulds. You

can distinguish between two kinds of scientists: the classical and the romantic types, as Wilhelm Oswald describes in his book, "*Grosse Männer der Wissenschaft*" ("Great Men of Science"). The latter is characterized as one gifted with genius, who accomplishes great feats without any efforts right at the outset in his young years, whereas the classical type develops slowly and steadily and gains great success only after years of incessant toil. If this classification were to be applied to August Föppl and Ludwig Prandtl, the former would come under the heading "classical type" and the latter under "romanticist". August Föppl owes his success to disciplined and tenacious work. In contrast, success lands of its own accord in Prandtl's lap with apparently no need for any effort on his part. At the age of 23, he opens up with his doctoral dissertation a new area in the theory of elasticity, and at 29, he initiates a new era in hydrodynamics through his work on boundary layers. Truly, it is a romantic climb! But August Föppl is the superior teacher. His lectures and scientific works are presentations as clear as a crystal. Prandtl, as a teacher, could not demonstrate that much success. While his teaching was very stimulating for advanced level and doctoral students, he had difficulties with lectures for beginners. It might have been so because, in his student days, fundamentals of mechanics posed no difficulties whatsoever for him. They were more or less obvious for him. Therefore, he could not imagine the difficulties students faced and had to overcome.

With all the respect the two eminent men felt for each other, there were strong differences, so that occasionally, when they were together for weeks in Ammerland, there was a little strain in the relationship between father-in-law and son-in-law, although it never reached the breaking point. The difference in age between the two was only 21 years, but these were times of drastic breaking away from the past, dividing two epochs. My father still had his roots in the second half of the 19th century, marked by its authoritarian and rigid outlooks, whereas Prandtl was coined more by social ideas and progressive thoughts of our (20th) century. Therefore, he found it difficult to subordinate himself in all respects to our father, as we children did, regarding it as something most natural. The powerful personality of August Föppl also exercised a high degree of moral influence on the people around him so that his colleagues called him "*Gewissen der Fakultät*" ("Conscience of the Faculty"). From the bottom of his heart, August Föppl was very happy about the big successes of his son-in-law in science. Possibly he was the first to recognize the genius in Prandtl.

On the basis of my own experience in life, I have gained the impression that a talented person involuntarily experiences a certain pressure to shape his life in accordance with his talent. He will feel happy only if he has the opportunity to use his talent. As long as such an opportunity is denied to him, he will inevitably look for an opening that provides an outlet to his talent. If he is fortunate to find the proper sphere for activity, he feels destined to unfold his talent and looks for furtherance to reach the highest possible level. Prandtl took up only such problems that belonged to the regime of his exceptional talent. Although he was interested in a broad range of natural phenomena, he restricted himself to research problems of a special kind, and so, was thrifty in employing his intellectual potential. By this way, he threw open the doors leading to new areas in research, which has earned him ever-lasting reputation."

5. 1911-1918, daily routine

During the early years after marriage that took shape with harmony reigning, there were many new tasks facing Prandtl. The model laboratory, which was thought of from the very start as only a provisional facility, did not suffice for purposes of the steadily growing aviation research. In 1911, again at the suggestion of Felix Klein, Prandtl started drawing up a plan for a new larger research institute. *Geheimrat* F. Klein and *Geheimrat* von Böttinger favoured the idea of the new institute being built as a *Kaiser-Wilhelm-Institut*. The Kaiser-Wilhelm-Society was however of the opinion that the state of Prussia should bear a substantial part of the building and maintenance costs. Actual implementation of the plans drawn up for the institute however dragged on until 1925. But a first building stage could be finished already in 1918. When the first world-war broke out in 1914 the project was shelved for the time being. On the other hand, the planning work for a state-supported laboratory (*Reichsversuchsanstalt*) for aeronautics was pursued with vigour, in which Prandtl, with H. Hergesell, was involved as a consultant. The laboratory was established in Adlershof in the year 1912 under the name "*Deutsche Versuchsanstalt für Luftfahrt e. V.*" (DVL).

An entirely new undertaking for testing of aircraft propellers was started in 1912 in Arenshausen outside Göttingen. The measurement data were made available to aircraft manufacturing companies. Prandtl had to cope up with the burden of additional work due to the large number of requests for advice on technical problems and the expert's reports that are a part of the same. The concept of employing the measuring devices to examine the force exerted by wind was so novel and convincing that one started thinking of widening the scope of applications of this method. For instance, bridge builders were interested in checking the force exerted on the bridge pillar supports by wind gusts, and this question was answered satisfactorily by the measurements. Again and again, inventors approached Prandtl with requests for expert opinion on their projects. I remember that one in fact believed to have invented a device for perpetual motion. Again as an example, an unknown inventor sought Prandtl's opinion on his (the inventor's) work.

Prandtl's reply in 1909:

"To answer your question, please permit me to say that, in my opinion, forces due to wind cannot be measured at all by the device suggested in the enclosure to your letter..." Prandtl suggested an improvement that he supported by a scientific foundation adding sketches to the same. When this correspondence came to an end, a solution to the problem was discernible. Although he was not happy on being approached by such inventors, he conscientiously replied to every inquiry. I wish to include some further examples of such correspondence with inventors.

5 December 1912:

"Dear Herr K.

I have thought about your project carefully and thoroughly and believe it deserves to be fabricated. But I cannot conceal that unusual difficulties will still have to be overcome."

22 March 1912:

"Dear Herr M.

In reply to your inquiry I am sorry to say that we cannot issue a general expert's certificate on aeronautical inventions. However, a customer's order can be placed by filing in an application to the laboratory. The laboratory will then undertake to measure the forces exerted by airflow on models in experiments. The costs will be invoiced to the customer placing the order. They amount to 60 Marks per day of experiment."

9 June 1912:

"Dear Herr A.

Your letter of request to *Geheimrat* Böttinger was passed on to me by him. After taking note of your descriptions I can only advise you not to follow your idea of a fan flier (*Gebläseflieger*) any further since that is sure to fail."

The following letter written in 1911 is about Prandtl's desire to help the aviation pioneer August Euler carry out an air-show in the surroundings of Göttingen. Euler was the first German to pass a flying test, so had obtained a pilot's license bearing the number 1. He organized the first regular air-mail postal service. Later, he laid the foundations for German air-traffic laws. The purpose of Prandtl's letter to Senator Friedrich Jenner was to prepare ground for the air-show.

"...Euler wishes to fly over the *Kleine Hagen*. He thinks it is sufficient to cordon off by teams and security personnel, even if the number employed for this purpose is small. He thinks the danger lies only if the public, which has paid, feels it is only tolerated so be it much more peaceful. Short notices of explanation in the newspapers on the necessity for the airfield to be kept clear would be, in his experience, very effective. ('No flights take place as long as the airfield is not clear.') Euler very much likes all the people of Göttingen to see something of his flights. It is only access to the aircraft and the take-off site that he would like to see reserved for the privileged. The costs incurred for the air-show, which consists of transport and travel allowances, costs for material and so on, will be borne by Euler; Göttingen will be required to bear costs only for erecting barriers and tents for the flying and supporting personnel (a few in number). In the matter of mobilizing funds there is perhaps a possibility of the city of Göttingen contributing some money since the show is for the whole population. The *Luftschiffverein* (airship society) will also contribute their share and, in return, earn the right for their members to enter the take-off site by showing their membership card. All in all, if the weather is also good, the air-show may be expected to be delightful for Göttingen.

With best wishes, sincerely yours, L. Prandtl."

After the above correspondence by letter, Prandtl had established contacts with August Euler as early as 1909 at the First International Airship Exhibition (ILA) in Frankfurt am Main. As a result of these Euler had offered in the spring of 1911 to organise air shows in Göttingen to promote scientific interest in flying. Prandtl took this opportunity to invite the then representatives of aeronautical sciences for a meeting in Göttingen. Thus, an aeronautical congress was held in November 1911 at which a number of interesting technical lectures were presented [37]. Eleven years later, Prandtl recapitulated [41]: "The Congress went on in high spirits in a way I had not experienced hitherto, not in the least due to the successful part played by the social programme. It did so not in the least since there was complete agreement regarding the goal to be pursued among all who had gathered. It is therefore no surprise that the general spirit, also expressed in the speeches, favored the holding of such a meeting again soon. We of the Göttingen society were given a mandate to organize such a meeting." Von Böttinger, Klein and Prandtl had taken this upon themselves, and had made preparations for the founding of the society "*Wissenschaftliche Gesellschaft für Luftfahrt*" with the prince, Heinrich von Preussen, as honorary president. This society continues to exist today under the name "*Deutsche Gesellschaft für Luft- und Raumfahrt e.V.*".

There were also letters with contents of a more private nature in which requests were made for advice and material help. I wish to give excerpts from these in order to characterise his deeply rooted and true humanitarianism.

A rather lengthy correspondence with a person Z. in Göttingen who, evidently, lived in the neighborhood, indicates the desperate state he was in. He requests Prandtl for a loan of a larger sum of money since he had landed in distress due to speculative trading. Prandtl is willing to help, and also mediates between the members of the family who were at odds with each other.

Prandtl, 1 September 1910:

I am very sorry to know of your bad luck through your letters. You have not erred in looking for help from your former room mate (neighbor). I will give you the loan you wished for.

Z. answered:

"Dear Professor Prandtl,

Thank you very much for your kindness with which you have helped and pulled me out of misery. Your readiness to help is a strong evidence of your friendship, and it has done me good twofold, since my personal friends---or better said, so-called friends---all left me in the lurch.

Your devoted Z."

The conflict between the members of the family could also be brought to a peaceful end later.

This was Prandtl's way: When requested for advice and help, he was always spontaneously ready to help. I know of several instances in later days when people approached him with requests and they got loans from him.

A letter belonging to a different sphere also appears to me to be of interest. In a letter of 1913, Prandtl conveys his assent to his membership of *Keplerbund*. The society *Keplerbund* for furtherance of knowledge on nature had framed a set of scientific requirements and principles which were as follows.

1. Freedom of science,
2. Objectivity in research,
3. Support of science and natural philosophy,
4. Acceptance of inadequacy of science to define a *Weltanschauung* all by itself,
5. Acceptance of neutrality of science in questions of *Weltanschauung* and religion,
6. Hold the opinion of the right to believe in God, i.e. its compatibility with scientific thought, as a logical consequence of point no. 5.

In his letter of agreement for membership Prandtl wrote as follows:

25 March 1913:

"It is only now, after close of the semester, that I am replying to your circular sent quite some time ago. I have given a genuinely sympathetic thought to the matter in your letter and find I can subscribe to all the six points you list therein. I am also in complete agreement with the objectives of your society, if, in putting them into practice, the "guidelines" as laid out are followed. Opinions expressed earlier, which were obviously coming from unfavorably disposed quarters, had given me the impression that the goal of the *Keplerbund* is to lead those interested in sciences to the old positive religions.

I suppose I can presume from the guiding principles set out in your circular that the *Keplerbund*, just as it works against subordinating the religious outlook to realization of the truth of nature, also stands against interference by ideas traceable to religion in unprejudiced pursuit of the sciences (belief in supernatural powers etc). If this interpretation (of mine) of your objectives is correct, I will be glad to be a member of your *Bund*.

I wish to mention one point of inaccuracy in your circular that drew my attention: there is talk of an "artificial animosity" between sciences and religion, for which monistic-material circles are held responsible. In my opinion, the positive religions that have stemmed against scientific research, in particular against the theory of evolution, are more to blame for this animosity, and monism is only a reaction to this backward leanings, although an overreaction shooting far beyond the goal. "

The load of work increased many-fold in these years, as already mentioned. Prandtl saw the necessity to look for an assistant for his undertaking. In response to an advertisement for the post of an *Assistent* in the *Modellversuchsanstalt* (Laboratory for Model Testing), there was an application from only one young scientist who had worked in the field of hydrodynamics. As Prandtl showed him around the laboratory, they talked with each other with excitement. Obviously this young engineer was highly talented and excellently suited for the post. It was *Diplomingenieur* Albert Betz, who was to become later Director of *AVA*, who was appointed as a "*Hilfsassistent*" to Prandtl on 1 September 1911. There were, however, only a few years of research work together possible, until war broke out. Albert Betz then reported himself voluntarily to do army service. But within the following year, it turned out that he was indispensable in the *Institut*. Prandtl therefore wrote to the "Kurator" on 25 June 1915: I would request your Honor to make the arrangements necessary for Dipl. Ing. Albert Betz, who was a *Hilfsassistent* earlier, to be employed again in his earlier post, for the work of assisting the building up the *Modellversuchsanstalt*. Dipl. Ing. Betz was doing voluntary war service in the army, but, was discharged from the army and placed for services at my disposal."

And it happened that way too. After his final discharge from war service, he was back in his earlier place of work.

Most of the assistants and technicians of the *Institut* were drafted to army service since August 1914, so in the beginning, Prandtl had to run his undertaking without the trained personnel.

In 1912, the *Motorluftschiff-Studiengesellschaft* (Society for Study of Powered Airships) was dissolved, and thereafter the *Modellversuchsanstalt* was taken over by the university and annexed to the *Institut für angewandte Mechanik* (Institute for Applied Mechanics). The running expenses were borne by the Ministry of Education (*Kultusministerium*). The success of the laboratory was all too evident, and the facilities that were developed first here served as an example for other research centers of this branch of science. But, as said earlier, the first world-war brought the planning work for a larger laboratory to a standstill. However, in 1915, the army's directorate declared its interest in further development of the *Modellversuchsanstalt*. The army and the navy had made continuous use of the experimental facilities that hardly met the requirements. So, Prandtl wrote a new memorandum (*Denkschrift*) to emphasise the necessity for building a new facility. I will quote from this memorandum:

"The trend of development taken by the work done at the *Modellversuchsanstalt* has given rise to the thought that it would be in the interests of the army and navy administrations to help establish a larger aerodynamics laboratory that is suitable for dealing with foreseeable problems in the development of military and naval aeronautics by granting funds for starting the laboratory and to cover its recurring expenditure."

The memorandum was handed over in person to Prince Heinrich of Prussia in Kiel, who forwarded Prandtl's plan with a personal recommendation to the War Ministry and to the *Reich's* Admiralty:

"Kiel 30 April 1915

Respected Professor Prandtl,

On the occasion of my visit on the 27th of this month to the ship-yard Max Oertz, Hamburg, which was to inform myself of the progress being made on the presently very important task of building sea-borne and land-borne aircraft, Herr Oertz handed over to me your memorandum that had been received the same day together with three copies of an off-print from the *Zeitschrift des Vereines deutscher Ingenieure (Fachgebiet Luftschiffahrt)*---(Journal of the German Society of Engineers (Aviation Section)). While handing over these documents, he added the remark that it is important that they reach the proper authorities, and requested me for assistance in this matter.

Being convinced of the importance of the contents of the documents and of the necessity to enlarge and support the Göttingen undertaking, I offered to do the needful with everything within my means, and have already sent two copies each to the War Minister and to Admiral Dick of the *RMA (Reich's Admiralty)* with a covering letter. In the covering letter, I have attempted to state briefly the mutual connection that exists between the Göttingen institute and airplane builders, pointing out that the stage of empirical studies has in fact been crossed and that science, besides primarily supporting building of aircraft, furthers the cause by scientific investigations and establishment of facts.

Although I am not in a position to judge or influence official thinking in financial matters, I am happy that I have been able to draw attention to a matter which, for one, is very dear to me, and, to the close relationship between science and design that was also proven beyond doubt by Herr Oertz's lecture supported by design drawings. A goal that I have always dreamt of has been reached with this, and will probably be further pursued. This is primarily thanks to your efforts. -

The nature of events in the years 1914/15, and in particular in the past 9 months, have been such that I have not been able to attend personally to these details, but I am happy there has been an opportunity for me now.

The sole purpose of these lines is to let you know of this.

In the hope of succeeding to extend due support to you in your efforts in favor of the *Reich*, I send you my hearty greetings and remain, my respected Herr Professor, yours . . .

Heinrich Prince of Prussia"

Shortly thereafter, a meeting took place in Berlin of which Prandtl soon sent a note of information to Felix Klein. His shock over the losses and suffering in the war are very clear.

Berlin, 11 May 1915:

"Dear Herr *Geheimrat*:

The outcome of today's conference in the War Ministry is simply overwhelming, in order not to say devastating (particularly from the standpoint of my existence). The decision has been taken to release war funds for the new laboratory for model experiments which will be built as fast as possible on the Böttinger lawns in order that the measurement data may assist war efforts." (*Geheimrat* Böttinger, Commercial Director of the company *Bayersche Farbenfabriken* in Elberfeld (now a district of the city of Wuppertal), had placed his plot, bought in 1907, at the disposal of the planned extension.) "I have promised the first results in half a year, which was declared as acceptable. According to this, the officials reckon with a prolonged period of war. I have already reclaimed my *Assistents*, will restrict my teaching activities, perhaps will have to give up the dean's position. Everything else in person.

Prandtl"

Just like Albert Betz, the other young *Mitarbeiter*, Dr.-Ing. C. Wieselsberger, could also be brought back from army service. G. Fuhrmann had already fallen in the war in September 1914 in Belgium. Betz and Wieselsberger were employed as *Hilfsassistent* on 15 May and 1 June 1915 respectively. The engineer Dipl.-Ing. Max Munk had already obtained the post of a *Hilfsassistent* in April. Thus, making progress was assured in executing the plans for extending the laboratory. In July 1915, the brother-in-law, Dr. Hans Thoma, was brought in to lead the building works in the new project in Göttingen. In the meantime, Else Föppl, Gertrud's sister, had married Hans Thoma, also a talented engineer. The co-operation at work with Thoma, whom the Imperial Docks (*Kaiserliches Werft*) in Wilhelmshaven had released up to 1 March 1916, enabled good progress to be made at putting up the new extension buildings.

On 29 May Ludwig Föppl wrote in a field post letter "Wireless Command no. 6: I learned from Gertrud that you are getting a new *Institut* now, upon which I wish to congratulate you. How much would your colleagues all envy you for serving your mother country (*Vaterland*) this way. I also congratulate you upon getting a person of ability like Hans Thoma as an *Assistent*."

23 June 1915:"You are now actively working in the service of the mother country by pushing ahead putting up the new buildings of the *Modellversuchsanstalt*. We, the wireless people, can establish without doubt that the enemies are superior to us in flying."

In the course of a few months that were full of work, a new high performance wind tunnel with a settling chamber of 4 meters \times 4 meters and a jet diameter of 2.25 meters was built, opening new avenues for research.

Professor Betz writes [3]: "Although during the war military interests were, naturally, given the topmost priority, it was noteworthy that the offices responsible gave the laboratory wide freedom to choose the tasks they set for themselves. There was a general

conviction regarding the importance of basic research on a large scale, and it was considered most promising if the researcher was helped to implement his ideas without forcing him into a straight jacket at work."

It is against the background of this concept of freedom of research that an inquiry by a biologist regarding animal flight can be understood. Here is Prandtl's reply:

20 August 1915:

"Dear Herr *Doktor*,

Unfortunately, the conditions prevailing do not permit me to say things favorable. The Laboratory for Model Testing that is being built now is financed out of war funds, and serves only flight technology. The laboratory gets a bigger and more powerful air-stream in which airplanes and parts of the same can be tested for their drag in flight. Other facilities are not foreseen at present, and will be added only if military interest is evident. But it is planned to continue building up this institute in peacetimes too. The question of whether sometime later special studies could be devoted to biological aerodynamics is still far away. You know that my attitude towards such questions is a sympathetic one, although I am more and more convinced that airplane technology has little to gain from studies of animal flight. In my opinion, conclusions useful for airplane technology are more likely to be drawn from flight studies of big birds (stork, condor, big marine birds). Smaller birds and more than even these, insects, fly under conditions so different from human flight that their study is hardly likely to further airplane technology. Of course I am not disputing in the least that research in these areas is fascinating and educative from a scientific viewpoint. After having said this, you would understand that, at present, I cannot give any assurance of biology of flight being accorded greater importance in the *Institut*. However, I believe to be able to say that, when the *Institut* sails in calmer waters, it will be possible to procure apparatus and facilities for conducting such experiments."

The job awaiting the *Modellversuchsanstalt* in its new building was to deliver the results of measurements to the army directorate. An able mechanic was urgently needed for this purpose.

Prandtl wrote to the *Reich's* Admiralty on 8 December 1915:

"The orders placed by the Imperial yards with the Göttingen laboratory have resulted in piling up of work in such huge proportions that, with the strength of personnel presently available, this work can be done only with much delay. I am therefore taking the liberty of asking the *Reich's* admiralty if it would be possible to place the services of a helper assistant (*Hilfskraft*) at my disposal for this work. One suited for this post would have the qualifications of a technician who is capable of taking readings from measuring instruments following instructions given to him, reduce the data and draw the curves for graphic evaluation work."

Since his suggestion was rejected, Prandtl wrote to the deputy of the general command in Magdeburg to get the release of the mechanic Julius Lotze who had worked with him earlier, released.

On 15 February 1916 he wrote:

"A laboratory for model experiments for aviation is presently being built in Göttingen under my guidance out of funds provided by the war office. Since it has not been possible to obtain mechanics for fabricating the measuring instruments for this work in sufficient numbers out of personnel freed from army service, I wrote sometime ago to Grusonwerke in Magdeburg-Buckau requesting them to return to my services the mechanic Julius Lotze who worked with me earlier. Herr Julius Lotze has been sent by orders of the war ministry to Grusonwerke as a fitter for their cannon workshop around a year ago. Since Lotze is not just a highly skilled mechanic, but possesses, due to his earlier work, the specialized knowledge required for the experimental work to be done, his assistance is invaluable for me in my work mentioned."

Prandtl succeeded in getting back Julius Lotze from *Grusonwerke* to Göttingen, where he was of much help in building up the new laboratory.

In the meantime, the need had arisen to employ a new secretary too. Prandtl made enquiries with his colleagues with the object of finding a suitable secretary. Problems, even those of employing a person, could be solved most reliably through personal relations. Professor Wiechert, director of the seismographic institute, had an excellent typing assistant, one *Fräulein* Frieda Kreibohm, who also did technical calculation jobs. Enquiries were made if this lady perhaps had a sister who could be employed. The sister was only 16 years old then and was still at school. When an offer was made to her to be employed immediately, she chose not to give up school in the last school-year. Until then Professor Wiechert could lend to Prandtl the services of his secretary for half a day. The work that had to be done was to reduce the measurement data gathered in the course of the experiments. On the very same day on which the younger sister, Hilde Kreibohm, passed out of school with the final standard examination, she went in the afternoon to the laboratory. She stayed there for over 50 years, for her whole working life; rising from the small position of a typing assistant to a senior secretary. When I visited here, I only asked her: "Can you type on a typewriter?" "No," she answered, "there were no courses offered those days. Professor Betz arranged for an old typewriter to be brought to our home for me to try out, and I learned practicing for hours."

Personnel strength in the office and the workshop grew steadily as the buildings of the *Institut* neared completion. In 1918, the personnel strength reached its record mark of 50 people. Dr. Wieselsberger and Dr. Betz headed a section each, for new design and theoretical work. There were among the helper assistants (*Hilfskräfte*) many students doing voluntary war service, so that the work of doing calculations could be done as desired. On 7 March 1917, an air stream could be generated for the first time. Prandtl made a note of this date himself.

Since the distances to be covered between the old and the new laboratory resulted in much loss of time and the old brick barracks had turned unsafe in some respects, it was moved in 1918 to the new plot of land given by Böttinger. With this, the plans of putting up buildings reached completion in a certain sense.

When the new building was completed and the military administration was more liberal in placing personnel at the services of the laboratory, it was again possible to conduct, besides the experiments, theoretical research work. Now Prandtl could once more take up work on wing theory that he had started in 1910 and bring the same to a stage of completion. The aim of this difficult theory was to explain how the relationship between lift and drag is influenced by the shape of the wing. At the meeting of the *Gesellschaft der Wissenschaften zu Göttingen* (Göttingen Society of Sciences) on 26 July 1918, he was heard presenting wing theory for the first time [33].

In his article felicitating Prandtl on the occasion of his 50th birthday Th. v. Karman wrote on the significance of wing theory [16]: "The main contribution of Prandtl to airplane technology is without any doubt his wing theory; more precisely, the discovery and evaluation of the so called 'induced drag', which paved the way for rational design calculations of airplanes, and in particular for calculation the influence of the span, for comparison of monoplanes (*Eindecker*) and biplanes (*Mehrdecker*), and of the influence of limit and stagger, all at one stroke. The analogy between a wing and a line vortex was probably known. Even the fact that, for a wing of finite span, the circulation at the tips if the wing cannot just disappear, but a 'braid of vortices' has to separate out, was established by Lanchester. The genius in Prandtl saw, however, at a glance that Helmholtz's theory of vortices, consequently applied under assumptions of lightly loaded wings, should lead to a complete theory for idealized wings; a theory that yields information on lift distribution, power requirement and so on that are independent of the profile drag. The discovery of (the existence of) minimal drag of the ideal wing, the so-called 'induced drag' is as significant for airplane construction as the discovery of the 'Carnot process' for the design of thermodynamic machines. Both deliver a reference scale for measuring the quality of the design, which is a basic principle according to which the huge volume of information contained in experience up to the present day suddenly became transparent and understandable..."

6. A day at home

In spring 1914 my parents had moved to a more sun-lit and modern apartment with bath and central heating on Bergstrasse (now Calsowstrasse). The main reason for the move was that offspring was expected. In November 1914, the happy parents could announce the birth of their first daughter Hildegard. A second daughter Johanna was born two and one half years later. Now the big apartment was full of life. At that time, the house was on the outskirts of the town; adjacent to it were beginnings of a plum avenue and several trails that led to meadows and allotment gardens. There was no garden of our own, but the meadows and woods in the neighborhood were splendid playgrounds for us children. My sister and I grew up there in much freedom. My mother, whose father was a strict disciplinarian, did not want to bring up her children sternly. She knew to guide us with love and understanding, but was firm in not allowing us to get away with any mischief. Understandably, she had taken over upon herself the main responsibility for bringing us up since our father whose thoughts were fully occupied with his plans, gladly left this task to his wife. When we children sometimes impetuously demanded of him to play with us, just when he came home tired, he could hardly resist our assaults. But my mother interfered at the right time saying: "Leave your father in peace! He wants to rest a little now!" By the way I clearly remember that she sometimes said: "You do not know what a good father you have."

Shortage was ruling everywhere during the post-war years. Even the coal ration sufficed for heating of only one oven. When Father was at home, which was seldom, for instance on a Sunday, we were admonished to be silent in order to keep disturbance to him as low as possible. I remember a scene that took place in the living room of the family. My mother was firing the oven, kneeling on the ground and poking in the embers. When she was thus engaged my sister and I did some mischief that angered her. Father was sitting at the large table, bent over his work. Mother's words of warning and rebuke went unheard, and the mischief was in full swing. She then turned to her husband appealing for support since, with her hands dirtied by coal, she couldn't inflict the punishment herself: "Ludwig, please give the children a beating." Father pushed his papers a little aside, got up and walked towards our play-corner. We were very tense waiting for the unusual punishment to be meted out by our father. The tension just couldn't get any worse. He hesitated a little when he stood next to us, turned to Mother and asked her to "clarify" what he was supposed to do: "Yes, but where?" We two sisters burst into laughter of relief---even our mother could not arrest her laughing. Even now I can clearly remember how Father tried to explain to us that his query was justified, since the measure of punishment had still to be decided, depending upon the offence that he had not observed himself. He would not have come upon the idea on his own to inflict physical punishment upon us- no, this thought would be absurd. Thus we often came away from such punishment when he was around, although we caused much disturbance to him. Later, he took over the particular responsibility at bringing us up through his loving words, which made us see the point and taught us proper behavior.

The serenity of his nature could be felt when he sat at the table and worked, totally absorbed by his immediate surroundings during writing and doing calculations. His

caring wife knew mostly how to keep us away. She encouraged us to jump around outdoors; and, as already said, Father was mostly in the Institute, and we were permitted to bring home our friends for playing.

Shortage in the post-war years, particularly in supply of food, had caused a state of general misery to set in. Prandtl wrote about this to a Swedish colleague, Professor Oseen in Upsala, with whom he was regularly in correspondence for years: "It looks very bad in the poor German mother-country, and it will get worse. One half of the German population should really be in the sanatorium in order to heal the effects of under-nourishment. Here in our place, food is in short supply, but, the countryside being in the immediate neighborhood, matters are not as bad as in the bigger cities. When necessary, one can just walk to the villages where there is still something."

My mother went mostly twice a week walking through the woods to the family Christmann in Herberhausen whom she knew well, and from whom she got milk for her children, and in fact often some butter and a few fresh eggs. Over the week-ends, our father also had the time to accompany her to Herberhausen. All of us then sat in the overheated living room, the grown-ups talked with each other, and we children took pleasure in looking around in the court and the stables. Our parents knew every trail in Hainberg well, and sometimes we returned home when it was dark. Thus, the week-end trips were full of adventure for us. People living in the smaller cities with no public transportation had to be able to cover much larger distances on foot than today.

Even during the week it was a regular habit for Prandtl to walk to his place of work. Prandtl was seen on this daily route lost in thought, looking inwards, hardly noticing passers by. But he took note of many small things along this route. In spring he looked for the first flower blossoms to come up behind the hedges of the small front gardens, and was joyous to see the snowdrops, and later violets and roses. He knew the planting patterns of these gardens very well, and followed their flowering time year after year. When we were all together at the table for lunch or dinner he made it a point without fail to mention his observations. On the way home, he was often accompanied by his younger *Mitarbeiter* (co-worker) who welcomed this opportunity to discuss their scientific problems with Prandtl. The discussion usually went on for a while in front of our house although lunch hour had passed. A young physicist is supposed to have pronounced the following dictum: "If one is too lethargic to think over a problem cropping up, one just has to tell Prandtl about the same. Either he can clarify it straightaway since he has thought over the same problem long ago, or, being stimulated by the question, he will not be in peace, and he will tell you the solution in the course of a few days." 1)

1) Taken from a talk given by A.Betz "Das Lebenswerk von L. Prandtl"[4].

7. Gliding

There was no stagnation in the special research work during the post-war years although severe restrictions on powered flight were imposed upon Germany by the treaty of Versailles. Dismantling in some works also hit aviation hard. On the occasion of a meeting of the *Wissenschaftliche Gesellschaft für Luftfahrt* (Scientific Society for Aeronautics) in Augsburg, a visit was arranged to the Riedinger balloon factory which was mentioned earlier. A newspaper journalist wrote: "On entering the large hall a cloud of sadness descends upon a lover of the mother country, since it contains remains of aviation equipment that succumbed to the rage of destruction even here. It went to the extent that even the baskets of the fetter balloons (*Fesselballon*) had to be cut into pieces."

Insofar as flying was concerned, there were sources of new impetus coming from students enthusiastic of flying who now devoted themselves to gliding. This was not in violation of the treaty of Versailles. Flying enthusiasts formed themselves into groups at different universities, and these fabricated their gliders themselves. Flying as a sport activity did not have military goals and hence could be pursued freely without being troubled by vigilance from the winning powers. The editor of the aviation journal of those days *Flugsport*, Oskar Ursinus, got the idea of calling for a gliding competition. The young designers were supposed to bring their gliders and assemble for this competition upon the heights of the river *Rhön*. Many types of gliders were brought over there and their pilots wanted to enter into the competition. The *Rhön* terrain was chosen for this purpose since there was a steady wind blowing over the treeless knolls there which could be used both as updraft and fair wind. The participants in the first competition in 1920 could fly for about only two minutes. The individual flights were timed accurately. In the second *Rhön* competition that was held in 1921, the winner W. Klemperer succeeded in flying for a duration of as long as 13 minutes and therewith set up a world record. As part of the efforts put in to improve this performance many refinements to the equipment were undertaken, and there was a willingness to learn more of the theory of flight. Seminars were arranged in response to this and were held on the water knolls (*Wasserkuppen*) there to instruct the young glider designers in aerodynamics. Prandtl and von Karman, Runge and Madelung taught them that correct and functional design was what mattered most, and also how to use to advantage the air stream under favourable weather conditions [21, 29]. In 1922, as a Berlin newspaper article reports, the record in flight duration already reached three hours. The number of participants in the *Rhön* competition increased, and so did the enthusiasm for this new sport activity. The hand-made models, each designed individually, also meant personal commitment of the one concerned. Excellent team spirit prevailed in the group. There, on the top of the water knolls, modest barracks had been built where the flying sportsmen stayed partly even over winter, using every favorable day for practicing. The *Rhön* gliding competition was in existence for many years [48]. On 25 July 1926, Prandtl got the following letter from the organizers of the competition:

"Respected Herr Professor,

We have the honor to send you herewith a list of the gliders registered for the competition, and a permanent pass with a badge as a member of our distinguished panel/committee (*Ehrenausschuss*), and hope to welcome you on the water knolls."

During this period our family was on a Pentecost (*Pfingsten*) trip in the *Rhön* area. The narrow gauge train took us from Fulda to Gersfeld. From there we began climbing up to the top of the knolls. It was warm and sunny at the lower altitude below, but at the top it was very windy and the sky started getting clouded. When we reached the top a flying sportsman was getting ready to take off. The glider had to be towed for a short distance with a tug by his fellow-sportsmen, and then it had to gain altitude of its own. Our father watched the flying sportsman spellbound and with deep satisfaction at the same time until he disappeared from our eyesight. After lunch, which we had in the main building, our father was fetched, since the gliding sportsman who had landed in the meantime, wanted to talk with the fluid flow professor over his flight and consult him on some problems that had arisen during the flight. In the afternoon it started raining, the knoll was soon clouded in fog, and the flying was called off.

8. The 'Call' to Munich

In the summer of 1920 Prandtl got a 'call' from the Munich Technical University (*Technische Hochschule München*). His father-in-law, August Föppl, had sought them to relieve him of his duties on his reaching 66. August Föppl still kept some smaller tasks in the laboratory for himself, but he wanted to withdraw from his lecture duties in mechanics attended by more than 400 students. At the time of refilling the post it was planned to divide the overburdened *Lehrstuhl* (chair) into two, so that the conditions of work looked quite favorable. It is easy to imagine that the prospect of returning to their home region of South Germany was very attractive to my parents. But Prandtl purposely postponed for some time taking the final decision, since that was not easy for him.

I would like to quote a few passages from a letter written by Prandtl in this period to Herr *Geheimrat* Dr. Duisberg, Director-General of the company *Farbenwerke Bayer*. Prandtl had been given hopes of being granted financial support for his steadily increasing research plans channeled through the newly founded *Helmholtz-Gesellschaft* (Helmholtz Society). That would have kept him in Göttingen.

20 November 1920

"With reference to the 'call' I have received, you were kind enough during our meeting in (Bad) Nauheim to indicate the possibility of extending financial support for my research institute in an effort to persuade me to stay in Göttingen, so I am taking the liberty of writing to you in this matter which is still awaiting a decision:

What makes the Göttingen position valuable to me is the research activity. Against this the teaching is not of much significance due to the small circle of interested people that my area of research finds at the university. Probably, I have to shelve for ever research plans as envisaged before the war for the *KWI* (*Kaiser Wilhelm Institut*) for Aerodynamics. I will have to be content with conducting the research work on a much smaller scale. But even for this, substantial amounts will be necessary to meet recurring expenditure."

It is not known to me how the matter in respect of financial support was supposed to be settled. In the meantime, news reached Prandtl that due austerity measures, the *Lehrstuhl* could not be divided into two. Prandtl was not willing to accept the extra burden associated with such a large number of students. He would then have had hardly any time to spare for his research work. In August 1921 he therefore rejected the 'call' from Munich. He then made recommendations to the committee as to who could be another suitable candidate.

Exactly one year later the offer from Munich was renewed, since, in the meantime, skillfully conducted negotiations had cleared the way to split up the *Mechanik-Lehrstuhl* into two. They were to handle distinct fields in the very broad area of mechanics and each was instituted with a chair for this purpose. One of these chairs had already been given to Ludwig Föppl. This time Prandtl decided in favor of Munich. On 30 December 1922 he

gave his assent. The actual move was delayed since searches for housing accommodation in Munich were in vain. This was in the middle of the inflation period, and the rent for an apartment was, as were the prices for all "goods", steadily escalating. In this phase of highly tensioned planning (some terms were still under negotiation: the position of an *Assistent* and an exclusive budget for the laboratory were to be applied for) Prandtl unexpectedly received an offer from *KWG (Kaiser-Wilhelm-Gesellschaft)*. The promise was given to him that, in case he decided to stay in Göttingen, a new Institute for Hydrodynamics would be built for him next to the buildings of the *AVA* that existed already. Everything got turned over once again and Prandtl decided to stay. But there was a set-back again, since due to the disgrace of the finance minister the money approved by *KWG* could not be disbursed. My parents were occupied with plans for the move again. I still remember a little of the hither and thither that was going on. A small incident clarified to me the meaning of what destiny had in store for us personally. Once, when we had plucked marguerite (Oxford Illustrated: ox-eye daisy) flowers on the lawn in the neighborhood with our mother, and we sat on a bench on the border of the woods, she picked up a flower from the bunch, and pulled out the white petals one by one to ask destiny playfully: Munich-Göttingen, Munich-Göttingen and so on. I cannot say any longer which of the two the marguerite oracle prophesized then. Only, I became very conscious of how heavily the yet to be taken decision was burdening my parents' state of mind.

There are letters left from the last phase of this development that Prandtl wrote to Ludwig Föppl to keep him informed of the then current status in this matter. They go to show how much he struggled to come to a decision that would be fair and just to all concerned.

Prandtl to his brother-in-law Ludwig Föppl:

13 July 1922:

Schröter asked me, of late, if I was prepared to accept the 'call' from Munich. I explained to him that I am strongly inclined to accept, but that I could not give a firm commitment before negotiating terms with the ministry.

On one matter I wish to sound you for your opinion. During the immediate past, due to the deanship I have not been able to work out my research ideas. There is no dearth of ideas since my doctoral candidates, whose numbers run into quite a few (almost half a dozen), keep me on my toes to think over matters for them. My strong desire is therefore not to have to sever all this, and I do not wish to leave the doctoral candidates entirely to their fate. Hence it is very important for me to be able to stay here until next Easter."

17 January 1923 to the brother-in-law:

"You would have come to know through letters to the family that I have accepted the Munich offer now, but have not yet given the date of joining, which has to wait until I find an apartment."

27 April 1923 to the brother-in-law:

In the light of the thinking going on regarding what I will be offered here, I of course wish to be certain that, if I go to Munich, there will be good openings there for me for research in hydrodynamics."

2 June 1923 to the brother-in-law:

"I am sorry to inform you today that the matter of the "new offer from Göttingen" has reached a critical stage. The intention that is made known--- and it seems to be almost certain that it comes through--- is that within a very short period, on the basis of April this year, a sum of 40 million per annum and a one time 500 million, would be mobilized to be offered to me for building the hydrodynamics division in the scientific department of the research institute proposed to be built. I am enclosing a copy of the letter I have written to the executive managing director (*Geschäftsführer*) of the *Kaiser-Wilhelm-Gesellschaft* in reply to his letter in which he requests me to respond by return of post if I would stay here when the intentions are confirmed:

"2 June 1923 to Dr. Glüm, Director:

Unfortunately it is not yet possible for me to comply with your wish to inform you of my ultimate answer today itself should the ministry give their definite approval to the sums of money offered. It would not be right to take a decision on a matter that drastically affects my personal future without at least a few days of thought.

As I conveyed to the Curator of the University yesterday when he called me in, I do recognize the stupendous accomplishment in obtaining such large sums in these times from the Reich and Prussia. The commitment to this cause by the *Kaiser-Wilhelm-Gesellschaft* and the Prussian ministry of education, that finds expression in reaching this goal in such a short time, compels me of course to give the matter a serious consideration."

13 July 1923 to the brother-in-law:

"As you would see from the enclosed copies of my letters bearing the same date to the ministry and the rector's office, after much thought in the matter of my 'call' to Munich, I have now decided, to make the decision in favor of Göttingen. While doing so, I cannot push aside the sentiment of feeling sorry that plans for our working together cannot be materialized. You have to start afresh to fill in the vacant position, and I wish you success in finding a suitable person. If you get a good teacher who applies himself full of energy to the work of teaching, you will probably have struck a better bargain at the end of the day than with me, if I, contrary to my good intentions, cannot shake off the research habit sufficiently."

13 July 1923 to the Bavarian Education Ministry:

"I have the honor to inform the Ministry for Education that, in the matter of my 'call' to the Technical University of Munich, a new situation has arisen through the Prussian Education Ministry and the Kaiser-Wilhelm-Society for the Advancement of Sciences (*Kaiser-Wilhelm-Gesellschaft zur Förderung der Wissenschaften*) letting me know of their intention to offer a sum that is high by to-day's standards for realizing my earlier plans for a hydrodynamic research institute. According to the information passed on by Berlin, the sum proposed for approval is 500 million, based on prices prevalent in April."

On 27 June (1923), candidates for filling the vacant professor's position in Munich were suggested to the brother-in-law. We may give here one suggestion of his:

"I know of only one candidate who satisfies all the requirements mentioned earlier, that is von Karman in Aachen. He has done outstanding work in all fields, some of them have opened new vistas. Besides, he is, as you know and as I hear again and again, a brilliant teacher. I am of course entirely aware that, due to his lineage, extending a 'call' to him might cause difficulties, but in my opinion such principles should not go so far that a university consciously destroys its scientific life."

So, already at that time Prandtl, in contrast to his Munich colleagues, pleaded without prejudice in favor of an esteemed Jewish scientist.

14 July to the brother-in-law Ludwig Föppl:

"My voluminous report with building design drawings and cost estimates for the Hydrodynamics Institute has gone to Berlin last Thursday. Since the concerned Berlin authorities are very much interested themselves in the matter making rapid progress, I believe, one will not have to wait for long for a decision."

24 July to the brother-in-law:

"I could resolve to give an ultimatum of 8 days to the Berlin people to the effect that I will decide in favor of Munich once this period of my ultimatum runs out. Of course a necessary prerequisite is that there is a suitable apartment for us."

29 July, Gertrud's letter to her brother:

"I often have the feeling that the present time, that is as unedifying as can be possibly thought of, will not be very favorable for building the new institute. I have tried a lot to dissuade my husband from this plan, but I have seen he is very much attached to the idea."

5 August to the brother-in-law:

"The Berlin people react with bitterness to my threatening letter and say that everything is already being accelerated. But the matter is very complex due to many authorities being involved."

7 September to the brother-in-law:

"I talked on the water knoll with the official in the *Reich's* finance ministry who is concerned with matters of aviation. He confirmed that their intention is to advance building the Annex to the Institute under all circumstances, particularly due to the strengthening of German aviation interests which one expects to achieve from it. Given this, it appears to me as if I had no right any longer to tax the patience exercised by all of you in Munich."

11 October to the brother-in-law:

"I was in Berlin during the last few days for a conference of the *Wissenschaftliche Gesellschaft für Luftfahrt* (German Aeronautical Society), and took the opportunity to talk with the *Kaiser-Wilhelm-Gesellschaft* (Kaiser-Wilhelm-Society). There they were very unhappy over the last crisis of the Government, since they had just succeeded in winning over the Finance Minister Dr. Hilferding to include my Institute in the budget just when he had to quit office. If it had not been so, a decision for me, however in a sense unfavorable to you, would have been within reach within a very short time. Now of course no one knows what course the matter will take."

29 October 1923 to the brother-in-law:

"If you ask me whether I still believe in my Institute being set up, I must of course reply that in the very moment, when things happen in Sachsen and Bavaria is rebellious, it looks pretty bad. At the end of the day it is not a matter for my private opinion, but one for those concerned in its cause to whom I have committed myself. But tomorrow I will push Berlin for a decision. I would rather wait for a "No" from Berlin than throw away the thing myself since I want to depart on good terms with the *Kaiser-Wilhelm-Gesellschaft* with whom I will still have things to do in the future."

28 November to the brother-in-law:

"After the new Cabinet crisis it is almost certain that I will leave Göttingen, so I thought a little woefully, and had much discussions with Gertrud on how we would set up ourselves in Munich.

Just then news came in from the *Kaiser-Wilhelm-Gesellschaft* that there would be a new opening for the Göttingen institute through a donation from an industrial magnate. It had the same effect on both Gertrud and myself, we were unhappy to have to give up Munich again. As a matter of fact we both are attached to Göttingen AND Munich, but only one of these can be THE reality.

Since I am not in a position to foresee the development, it is left to the Munich people to decide for how long the decision can be postponed."

28 November 1923 to the Rector of the *Technische Hochschule* Munich.

"Respected *Magnifizenz*,

It is extremely embarrassing to me to have to request you to give me a little more time instead of giving a final answer. I am doing so at the urgent request of both the *Kaiser-Wilhelm-Gesellschaft (KWG)* and of our present faculty. Due to the Cabinet crisis in Berlin, an opportunity to get an approval for the planned Institute has again failed although rudiments for starting were good.

However, the executive director of *KWG* who has been very entrepreneurial and energetic in this matter, has not given up for good. Instead, he surprised me by opening new prospects in which co-operation of a rich industrial magnate is a keystone, and entreated me to give him at least a few days' time. I am very conscious of my having no right to ask the Munich *Hochschule* to delay any further. But the request from *KWG* appeared to be sufficiently well founded for me to pass it on to the Munich *Hochschule*. If there is a possibility of establishing the second part of the research institute in Göttingen, and if this can be accomplished by my staying here, I feel it is my duty to devote myself to this task and thus carry out mission in life started, which is to continue research into the laws of motion of air and water. If this opening is closed my energy will lie idle, and I am convinced that in this case I can use it better in Munich."

3 December 1923 to the Rector of *TH* Munich:

"I have the honor to inform Your Magnificence that, according to a piece of news just received, building the institute here may be regarded as assured. The agreement reached, therefore, asks me to refuse the offer of the Professorship for Technical Mechanics in Munich. Even a few days ago I had expected things would go in exactly the opposite direction, and find it painful that now nothing will materialize of my plans that I had put together for work in Munich. The task before me in the immediate future here will be, due to the times, very difficult, but, if it is carried out in its main parts successfully, it will give me a bright opportunity for doing work in areas that are very close to my heart.

I request Your Magnificence to inform your Munich colleagues that even now, when my moving to Munich has been dropped, I feel strongly attached to Munich and will be available in every way when they need me."

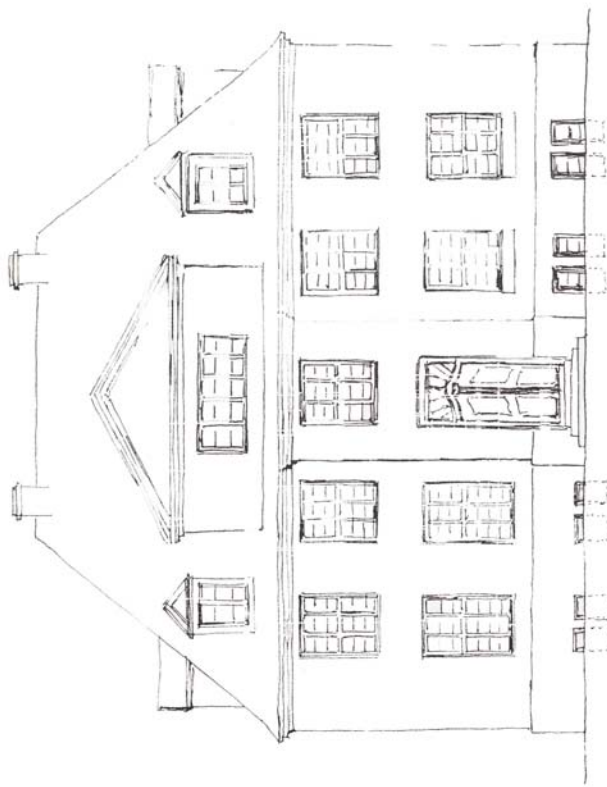
5 December to the brother-in-law:

You would have come to know from your Rector that the Institute has indeed been promised to me and therefore I will stay in Göttingen. I ought to be really happy over the coming research opportunities, but it has not gone that far up to now. The unhappiness over everything that I had pictured myself for my Munich stay and lost now, is still ruling with the upper hand. In addition, there is the concern that there may still be an obstruction coming in the way of building the Institute. But I keep on telling myself that, when others are offering me an opportunity for extensive research being regarded as the leading

expert of this area in Germany, I should not pull it down myself. I am quite hopeful of deriving much satisfaction out of work here when once the coarse work is done.

The children, getting to spend much time outdoors, are well. The *Bergstrasse* here permits leading a life entirely like in the countryside. They were therefore very happy on coming to know we would be staying here. They also have good friends here. We grown-ups would have been sorry that we could not have taken Hainberg with us!"

On 3 December 1923 Prandtl finally rejected the Munich offer. The Directors of *KWG* had been on the look-out for a private donor in order that the plans for the new institute did not have to be dropped. The Director-General of the company *W. Hoene-Aktiengesellschaft* was in a position to place funds at the disposal to help put up the new building. One half of the sum necessary was approved by the new finance minister Luther.



28. 3. 24
Prandtl

L. Prandtl's hand-drawn sketch of *Kaiser-Wilhelm - Institut für Strömungsforschung* (Kaiser Wilhelm Institute for Flow Research), inaugurated in 1925

9. Building up of the *Institut* and new projects

All the work that Prandtl had put in by way of building up did not have to be given up now. Even during the phase of construction work on the buildings the research work at Göttingen went on further without interruption with the help of *Assistents* well acquainted with the work and with reliable technicians. The new building was supposed to provide an opening for research (work) that was less oriented towards a specific purpose, independent of the other more application oriented Research Laboratory whose task was to investigate into the flow characteristics of airplanes, turbines and other models. In the year and a half that followed, during which the *Kaiser-Wilhelm-Institut* was established, extraordinary commitment was demanded of the personnel of the establishment. But the work of planning and the progress made at work, generated the enthusiasm for everyone to apply himself with joy and eagerness at work.

Ingenieur Walter Müller told me: "There were no fixed times of work then, neither for me nor for others". It was understood and natural for him to spend the whole of the evenings at the institute when the measurement data had to be reduced or when experiments had to be set up for the next day. 'There was also no specialization. Everyone could do everything.'

In the meantime the research work did not come to a standstill. New but important secondary problems concerning turbulence had arisen in boundary-layer theory. A few articles of Prandtl on the new subject of turbulence appeared in different scientific journals. Thus, simultaneously with the building up of the institute, there was continuous progress on the theoretical side, and in fact on new projects.

One of these new projects was the Flettner-rotor ship, an especially interesting project under the scientific supervision of the *Assistent* Dipl.-Ing. Jakob Ackeret (from Switzerland), which culminated in 1924 in a technically successful product. This was the so-called "rotor ship" (*Rotorschiff*). Precise studies of the performance of rotating cylinders, built as rotating towers on a ship's deck and exposed to the wind, had shown that they generate a larger driving force than the usual sails made out of fabric. The engineer Flettner, inventor of the rotor ship, brought his project to a successful end with the help the fluid dynamists. The prototype was built at the "Germania" docks in Kiel. Prandtl was often requested to come over there to give his expert's opinion on the functional efficiency of the ship. After it had proven itself in several trial cruises, the ship "Buckau" could be employed in coastal waters. Note made by Prandtl on 12 November 1924: "Cruise on the Buckau, with Prince Heinrich, Busley and many others, to Eckenförde."

My husband remembers that he had seen this unique ship that was gazed at with admiration by everyone on the section of the river Elbe known as *Ausseneibe*, and that its singing monotonous sound echoed far across the river.

December 1924, Prandtl wrote a newsletter for circulation:

"Regarding the invention of the Flettner sailing boat we have received letters of different types in such large numbers that it was impossible to reply promptly. A few typical questions have been answered below. We request you to be satisfied herewith.

1) There are no publications by us up to now on this subject. However the following articles will appear in the beginning of next year: One by Dipl-Ing. Ackert in *Zeitschrift für Flugtechnik und Motor-Luftschiffahrt*, one by Dr. Betz in *Zeitschrift des Vereins Deutscher Ingenieure*, and one by Professor Prandtl in '*Naturwissenschaften*'. Besides, the publisher 'Vandenhoeck und Ruprecht' in Göttingen will bring out a brochure titled '*Das Rotorschiff*' authored by Herr Ackeret.

2) Regarding the application of the rotating cylinder in other cases, it may be noted that they are meaningful only where, as in a sailing boat, one is interested in having surfaces of smaller size than at present. In all other cases, as in airplanes, windmills etc., the wing-like shapes presently in use are to be preferred due to their lower aerodynamic drag."

Shortly before this, on 17 November 1924, Prandtl had given a lecture on the rotor ship at the *Göttinger Physikalische Gesellschaft* (Göttingen Physical Society) [30].

In his preface to the brochure by Jakob Ackeret titled "*Das Rotorschiff und seine physikalischen Grundlagen*" ("The rotor ship and its physical foundations"), Prandtl wrote: "The sensational success of the peculiar Flettner wind-power propelled boat has suddenly drawn attention of the public at large to some facts that, until then, used to be discussed only in a small circle of specialists with technical knowledge. An explanation was sought as to how it is possible for a relatively thin and rapidly rotating cylindrical tower to replace a sail with an area ten times as big."

This brief note written for the layman explains the phenomenon perspicuously, although it pre-supposes a certain understanding for physical relationships.

The invention was explained at a public lecture in Göttingen to the interested public. The announcement: Stadtpark, Friday 20 February 1925, 8 o'clock. Lecture with slides by Professor Prandtl on the Flettner rotor ship.

From the (local) newspaper *Ortsnachrichten*, Göttingen, 22 February 1925:

"Yesterday, Professor Prandtl gave a talk on the Flettner rotor ship in a well attended auditorium. Due to the very nature of the subject, the lecture, for most part, was academic. But it was delivered in such a way that the layman could follow the chain of events occurring. It was extremely interesting to listen to a person who was instrumental in turning the Flettner invention into reality, talk on how the result, which justifiably created so much sensation in the whole world, was achieved by scientific foundation and diligent study of the characteristics of air flow. The speaker substantiated his statements, and was interrupted by applause, through projected slides. At the end of the talk, Prandtl raised the question of the rotor ship becoming important for navigation. He answered the

question by saying that the usage of the rotor ship would depend upon economic considerations."

However, hopes that were nourished with the coming of this type of ship---there were expectations of shipping cargo becoming cheaper---were not to come true.

It was due to economic reasons that this invention did not succeed in practice. The expenses necessary for maintenance of the engineering on board were so high that, for instance, fishermen were not willing to invest in the same. Since, without regular supervision by a mechanic attending to the smooth functioning of the high speed rotors, the boat could not undertake trips of a longer duration reliably.

Today, the energy saving principle of the rotating towers has returned under the name turbosail. Recently the oceanographic researcher Jacques Cousteau was on a research expedition of two and a half years with such a wind-powered boat. In June 1985 he was in the port of New York.

Another area of research pursued by the research laboratory at that time was the drag of land-based vehicles. It commenced with a set of experiments aimed at reducing the aerodynamic drag of locomotives in order to save energy. The wind force was investigated on a 1:25 scale model with its front and sides shielded. The calculations showed that in this case, at a train speed of 90 km /hr a saving of coal of 80 to 100 kg per hour could be attained [23]. These experiments were later continued successfully with a powered rail-car stationed in Göttingen and built according to the models tested. Sometimes we children were taken on the testing track to Northeim.

In the meantime the work of extending the laboratory had been completed. *Ingenieur W. Müller* still remembers from those days of a small mishap that occurred shortly before its inauguration. The floor of the director's office was covered with tiles of (synthetic) rubber in a black-and-white chess-board pattern made by the company *W. Hoene*. When he saw it, Prandtl didn't like this flooring at all. He said: " Perhaps this pattern would suit in a butcher's shop." He stood at the door and said: "I do not go in here!" The flooring tiles could still be changed. Beige-marmorated tiles were chosen and the flooring was done in time for the ceremonial act.

The inauguration was festively celebrated on 16 July 1925 at which the then President of *Kaiser-Wilhelm-Gesellschaft (KWG)*, Adolf von Harnack, was also present. At this function W. Hoene was awarded an honorary doctorate (*Dr. h. c.*) as planned.

At this juncture I wish to draw the reader's attention that it was quite in keeping with the tradition then to bestow such an honor on an industrial magnate. For instance, Klein was basically of the opinion that, if he wins over a rich industrial magnate to donate money to the University for building a new institute, he - the donor - should be given a degree of honor for his merits in supporting science. Although in the meantime a decision was taken against this practice in a faculty meeting, members of the same faculty voted with a majority in favor of granting the honor to Hoene who had made a demand of the same.

President von Harnack handed over the new *Kaiser-Wilhelm-Institut* to Professor Prandtl with the following words:

"We look for a good researcher meticulously. When we have found him, we direct streams of goodwill towards him, procure funds for him as generously as possible, and leave it to him to do what he considers right."

10. The new *Kaiser-Wilhelm-Institut*

As already mentioned, the scope of duties for the laboratory had substantially widened. Whereas in the war years it served primarily the purpose of airplane related investigations, it now addressed questions of wind-induced forces on iron girder bridges, electrical power transmission cables and high-rise buildings, in order to learn to build these structures with greater stability and thus protect them from damages due to storm. A journalist with insight wrote: "The building codes now in force are obsolete and urgently need revision."

The new tunnel of four meters test-section diameter permitted tests with larger models in the windstream. For instance, it was possible to suspend a full-sized blade of a wind-mill. The question addressed was how its shape could be improved in order to better utilize the energy in the wind. With the large number of research problems on which now work was going on in the different buildings of the *Institut*, it now became necessary for two directors to be in charge, Ludwig Prandtl and Albert Betz. The latter became the deputy director of the *Institut* and took over as the head of the *Aerodynamische Versuchsanstalt (AVA)*. Prandtl was in overall charge and attended mainly to work in the new *Institut für Strömungsforschung*. In November 1926 the personnel strength stood at 55.

Visiting colleagues were shown around the new laboratory and offices, and signed their names in the new visitors' book in the Director's office. My mother and we children were also permitted to go around the premises, and we saw with admiration the beautiful models in the wind tunnel. We were shown a new experimental facility that we liked very much: the rotating laboratory. It was meant for model experiments attempting to simulate on the laboratory scale the large-scale fluid motions on the earth. In the facility fluid flow behavior was investigated when there was rotary motion [25]. For us children it was a special attraction to board the rotating platform and be taken around a few times like on a merry-go-round. Dr. Busemann, who was conducting scientific experiments in this facility, was kind enough to let us ride on it many times. During the rotary motion in the facility, one was completely isolated from all external surroundings by the walls. The thinking was that the experience of dizziness is mainly due to the motion past near-by stationary objects. But we were in fact not entirely free of dizziness even in the closed laboratory when the rotational speed was high; neither was Dr. Busemann, although he had adjusted himself to it by incessant practice. Our father, who had also boarded with us, explained to us how the centrifugal force hampers the movements of the body to one side and eases them on the other. We tried our utmost to twist our arm against the direction of motion; but in vain, until the speed of rotary motion was lowered. Happy and enriched by this experience we finally disembarked from the facility. We then went into the buildings where the wind tunnels were situated. With Father taking us around, we quickly felt at home in the big halls. All the wind tunnels were surveyed in order of their size. Father's desire to entertain us children was really touching. Another helpful *Assistent* accompanied us to the control panels and switched on the blower of our choice. It was an exquisite experience to stand in the open section of the tunnel with hair blown off and skirts fluttering in the wind. One could imagine standing on a ship and the fresh wind blowing in the face. It was exciting. Then, all of a sudden the wind got so strong that one

could cross the tunnel only with difficulty. We could feel that a little more force exerted by the wind would make it impossible for us to keep our feet on the ground, and we would be blown off against the wall. Finally we visited the largest wind-tunnel of that time in which various models were held suspended by strings. They were taken out for a while and the facility switched on. This time we were contented with the magnificent noise that the blowers could generate at full load. The forces set free were calmed down and mastered again quickly. How much did we after all like this impressive noise generating facility!

The next day I told my friend Lilli Misch about this unusual entertainment; and since our primary school on *Bürgerstrasse* was not very far from *Böttingerstrasse*, we, the two small girls, decided to go on a merry-go-round trip directly after school closed for the day. But the enterprise did not succeed. Having come there, I told them at the gate that I wanted to see my father. He was not in his (Director's) office, nor in his *Institut*, but in a different building. Someone was sent out to look for him, and it took a long time for him to come. He smiled with embarrassment when he saw us, but sent us home firmly. He did not show any sign of irritation on our pulling him away from work, but I had the experience of his not being available for me on sudden call, and that was difficult to comprehend. My friend, who lives in America now, also remembers our plan very well, and the scene that put everything to an end. Had my mother known of our plan, she would have obviously held us back. Never did she call her husband in the *Institut* from home, so much did she hold his working world in respect. She knew that he was extremely busy, and that he invested all his capacity for work for the cause of the prosperity of the Laboratory and to its various research tasks.

Every year there was a party organized for the staff of the *Institut* personnel at a guest-house in the countryside. The young people liked the opportunity of entertainment at the evening dances. Before that the participants thought up and arranged exciting amusements through all kinds of gags. Once, in order that the various items in the program may proceed in an orderly manner, they were laid out on different tables. However item 3, intentionally left out in Prandtl's list, had the entry: "Prandtl plays with a toy". Someone was required to bring in and place on the table a kind of technical toy when Prandtl was giving his little speech. As the air was thick with suspense, the gag succeeded: Prandtl, attracted as always to unknown objects, reached for it spontaneously and began to play and experiment with it. In the meantime, everyone had come over from the other tables to watch from close quarters. Prandtl then noticed that his love of playing with toys had been exposed, and he ended his involuntary performance with a smile.

In spite of his busy program of work, those were years of great happiness for the head of the Laboratory. Another incident from those days has been put down on record by Frau Margarethe Winter, nee Weppner, in *Göttinger Monatsblätter*:

"I can recount a nice conversation I once had with the renowned Professor Prandtl. By chance, on a nice spring day, we left the former *AVA* together. Prandtl felt like taking a small walk, and asked me if I would accompany him for some distance. We walked together, and he noticed that I had a minor walking disability: I had just had an

inflammation of the walls of the vein (phlebitis!). He said spontaneously, that that was really a matter of "fluid flow" in the blood vessels; he wanted to think it over, and perhaps he should sit together with a doctor and discuss it. But we never came back to the subject again."

11. Journey to London

An event of special significance in the year 1927 was a journey to London where Prandtl was to deliver the Wilbur Wright Memorial Lecture at the Royal Aeronautical Society. Roughly a year and a half earlier he had begun to learn English under private tuition, supported by his wife Gertrud who spoke English well. It was already a sufficient hindrance for him that he had to get the publications from England and America translated, although he understood the technical terms. His very capable teacher, Beatrice Dammers, daughter of an Englishwoman, supported him with her best efforts. It is surprising how, with his heavy load of work, Prandtl mastered sufficiently well and in such a short time, a language that he had not learnt at school as to deliver his well prepared lecture in English in London.

Newspapers in both England and Germany followed his journey closely. For example, The Daily Chronicle said on 9 May 1927:

"England to honor 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 honor, which in all the history of flying has only be(en) 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 (Aeronautical) Society.

Previous recipients have been:

1909 The Wright Brothers
1910 Professor Chanute
1915 E. T. Bust and Professor G. Bryan
1926 Professor Lanchester"

The announcement proclaimed that Prandtl would be receiving the extraordinary and highly esteemed medal in person.

The flight Hannover-London, on a Deutsche Lufthansa aircraft, was Prandtl's first journey by air; and for him a very special kind of experience. He made a record of his observations by noting down key words along with the time:

"Thursday, 12 May 1927:

4.58 Rotterdam, the Rhine estuary, Sun
5.14 on the sea, ebb tide
5.25 big port city
5.56 sea channel with city
6.06 big seaport (Dunkirk)
6.20 on the sea, very hazy
6.27 last land across, aircraft is very steady in the air

6.35 land in sight, port, cliffs."

The *Göttinger Zeitung* said on 14 May 1927:

"Professor Prandtl in London

A report from London says that Professor Prandtl from Göttingen University arrived there by air the evening of day-before-yesterday. Professor Prandtl will be given the highest honour that British aeronautics can bestow, viz. the Gold Medal of the Royal Aeronautical Society."

The Daily Telegraph, 14 May 1927:

"Professor Prandtl arrived in London by air on Thursday night. In a conversation yesterday with a press representative he said: 'It is a great honor the Royal Aeronautical Society is about to bestow on me, and nobody realizes it more than 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 gave the important "Lecture" [32].

On 17 May Colonel Forbes-Sempill (pilot and aviation expert), President of the Royal Aeronautical Society wrote 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 cinematograph 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 aeroplane in flight."

An article in the *Göttinger Zeitung* of 18 May followed:

"Wolff's telegraph office reports that Professor Prandtl of Göttingen University gave a lecture on Monday in London at the Royal Aeronautical Society. This received special

attention since the German scholar, a leading authority in this branch of science according to the unequivocal opinion of all British scientists, was the first person who was not either an Englishman or an American to be invited to give a Wilbur Wright Memorial lecture. The Royal Aeronautical Society emphasizes in its invitation to this lecture that, just as the Wright Brothers brought manned flight into the realm of practical possibility for the first time, Professor Prandtl has made it possible to understand how and why the air sustains aeroplanes in flight. As already announced, Professor Prandtl will be presented today with the Gold Medal of the Royal Aeronautical Society that has up to now been awarded only to six men."

The rather long list of reports that I have included here on this special honor to Prandtl should be understood against the background of the situation prevailing during those post-war years. The majority of Englishmen still regarded the disagreeable German more than just censoriously. The fact that Air Vice Marshal, Sir Sefton Brancker, in his welcoming address at the Memorial Lecture, referred to Prandtl as 'an important citizen of a great nation', made him (Prandtl) conscious that he was not just facing scientists, but had to represent as a German his mother-country that had been humiliated by the victorious powers of the world war. This recognition was registered with gratification in his home country.

It is appropriate to add here that Professor Lanchester from England, an earlier recipient of the same award, had addressed the same problems as Prandtl. In order to clear any doubts that could possibly arise on Prandtl having worked out his wing theory on his own, Prandtl said during his talk in London:

"In England you refer to it (the wing theory) as the Lanchester-Prandtl theory, and quite rightly so, because Lanchester obtained independently an important part of the results. He commenced working on the subject before I did, and this no doubt led people to believe that Lanchester's investigations, as set out in 1907 in his "Aerodynamics," led me to the idea upon which the aerofoil theory was based. But this was not the case. The necessary ideas upon which to build up that theory, so far as these ideas are comprised in Lanchester's book, had already occurred to me before I saw the book. In support of this statement, I should like to point out that as a matter of fact we in Germany were better able to understand Lanchester's book when it appeared than you in England. English scientific men, indeed, have been reproached for the fact that they paid no attention to the theories expounded by their own countryman, whereas the Germans studied them closely and derived considerable benefit therefrom. The truth of the matter, however, is that Lanchester's treatment is difficult to follow, since it makes a very great demand on the reader's intuitive perceptions, and only because we had been working on similar lines were we able to grasp Lanchester's meaning at once. At the same time, however, I wish to be distinctly understood that in many particular respects Lanchester worked on different lines than we did, lines which were new to us, and that we were able to draw many useful ideas from his book."

Many years later, in 1947, Prandtl expressed himself on this problem again [31]: "Perhaps the observation is not without interest, that even here it is a contradiction that stimulated

my first occupation with the subject of wing theory. I am referring to the misleading concept of the vortex system of a (lifting) wing in the otherwise laudable book of F. W. Lanchester (Translation by C. and A. Runge, 1909)."

Prandtl stayed for a week longer in England and accepted many different invitations. He also visited his English colleague Professor G.I. Taylor in Cambridge, with whom he had shared many years of warm friendship.

Many congratulatory greetings were awaiting him on his return. At the end of the semester, the students honored him by taking out a torchlight procession.

From *Göttinger Zeitung* of 14 July 1927: "**Torchlight procession of the student body. Honor for the aerodynamicist Professor Prandtl, who was recently awarded the highest honor in London for his achievements in aeronautics.** The procession moved along to Calsowstrasse 15, where a festive ovation was staged. In his address, a representative of the student body praised the achievements of Professor Prandtl in aeronautics, and through them, in the cultural attainments of mankind: "We owe our knowledge of flight to his research. The world looks towards Germany, towards our small Göttingen, towards our distinguished scholar. The Student Body of Göttingen honors the teacher by a thundering *Hoch!*" The air was filled with the sound: 'Vivant professores!'

In his address of thanks to the student body, Professor Prandtl, with the modesty of a true scholar, tried to present his achievements as if they were not of any extraordinary value. The credit, he said, should go chiefly to Professor Felix Klein, to whom we owe the *Aerodynamisches Institut*. Besides, the contribution of his (Prandtl's) *Mitarbeiter* had been substantial. But, much as we honor Prandtl's modesty, we still adhere to the view that the major share of the credit belongs to him. Just as the artist and the good violin go together, so do Prandtl and the *Aerodynamisches Institut*---to perform what has in reality been performed. Professor Prandtl ended his address by a *Hoch* to the German Fatherland (*Vaterland*). The National Anthem was sung, and the procession went to *Theaterplatz* where the torches were huddled together."

I still remember this evening well. I had been probably already asleep for a while when I was fetched to the living room. The large group of torch bearers presented a wonderful sight from the open window above. My father stood at the middle window, with the upper part of the body slightly bent forward, and holding on to the window frame with outstretched arms.

The student who addressed the gathering then was Gustav Messmer. Later, he did his doctor's degree with Prandtl. In the year 1939 he was 'called' to the professorship of applied mathematics at the *Technische Hochschule* in Darmstadt, where he stayed until 1949; he was appointed as the *Rektor* of *Technische Hochschule Darmstadt* from 1947 to 1949. In 1952 he accepted an offer from Washington University in America, where he died in 1981.

There was a change of staff at the *Institut* that I should mention. In a room next to the Director's office there was a new secretary sitting at the typewriter. She had started working on 19 May, the very day her new boss returned from London. It was *Fräulein* Eleonore von Seebach. She had come to know about the vacancy for the secretary's post through friends, as it used to happen generally in those days. *Fräulein* von Seebach told me that right at the time of introduction, Prandtl asked her to take down a dictation to convince himself that the young lady had the ability he expected of his secretary. She was then asked to report for duty at the appointed hour for a probationary period. She has been there since then for 43 years as a private secretary, continuing even after Prandtl's death, and serving his successors as an experienced secretary.

She told me that she remembers the early days very well. Prandtl dictated a stenogram, and did not abstain from making corrections of style in the finished draft of the letter before it could be typed. Correspondence was never left unattended, and replies, to the point, were written promptly. He was rather dissatisfied when he was not understood immediately. He could not stand dim-wittedness, but was very patient and calm while dictating to her. *Fräulein* von Seebach adjusted herself admirably to him so an excellent understanding at work developed between them. Beyond these duties she also kept herself available for typing scientific articles for the *Assistents*. She typed Prandtl's book *Führer durch die Strömungslehre* [27] from dictation. She also remembers the egomaniacal letters Prandtl used to receive from inventors, to whom he replied with patience and clarity, and who, out of disappointment at not being recognized, kept stubbornly presenting their ideas again. They would often not understand the Professor's chain of reasoning showing the flaw in their thinking. And he then had to frame the proof of their false conclusions in even more detail.

12. Journey to Japan

When my father was making preparations for the next big journey, we, his daughters, now 12 and 14 years old, actively participated in the task. It was a journey round the world that was to last for half a year. The main reason for the journey was an invitation from Japan. A congress was to be held in Tokyo. Following the congress, a journey through America had been planned, during which Prandtl wanted to visit different universities.

Big trunks for overseas travel arrived at our house, and my mother took care of buying new clothing. She had really wanted to travel with her husband on this interesting journey, but the thought of leaving us alone outside her care for so long was something she could not live with.

Travel to Japan in 1929 was an adventure far more sensational than it is now. Today a plane journey to Japan is nothing unusual, but in earlier days, one had to travel over land across Russia, as there were no flight connections over such large distances.

In his travel kit there was a Leica, which was the best camera in the world those days. He thought he would awaken his memories later by looking at the pictures. On 13 September he left Göttingen and traveled eastward. My mother received more than 70 letters from him during his long absence from home. He numbered them all serially right from the beginning.

Prior to writing anything in particular from these letters, however, I wish to quote excerpts from a newspaper article in which my father, having just returned home, summarizes his impressions of the journey to the journalist.

March 1930 - Interview with Professor Prandtl:

"Impressions of and experiences on his journey to Japan and America: As has already been briefly reported, the well-known Göttingen aerodynamicist, Professor Dr. Prandtl, returned to Göttingen on 5 March, after traveling around the world for almost half a year. In an interview kindly given to our representative, Prandtl gave an overview of his travel impressions that are summarized in the following:

'The goal of my journey that took me through Russia, Japan and America, was really Tokyo. The World-Engineering-Congress held a conference there at the end of October/beginning of November last year, in which I was specifically invited to participate. It was dear to me that I could not refuse this opportunity to get to know other countries and, wherever possible, to pursue general and subject-oriented scientific studies there. The journey became correspondingly longer. The journey started on 13 September, and first took me by train to Moscow. On the program in the Russian capital there were visits to many different institutes. The standard of the equipment in these laboratories was amazing. At present there are new experimental facilities. In spite of the difficult

situation, the Soviet government is deeply involved in everything that serves to further technology.

“From Moscow it was a ten-day long journey towards the Far East by the trans-Siberian railway. Even this rail route left an impression of sturdiness. The tracks, the cars and the machines were all in impeccable condition, and we arrived in Vladivostok with only a three-hour delay. Originally I had planned to travel through China, but due to the Sino-Russian dispute this route is blocked.

Now to Japan: This is a country whose rapid advancement is clear in every way. An enormous industrial development is noticeable in the whole country. In no other country has the installation of electrical power been managed as it has been here. Every village in Japan has electricity. This development is all the more amazing considering that six years ago there was a big earthquake that had a devastating effect on the country. Big cities have either been entirely or are being rebuilt as we speak. Japan is a country whose native art is blossoming to the full.

Everywhere there are lovely objects for sale, and they are truly lovely.

The Congress itself, which was the real goal of my journey, was well organized by the Japanese. The number of participants was large: from Germany 30 representatives had traveled to Tokyo, and in addition there were about 30 engineers who were working in Japan. Regarding the hospitality of the Japanese, there can be nothing but praise. The congress participants were treated to lunches and dinners again and again, were much pampered, and there were many festivities held."

At the time of the Congress there was still the old Nippon. This changed only at the beginning of the thirties when the modern outlook of the European West started to influence the whole life of this Island kingdom in the Far East.

"The scientific institutes made a good impression. Aerodynamics is also highly cultivated, and there are more wind-tunnels than we have. Apart from the special scientific studies, I had a four-week long stay that was devoted to getting to know this interesting country.

"The journey then took me across the ocean to America where I spent two and a half months. Of course I was particularly interested in their aeronautical institutes.

"In general, at the American universities, I did not find many more facilities than we have in Göttingen, but only the facilities are available in a larger number of universities. There are special laboratories for aeronautics in many universities. They have mostly wind-tunnels that are both the same size as in Göttingen and smaller. The National Laboratory in Langley Field near Washington (DC) is superb, and excellent work is done. Their facilities surpass what we have in Europe. For instance, there is a wind-tunnel with a test section area, the diameter of which measures six meters. Full-scale aeroplanes can be installed in the test section, which means that better studies on propellers and engines can be conducted.

'The landscapes? Of course they were all very different. In the Siberian steppe there was nothing but grass, and then again forests of low birch trees. In the American steppe the scene is the same, only with other kinds of trees. There are expanses where many acres of pasture land can provide fodder for only a single cow: grass struggles to grow there. Japan with its rice fields and colorful temples is of course entirely different.'

Loving hands had decorated the door of Prof. Prandtl's office with a wreath when he returned, and the room in which he received me was full of colorful flowers. And certainly, this honor gave him the same joy, or perhaps even more, as the floral presents bestowed upon him on his journey." (End of the report on the interview)

This experience of a round-the-world journey seems to me to have been of very special significance in Prandtl's life. It was a period when he often encountered the unusual, gathered many impressions, made manifold observations and mused over them- so much so that I wish to pick up the course of his journey again through his letters.

The first stop on his outward journey was in Berlin, where he met Professor Nägel from Dresden. Professor Nägel was also a participant in the Congress, and the two of them went on to make further journeys with one another.

15 September 1929:

"At the end of a 40-hour railway journey we arrived at 11.30 in Moscow. We were photographed and filmed as we got off the train. After that we were taken by car on a short round-trip with splendid roadside views: a propaganda procession with school children carrying slogans on red sign-boards; then to a church (*Erloeserkirche*) where there was a festive mass and the choir singing was going on, then further around the Kremlin with its many towers, and finally to the hotel, where I have a splendid room with a bath. Today's reception and the first impression of the city with its kaleidoscopically changing views will probably stay in my memory for ever."

He gave three lectures in Moscow. He was invited to meet the German Ambassador, attended a performance of the Bolshoi Ballet, visited the Tretyakov gallery and the Museum of the Revolution.

On 29 September the long journey across Siberia started aboard a sealed railway train.

29 September:

"In the early hours of this morning we crossed the Ural mountains, a flat elevation of about 400 meters, mostly covered with birch wood trees."

2 October:

"Now we have been on board the train for 4 times 24 hours, and will have soon completed one half of the train journey. The clocks show it to be already 5 hours ahead of the time in Germany. Around 10 o'clock yesterday evening, we crossed the Ob river near the city of Novosibirsk. It is a huge torrential stream, with nothing like it in Germany. The thousand lights of the largest city in Siberia and two brightly lit steam boats cast their reflections in its waters."

2 October:

"This morning we saw mountains in the distance, not unlike in the Black Forest. The woods, with the golden yellow of larches and the green of the pine trees, and the grayish yellow of the withered grass, are very beautiful, particularly in the early morning red of the rising sun."

3 October:

"Today's experience was the Baikal Lake. The train moves along the lake for about six hours. Unfortunately it was one o'clock at night when we came there. We were therefore in a position to enjoy the landscape only from a quarter past 5 up to a quarter to 7 in the morning, at sunrise. There is surf on the lake with big frothy crests. The dark grayish green water, the sky with dark gray clouds, the mountains on the shore, all shone with the early morning red. We slept again from 7 to 9."

6 October:

"This is the last postcard from the Siberian railway. At 2 in the afternoon today we crossed the Amur river over a bridge that measures more than 1 km. From half past 2 until 3 we were in Khabarovsk, an important trading city. This region is quite charming, the blue mountains on the far side already belonging to China. One sees many Chinese faces at the railway stations, mostly workers, some in European clothing, some in remarkable rags. By the way, the entire journey from Moscow is 9330 km."

7 October, Vladivostok:

"The hotels are overcrowded, since they were not prepared for the heavy flow of traffic going through here because of the blocking of the Chinese railway. We were extremely lucky: Nägel found the German Consulate's car. After a bit of a wait, the secretary of the Consulate to whom we had been asked to convey greetings from the Russian Embassy in Moscow met us, and he got our baggage transferred to the Consulate first. While we were sitting there, we were pleasantly surprised to be invited by the Consul's wife to stay with them."

From Vladivostok it took them several days to travel by boat to reach Japan. On 11 October they were received hospitably in Kobe. Professor Wieselsberger, who had been an *Assistant* in Göttingen, and Mr. Takao, Director of an airplane factory, had come on board to greet the two visitors.

12 October:

"Something very special today: Mr. Takao invited us to take part in an excursion with some Japanese ladies picking and eating mushrooms. For this purpose, one rents an area in the hills near where the mushrooms grow, which is cordoned off so that others do not steal the mushrooms. The whole party drove over in four cars. To start with, on a river bank where the cars met, there was an elaborate exchange of greetings of the men amongst themselves, with each bowing three times. Thereafter the party drove further by car, and then walked for a quarter of an hour to a small hillock on which there were mushrooms (of a different kind from ours). Everyone got a basket for collecting the mushrooms. In the meantime, small cooking ranges made out of potter's clay had been heated by charcoal. Chicken, different vegetables, bean curd and eggs were all cooked on these ranges, laid out on a table-cloth, eaten directly, then roasted again. The food was of course eaten with chop-sticks, which everyone likes. Then there was *sake* to drink and lots of photographs were taken. All in all, quite a charming experience. In the afternoon, we visited an airplane factory."

16 October:

"Drove by car to the park-villa of the airplane factory owner outside the city of Kobe. We drove there by car. The house was in a beautiful garden with a lake and bridges, a small hillock and several small cottages for drinking tea. At first we took the main house for a big tea room, but we were assured that the family really lived there. The total absence of any furniture is very queer. There are only pillows and arm-rests, and one sits on the floor. You take your shoes off in front of the house. At first tea made out of seaweed (tang) was served in the garden: then ceremoniously we washed our hands, then waited in another pavilion until the gong was sounded, and were finally led into the main house by its owner, to be seated on the pillows (arranged in the shape of a horse-shoe). The women provided things to eat on a small table in front of us, but did not join in eating.

On the next day we visited Osaka (45 km from Kobe): a very interesting city with a fort and temples. Invitation by the Consul-General in the evening. Today a day of rest, which was also very much needed."

20 October:

"Finally we are in Tokyo. The last two nights we stayed in Kyoto, in the famous Mijako-Hotel, a true spa hotel built on a hill. The view reminds one of Baden-Baden, but the mountains are more beautiful. In Kyoto there are wonderful temples, three of which we visited (one should really visit at least ten). In the evening, a stroll through the shopping area, colorful beyond imagination. Yesterday we were at the temple-city of Nara, a place of pilgrimage with Shinto and Buddhist temples, all in a wonderful park, where packs of tame deer roam about. Here there is a huge bronze statue of Buddha that seems gigantic in the dark temple hall with a high ceiling.

Tomorrow, the day-after-tomorrow and the next day from 2 to 4 o'clock my lectures [38]: on Thursday at Baron Shiba's, who is the Director of the Aerodynamics Institute."

3 November:

"The invitations continue coming. I do not keep count of them any longer. All I can say is that we have been invited to tea in splendid gardens, to theater performances, lunches, dinners, balls, etc., every event outdoing the other in winning ways. The lectures have entirely receded to the background."

9 November:

"The Congress is now over, and this morning we traveled down to the temple city of Nikkio. A richness of form and color beyond imagination. The big buildings are riddled with ornamental pieces, small figurines no bigger than a hand in size and which, each and every one, have been worked out so carefully and with attention to the minutest detail. Everything is in red, green, blue, black. The temple beams are painted in red and are polished. Tomorrow we are going by car up to a height of 600 m to see a waterfall and a lake."

11 November:

"Yesterday we took Herr Nägel to the railway station. From now on I have to be on my own. He was, with his versatility and broad knowledge of languages, of much help and support to me."

On the following day Prandtl traveled eastwards. Subsequently, he was presented with farewell gifts (a pin with pearls and landscapes painted on silk).

18 November on board the ship "President Pierce":

"Yesterday was Monday, 18.11 and it is 18 November today again! We spent yesterday (the 18th) with Japanese people, while you were sleeping, and today (the 18th) with Americans.

Today we had sunshine for the first time, and also a very beautiful sunset. Imagine a green evening sky, olive colored at the bottom, topped with steel grey. On top of that it was violet, and in the green stripes there were vermilion colored clouds. To the left of this harmony of colors the sky was deep blue, lower down whitish, and brownish on the horizon. Later the green turned to yellow and still later to red, and now the colors were similar to those we are used to. The starry sky looks very much different here, imagine the northern sky without the great bear."

21 November:

"The ship berthed for two days in Honolulu. We were greeted with Hawaiian music. I walked over the landing bridge into the big customs hall, and was much surprised to be received by a gentleman who asked me if I was Professor Prandtl, and then garlanded me with fragrant flowers placed around my neck. Here there are trees and shrubs blossoming in all seasons, and how beautiful!--they are brilliant yellow, bright red, dark red, pale lilac, brilliant reddish violet, all flowers unknown in our place; and a wide variety of fruits. The main goods produced are pineapples and cane sugar. Honolulu is on the slopes of a giant volcano. The mountains forming the rim of the crater have very interesting forms. I learned from my escort that I am invited to lunch the next day and that I am supposed to give a small lecture there. My usual themes were all unsuitable for this purpose, and so we agreed that I give a talk on gliding. We got into his car, and drove up the mountain and over a pass to the other side of the mountain chain on the inside of the crater. The mountain walls drop very steeply. The landscape is very romantic with the blue sky in the background. Then, at dusk we returned by a different route.

There were about 20 men at lunch. Beautiful club house, address by the presiding gentleman welcoming me. My speech came next, the first time in English without notes."

When, after twelve days, the ship landed in San Francisco reaching American soil, there began for Prandtl the American lecture tour that took him to many well known university towns. A stay in Pasadena was followed by a few days in Urbana, after which he stopped in Chicago, Detroit, Wright Field, Washington, Ann Arbor, New York and Boston, giving lectures in all these places. He also made sure that during the long journey through the rest of the continent he visited famous sight-seeing spots.

Accordingly, he visited the island of Catalina, and took a trip there in a boat with a transparent glass floor. "One sees the underwater gardens, sea plants and many kinds of fish. In contrast to the mainland of California, where there are only roads for cars and a pedestrian in the outskirts arouses "suspicion" and is barked at by dogs, on the island, there are even nice walks (more precisely bridle paths). Today I walked along one such path which, on reaching the mountain ridge, suddenly exposed the ocean to view. In the far distance, the Californian mountains are visible. The sun was close to setting, and the calm and peaceful sea of the Pacific Ocean shone in the gold of the evening. Over that I could see the blue sky covered with the light silky sheen of the clouds. On both sides of the pass, left and right, there was a small peak, and I climbed both."

During his stay at the Grand Canyon he writes in a letter to his youngest daughter:

27 December 1929:

"It is now high time that I write to you for your birthday. I am sending you a small gift- a book with views of this wonderful region where I arrived today. Imagine a vast plateau with pine trees on it, 2100 m above the sea---that is roughly the height of the *Karwendel* peak. To the south, past the woods, you see the blue mountains. But there is more on the other side! A big river has carved out for itself a valley with a thousand branches, and the bare rocks are visible everywhere. At the top it is shell limestone, and lower down it is

red sandstone, the same as can be seen on the surface near *Reinhausen* and *Bremke*. And then there are three or four other kinds of stone, all in horizontal layers. The river valley lies lower than *Mittenwald* as seen from the *Karwendel* peak. The air is very clear, one can see very far into the distance, and the shadows are almost sky-blue. In this setting there are stones, white and red and gray and violet-brown in color. A wonderful symphony of colors, changing with the time of day, from hard colors in bright sunshine all the way to soft tones in evening twilight. So much for the Grand Canyon. I think Mother will give you a present from me from the Japanese chest."

In Detroit there was only a visit to Ford plant.

Detroit: 16 January 1930. Prandtl, carrying only a small suit case on this leg of the journey, was picked up at the [Detroit] railway station by a friend who wanted to take him by car to the hotel. But before that they stopped at a restaurant to have dinner together. When they returned to the car there was a sad surprise in store, since thieves had broken into the car and Prandtl's leather case had disappeared. This theft upset him a great deal, for the case contained, besides his change for the night, the Japanese pin of honor and the 13 films, still to be developed, that he carried with him as a precious souvenir of his travels. His personal experiences had been recorded on those films. With the eye of a landscape painter at work, he had been looking out for worthy motives, in the quiet and joyful hope of having enough time during the long journey to view all kinds of sights that he deemed worth seeing. The next day he had an announcement published in the newspaper asking the return of at least the films in exchange for a reward,-unfortunately in vain. The loss made him sad for a long time.

9 February 1930, New York:

"On the first day, in the morning, I was "Downtown", the main business district. I saw the sky scrapers and the great bridges over the East River, and went to the office of NordDeutsche Lloyd. There I was introduced to the director as an important visitor. He enquired opportunely about the state of affairs in Russia and Siberia. In the evening I went to one of the hundred theatres on Broadway to see a talkie - Disraeli! The actors are excellently present, with perfect reproduction of voices and other sounds like walking, rattling crockery, fine music---everything utterly superb. [Note: Talkies had not yet been released at that time in Germany.]

On Saturday afternoon, I was in the Museum of Natural History, a first class collection highly worth seeing. In the afternoon, I was in the Art Museum , with many paintings by Rembrandt, Frans Hals, Van Dyke and so on, Egyptian, Greek, Roman antiques, artifacts from the Middle Ages and modern times, from China, Japan, India, Persia - an overwhelming abundance of beautiful artifacts."

19 February:

"This is my last letter from this country. The lectures in Boston went off well. On Saturday I was at Harvard University where I visited some laboratories. In one division I

witnessed films showing the growth of chicken embryo tissues, the division of cells, and so on. The glass flowers in the museum are wonderful. They are made out of glass in natural form and color, by a man in Dresden, but can only be seen at Harvard. "

On 1 March my mother went to Bremerhaven, happy to pick up her husband on his return home, directly from the boat. There was so much to talk about then that we needed days to share all that he had experienced. Reports, comparisons, and passing references to the visit to Japan made during conversations remained a central theme at the table for a long time after the return home. And there was a clear indication on how deep the impressions were that this country in the Far East, with a very refined but entirely different culture, made on our father.

Children retain in their memory a vivid picture of the themes and objects that recur again and again in their parents' conversations. And I summarize here from memory some of those impressions of Father's Japanese experiences.

I believe that the behavior of the Japanese among themselves impressed my father the most. He said that noisy or crying children were not to be seen there. In their daily life, the Japanese came into contact with each other in a friendly manner. The modesty and self control acquired by virtue of their upbringing has become a part of their life that strikes us as especially courteous. Japanese people love giving presents, always tasteful objects offered with the utmost humility. This all serves to demonstrate the loving attitude they exhibit in their relationships with other human beings. He especially praised their noble hospitality. Their pronounced sense of cleanliness contributes to an outsider's feeling at ease. Everywhere one notices the unusual diligence of the Japanese.

For us, the Japanese objects he brought with him---two kimonos (tied around the waist with obi), wooden shoes, stockings lined with cloth, small hairpins, and of course several pairs of chop sticks- all these allowed us to establish our own intimate relationship with Japan.

13. A day at home again

Now our home had again a pivotal point, and we knew ever more than before the extent to which our father's nature set the course. The old habit of going with my mother to Hainberg on Saturday afternoons was continued as a matter of course. After the stop for coffee my father was often disposed to continuing his walk alone through the woods. He took small unknown trails, of which there are many in the surrounding woods, always with some special goal, whether it was reaching a beautiful view point or a spot with rare flowers that had not been discovered yet by the people of Göttingen. Sometimes I accompanied him on these "deer-stalking walks", and he explained to me untiringly a great deal about plants, soil constitution and landscape. With his wide knowledge, he could not always put himself in the place of his dim-witted 13-year old daughter, who was not always able to follow his explanations with attention. On the other hand, I was quite interested in his plans to render passable the hidden trails in the woods by cutting off branches in the way. On such rambles through the woods he would always look for flowers and bring with him a beautiful bouquet for his wife. He had a wonderfully close relationship with things that surrounded him in nature. He asked himself questions on plants, rocks, and clouds untiringly. Simply taking a stroll without observing was something he just could not do. Everyone accompanying him on these walks was enriched by his eagerness to communicate. He was always particularly interested in clouds and in the flow in the various atmospheric layers. The beauty of some cumulus clouds brought forth expressions of joy, and he spoke with equal enthusiasm about the changing moods created when the landscape was illuminated in different ways by passing cloud patches.

At night, when we children were finally in bed, my mother regularly read for my father for almost an hour. He could not spare time for reading modern literature himself, but liked to listen to it and did so with attention. This reading hour meant relaxation for him, and shutting off his mind from usual trains of thought. The books chosen by my mother were mostly recently published biographies or novels, for instance Thomas Mann's *Der Zauberberg* (The Magic Mountain). Once, listening to a reading of Erich Edwin Dwinger's *Die Armee hinter Stacheldraht* (The Army Behind Barbed Wire), my father was so greatly moved and distressed as he mentally reconstructed the experiences of a cruel war scene, that my mother had to put the book down and stop reading. Oswald Spengler's *Untergang des Abendlandes* (The Decline of the West) was another book so read, and provided occasion for many discussions.

When Mother died in 1940, Father had to go without this loved custom of being read to. He missed it so badly, that I decided to cheer him up by reading to him for some time. Later, he was content with listening to broadcasts on the radio at this evening hour.

After this reading hour, with no more demands made on him by anyone, he would sit at the big table in the middle of the room, spread out his working papers, and passed hours during which he worked away on his scientific problems. Light in the front room was never switched off before half past one. Neighbors knew the light in those windows, and

I was told that people walked home feeling safe in the poorly lit street at that hour, since Herr Professor was still awake and his light was burning.

In his working room there was another table at the wall which served for keeping mail still to be dealt with and scientific journals. In time, the two piles would grow so high that one was afraid of one or the other toppling over. My mother then pressed for clearing the piles and helped at sorting them out. Although my father had chosen as his maxim the guideline: "No postal correspondence can be so urgent, that, either it becomes even more urgent by leaving them, or, it will be settled in the meantime of its own", he was quite willing to follow the suggestion of his orderly wife on Sunday morning. After that he liked to sit at the piano, and would happily 'prelude' away. Again and again, however, it happened that he would search in the pile for some paper that had been laid there and he wanted urgently before starting out for the *Institut* in the morning, but in vain. There followed repentance for time lost, and he would be very depressed by the failure of the search. Then my mother would join in searching---and although my father had spoken of a blue covered exercise book, she found a yellow one with the right label and ask humorously: "Is it perhaps this one?" Her invaluable gift for picking out the right piece from those piles appeared amazing to me, and made her indispensable to her Ludwig in such situations.

14. Journeys on vacation

For all those years we went on journeys during almost all the holiday periods. During the Easter holidays, our destination was a spa in the Harz mountains, where we met with the family of Professor Otto Föppl from Braunschweig. My father arrived for the most part a few days after us since he had a lot to attend to; but he used the single holiday week that he allowed himself to go off hiking through the fragrant fir tree woods and enjoyed being together with the two families. For the holidays at Pentecost we had arranged accommodation in Sooden-Allendorf, and here too we met with the Braunschweig family. There were also interesting subjects of conversation for my father during walks with his brother-in-law. My father was not a demanding holiday guest. He was always keen not to disturb anyone, and he returned the attention paid to him with kind words. He never made use of his position, something which he could have done to turn any situation to his advantage. On the contrary: it seemed to me that he placed other guests in a position above his own. As a matter of course, he seemed to regard being considerate to others and showing mutual respect as a natural form of behavior.

We spent most of the summer holidays in Föppl's old house on the Starnberg lake. The name Ammerland sounded particularly pleasing to us in our ears. It was associated with the delights of a carefree countryside life, and also with feelings of warmth aroused by our feeling of being at one with our kith and kin in Munich.

The train journey to Munich took almost ten hours in those days, but the expectation of reaching the destination we were longing to arrive at, made the journey pass by quickly. I wish to put on record here an incident that occurred on one journey: we were traveling in an advance party with Mother since Father's university vacation always started 14 days later, after our school vacation. A gentleman came into our compartment in Würzburg and started an animated conversation with my mother. On learning that we were from Göttingen, he asked abruptly: "Do you know a Professor Prandtl there?" I have not forgotten my mother's spontaneous and hearty laughter at this question. We children laughed too, out of astonishment, since we were quite unaware of how well known our father was.

My father very much liked the informal way of life in the Föppl-House. It was, because of this relaxed spirit, the most perfect place to spend the holidays: swimming in the clear waters of the lake, hiking trips to the nearby mountains, and in between stimulating discussions on scientific and technical matters with the brother-in-law and colleague, Hans Thoma. On one trip - we had then climbed up through the garden- I remember a rare natural phenomenon that my father was fascinated and excited about. Looking down from sunny heights over the fog layer, one discovered one's own shadow. The strange thing was that we saw the head in each shadow surrounded by rays in the colors of the rainbow. Of course he knew the physical explanation for this phenomenon, viz. that light is refracted by the minute fog particles. But despite knowing the reason for it, he could feel a natural delight on seeing the phenomenon.

In the summer of 1929 my father was to have a new honor bestowed upon him. At the General Meeting of the German Society of Engineers *VDI (Verein Deutscher Ingenieure)*

held on 22 June in Königsberg, a festive occasion attended by 800 engineers, the announcement was made that Prandtl would be given the Grashof-Memorial-Medal, the highest honor that the society can confer.

On 3 August 1929 Prandtl received the following letter:

"In concurrence with the council of the German Engineering Society (*VDI, Verein Deutscher Ingenieure*) I have the pleasure of inviting you and your wife to my villa on the shores of lake Starnberger See on 10 August to present you with the Grashof-Medal.

With deep respects,

Oskar von Miller."

Accordingly, on a nice summer morning on the 10th of August, several gentlemen from Munich set out in a private motor-boat from Starnberg across to Ammerland. We picked them up at the steam-boat foot-bridge and led them through the meadow paths to our house. Herr Oskar von Miller, the founder of the *Deutsche Museum* in Munich, was among them. All the gentlemen were, as was made known, invited to his beautiful country house in Niederpöcking. All of them went together, around noon, on board the motor-boat in order to cross over comfortably to the other shore where the presentation was to be held. In the evening of the 10th of August the honored guest was of course brought back to Ammerland.

For my father, there was another special travel destination in Upper Bavaria that he visited mostly in September when we children had returned to Göttingen with our mother. The place was Schleching, close to Marquartstein. There, his two cousins, Klara Prandtl and her sister Anna, had a quiet little inn. With these two he shared memories of common experiences of childhood and youth, and he was always received there with warm hospitality.

In the summer of 1930 we traveled once to Dahme on the *Ostsee* (Baltic Sea). The International Mechanics Congress was to be held in August in Stockholm, to which, of course, the wives were also invited. My parents wanted to shorten the long journey there by traveling straight from Dahme to Sweden's capital. It is perhaps worthy of note that the Föppl brothers and sisters all went there together: Professor Otto Föppl, Professor Ludwig Föppl, Professor Hans Thoma and Professor Prandtl, husbands of the two sisters, were all invited since all the members of the family held chairs in mechanics. However, at the large banquet the table was set for only one Professor Föppl at the long table, since the prudent Swedish waitresses believed it to be an error of oversight that the original name was listed twice. The result was that Ludwig Föppl, who had no seat at the table, was requested to take a seat with the "*Festordnerinnen*". It so happened that through this arrangement he met Christina, who was later to become his wife. Incidentally, within social program's framework it must have been a wonderful family meeting in this charming city in the north.

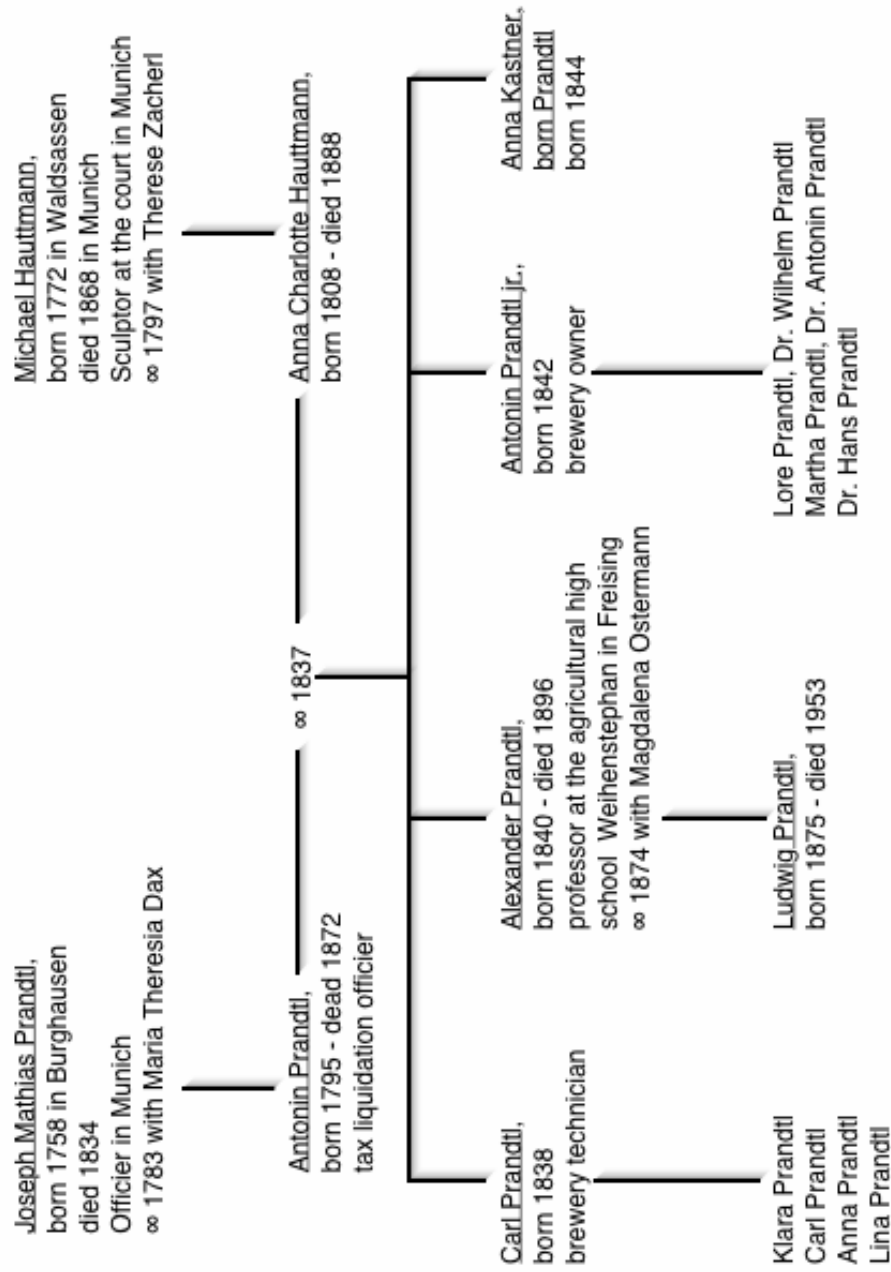
In 1931 my mother went to the spa Bad Kissingen for medical treatment for health reasons. His conscientiously written reports to his wife go to show the attention my father paid in taking care of the minor domestic matters during this time: "Marie is looking after us quite well. As a sign of my contentment I am sending her to the theatre tomorrow: "*Land des Lächelns*" (Land of Laughs). The children got their school reports today. For the grades 1, 2, 3, 4 in the main subjects I have rewarded them with 40, 20, 0, -20 *Pfennigs*."

During those weeks, at the request of his daughters, he also once took the time to cycle around for an hour. When we were riding on our bicycles side by side along one of the Göttingen roads, in the far distance and in the opposite direction, a car came along at a modest speed. Those days, cars made their appearance in the outskirts of the city only rarely, so that cyclists and pedestrians did not feel any intrusion into their freedom. I asserted: "We two can keep cycling along side by side since we do not need more space than a car coming in the opposite direction." This drew a firm reply from my father: "No, we will now ride one behind the other; one should always make it as easy and comfortable as possible for the other!" This was one of his guiding principles in life that determined his thoughts and deeds in his interactions with other people.

As a matter of course, in 1932, for my confirmation, he went to the evangelical church. He wrote a few lines in my small bible that made me very happy. "Remain true to your kind! To fulfill one's duty in large matters as much as in small is the best way to make one's soul cheerful and peaceful."

small genealogical table (or family tree) of the Prandtl family

The PRANDTL family-tree





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

The grandparents (Antonin Prandtl with his wife Anna Charlotte, nee Hauttmann)



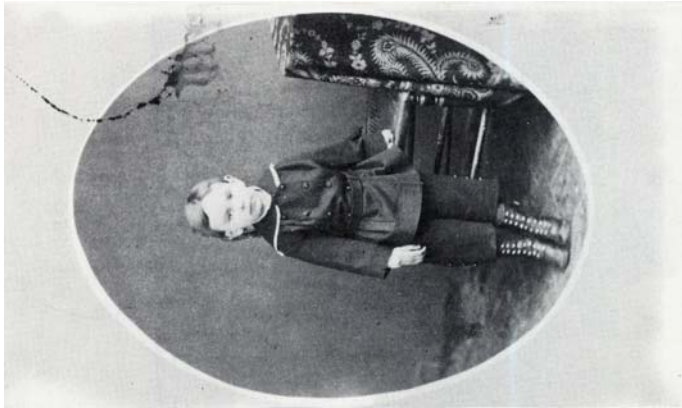
The father: Alexander Prandtl



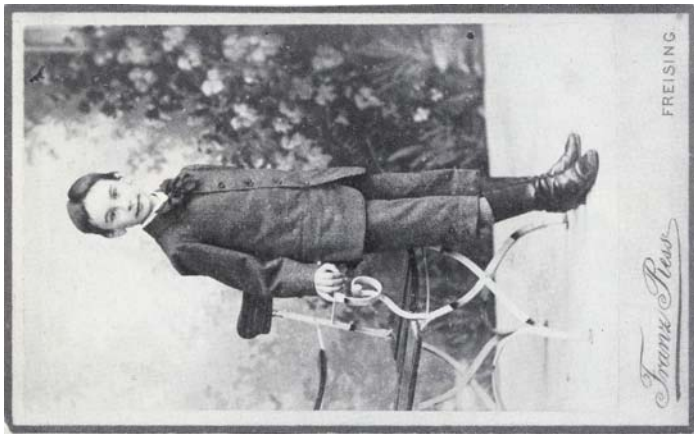
The mother: Magdalena Prandtl,
nee Ostermann



6 years



Ludwig: 4 years



10 years



12 years



17 years



20 years



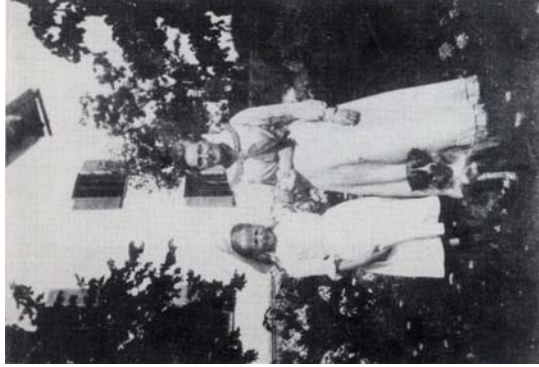
L. Prandtl 1901,
Professor in Hannover



Prandtl at his self built water tunnel 1902



1909 L. Prandtl, newly married



Gertrud Föppl with her
10-year younger sister
Else



Prandtl at the piano



signed sketch from his youth (following Nature)



The Friends, L. Prandtl and K. Schwarzschild with their wives,
both newly married



Gertrud Prandtl with her daughters Hilde
and Hanna



L. Prandtl with his first daughter
Hilde



Modellversuchsanstalt in Göttingen 1908



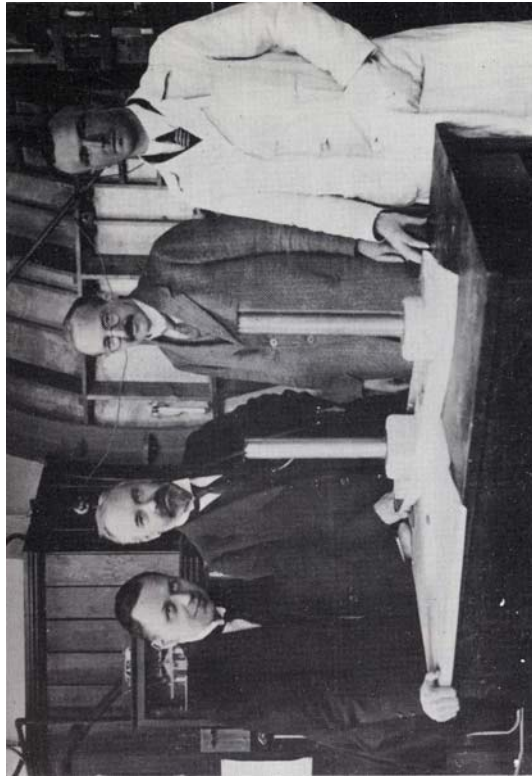
Die Aerodynamische Versuchsanstalt (AVA) 1918



Prandtl with his *Institut* -personnel



L. Prandtl 1924



With a model of the Flettner Rotor-Ship
from left to right: J. Ackeret, L. Prandtl, A. Betz, R.
Seiferth



Eleonore von Seebach at her
table in the *Institut* 1927



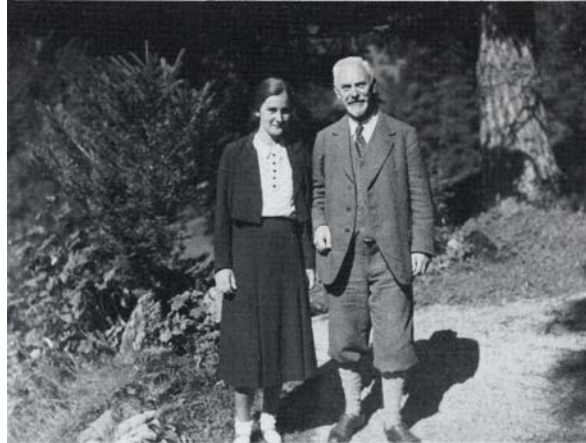
*Mitarbeiter of KWI, from left Thiro, Gördler,
Oswatitsch, Dumitrescu,*



L. Prandtl and A. Betz on their way to a lecture



The woman pilot Elly Beinhorn on a visit to Prandtl 1931



L. Prandtl with his daughter Hanna



In Fluid Flow Research *Institut*



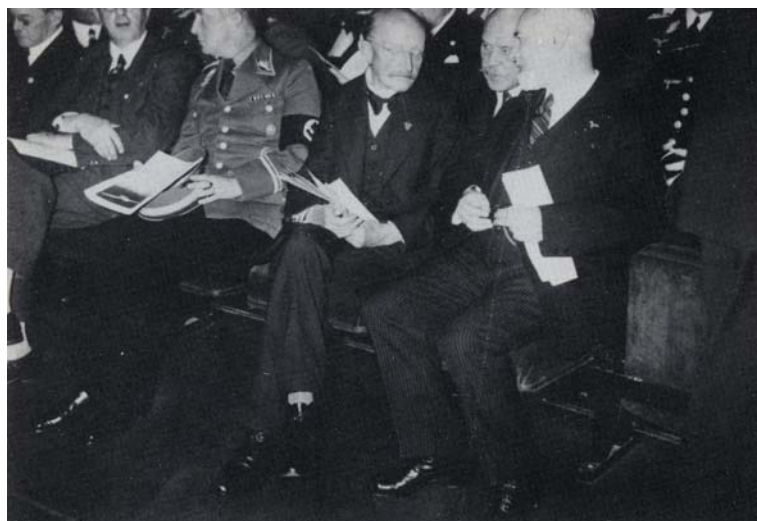
On the way to a university convocation



L. Prandtl and Prof. H. Blenk, 1938 in America



Prof. Ludwig Föppl, the brother-in-law, summer 1940 in Mittelberg



Geheimrat Max Planck, Prof. A. Sommerfeld and L. Prandtl in Berlin

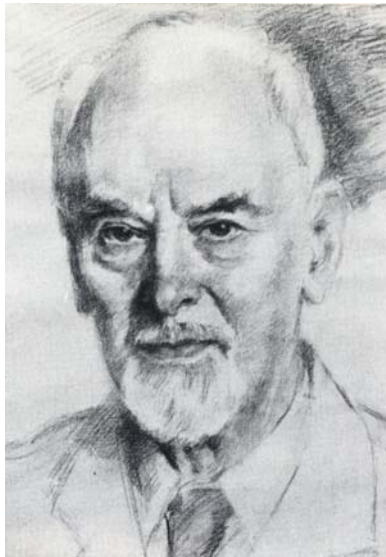


*Bundespräsident Th. Heuss,
L. Prandtl, W. Tollmien*



*from left: A. Betz, O. Hahn, L. Prandtl,
K.F. Bonhoeffer (back), W. Heisenberg,
Bundespräsident Th. Heuss*

*Bundespräsident Th. Heuss, President of
the Federal Republic of Germany, in
Goettingen*



Sketch made by Gottfried Stein 1950



Lu Schang, nee Hsin Cheng, with her husband, and Johanna Vogel-Prandtl at Ludwig Prandtl's grave

15. The year 1933

Now I come to the year 1933 and the time that we lived under the National-Socialists (*NAZIs*). As long as the Weimar Republic still existed my parents voted for the *Demokratische Partei* which merged into the *Staatspartei* in 1930. However, they engaged themselves very little with political issues and trusted the democratic government of that time. This republic appeared to have proved itself, so that, in spite of the economic crisis and the permanent quarrel between the parties, there appeared no need to have serious doubts about its continuing to function.

In the house at Calsowstrasse 15, in the floor above ours, when the window was open, there was often a husky voice of a new election campaigner from the radio. We learned that his name was Hitler and he had enthusiastic followers. My parents took scant notice of it. They did not even nurture the thought of buying a radio then. When the downfall came, it was unexpected for them. One could hardly understand how Hitler had succeeded in taking over power. And thus began his twelve year reign as a dictator.

"The political corruptibility of the middle-class mind³ (*Die politische Verführbarkeit des bürgerlichen Geistes*)" (H. Plessner) could soon be felt in Göttingen too. To a large measure, a politically radical initiative originated from students who had subscribed in an increasing number of members to the *NAZI* ideas even before 30 January 1933. Prandtl had a composed attitude towards the political situation until then, since it had come by upon us without our involvement.

However, he was moved and enraged over ordinances that affected his colleagues.

In an article in the daily newspaper, *Göttinger Tageblatt*, of 7 August 1987, Dr. Marianne Wiener-Bernstein remembers what some colleagues of her father, Professor Felix Bernstein, who in 1933 had to emigrate, after he had been expelled from his *Institut für Statistik* (Institute for Statistics), had said. I quote from the above-mentioned article: "I also know that Professor Ludwig Prandtl upbraided the Nazis aloud in his seminars."

In the time that now followed, aeronautics research, in particular, received special attention from the new government, an effect of which was that plans for erection of big buildings on the *Institut's* site were realized. The considerably larger complex was headed by Prandtl as the first director. Generally, for a scientist engaged in research such a development in general brings in much satisfaction. One may conjecture that Prandtl would conduct himself in public as per the expectations of the day, viz. fall in line with the political wishes of the supporters of the new projects, and i.e. align himself. But Prandtl did nothing of this kind. In all those years, he stubbornly refused to become a

³This book does not seem to be available in an english translation. A search showed Helmuth Plessner as the author of the book with the following title in german which is available in libraries in U.K.: "Die verspätete Nation: Über die politische Verführbarkeit bürgerlichen Geistes" published by Suhrkamp in 1974.

member of the Party or even allow a portrait (or picture) of Hitler to hang on the wall in his Director's office. However, he was also never given the option, like so many others, of either subscribing as belonging to the Party, or to resign from his office. But I am sure, that in such an event, he would have given up his Director's position before giving up his convictions to accept such a compromise. The majority of the young people in his *Institut* also shared the same outlook.

But I remember an incident in these thirties when he came home for lunch very worried and reported to my mother the following: He had walked home accompanied by an *Assistent*, and this *Assistent* had told him on the way that he, availing the opportunity, wished to now become a member of the Party. Prandtl found this attitude downright enraging, but he composed himself and advised him, more in a fatherly tone, to refrain from that step. One should not subscribe to the ideas of the *NAZIs*, he should reflect on the matter. The *Assistent's* reply that was repeated at our lunch table, which has engrained itself in me word by word is: "*Herr Professor, wir wollen auch mal etwas werden, Sie sind schon was!* (Herr Professor, we too want to be someone (important) some day, you are already someone (important)!)"

Many conversations of these days, carried out in an excited state, have still kept me conscious of the extent to which, in the year 1933, Prandtl was hurt by the baiting of his Jewish colleagues. Much has already been published upon the development that started with the *Reich's* laws and the passing of an ordinance sending German professors of Jewish origin on compulsory leave, to be later converted into an irrevocable dismissal. For example, in the books by Alan D. Bayerchen [7], *Scientists under Hitler*, (Wissenschaftler unter Hitler), Constanze Reid [42], a biography of Richard Courant, Max Born/James Franck: *Luxus des Gewissens* (Luxury of the Conscience, book accompanying the exhibition of *Staatsbibliothek* (Library of the State) Berlin, with text contributions by F. Hund, H. Maier-Leibnitz and V. F. Weisskopf [47]). (to check title of translations of these books) Here I will restrict myself only to those in which there is a reference to Prandtl.

From the publication "*Luxus des Gewissens* (Luxury of the Conscience)":

"James Franck, who served in the First World War in the combat troops, was not dismissed from the office he held in his teaching post. But his pride and solidarity with his Jewish colleagues made him take a path of his own. On 17 April 1933 he resigned."

Prandtl was deeply hurt and sad. Even as late as 10 February 1933, together with other colleagues, he had signed a letter to Franck who had received a 'call' to Berlin, with the object of keeping him in Göttingen.

"The significance and performance capability of our faculty rests upon personalities working together as a group. In the last few years the group has already suffered heavy losses with far reaching consequences. Your departure would leave the edifice that has been built here with your assistance, exposed to decay in particularly difficult and dangerous times."

Signed: Hilbert, Born, Windaus, Prandtl, Reich, Pohl, Neugebauer, Courant, Schermer, Eucken, Kienle, Angenheister and a few others.⁴

The biography of the Jewish colleague Courant contains a detailed and accurate account of the course of events in the University as far as Courant himself is concerned. The chapter " Spring 1933 " presents an account of how much Prandtl stood up to help the colleague in distress about whom rumors were spread that he is a communist agitator. I wish to quote a few passages from this book.⁵

'Although he had not received official notice of his status, he made up his mind to approach officialdom.

Seeking a colleague unaffected by the *Reichsgesetze* who could present his version of his activities to the administration of the university, he chose Prandtl. The professor of mechanics was generally considered a somewhat naive person. But during the hectic week following the announcement in the paper, he had acted with courage and decision, dismissing one of his *Assistents* when he had discovered him to be a spy for the *NAZI* powers at the university. '

This person is said to have tried to ward off his dismissal and someone remembers the words uttered at the time of his taking leave: "Herr Professor, you will repent it, you will think of me!" I wish to include here that it is hard for anyone to understand today what it meant at that time to dismiss relentlessly from his post someone in the favor of the ruling party ruling and who was supposed to render services as a police spy to his superiors. One should keep in mind that, on the top of everything, Prandtl, by his very nature, was not inclined towards radical solutions.

Now back to our text on Courant where it goes on: "It (both Prandtl and Courant) decided that Courant should write a letter to Prandtl setting out the facts of his political activities after the First World War. Prandtl would then present the letter to the *Kurator* (trustee). "

I wish to quote one more passage from the Courant-Biography. It concerns the drafting of a petition in his support, conceived by Courant's colleagues, Friedrichs and Neugebauer, which was to be sent to 65 colleagues. It was a declaration on the reputation Courant had achieved on taking over the *Mathematische Institut* as successor from Klein. The author (Constance Reid) writes⁶

"... sixteen replied not at all..., twenty-one refused to (put their signatures) sign but wrote letters explaining their reasons.

⁴ In 1953, the year in which the city of Göttingen celebrated its 1000 years of existence, Franck, Born and Courant were honoured by granting them honorary citizenship of the city of Göttingen.

⁵ Author quotes from the German translation, here verbatim from the English original Constance Reid: Courant, Springer-Verlag, New York, 1976, p. 145

⁶ Author quotes from the German translation, here verbatim from the English original Constance Reid: Courant, Springer-Verlag, New York, 1976, p. 150.

There were various reasons...There was an admitted feeling on their part that, much as they would like to support Courant, they did not want to bring themselves as individuals to the attention of the government. He was ashamed, the writer concluded, but he had to admit that he dreaded the consequences if he signed. "

With this response, Professor Kneser, a former *Assistent* to Courant, considered it to be more effective to draft a letter that would reach the minister straight.⁷

"... The suggested letter, which was signed by Friedrichs, Kneser and Prandtl began (as follows):

'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.

The letter concluded with a request that the three signatories be heard in person (and, if this was not possible, that they be permitted to contribute their testimony regarding Courant in writing)."

At the end of two weeks, the petition drafted by Friedrichs and Neugebauer was signed by 28 colleagues, some of whom were: Heisenberg, Hilbert, von Laue, Planck, Prandtl.

These text passages that I have taken from Courant's biography, appear important to me to prove the extent to which Prandtl exposed himself without fear of possible repercussions.

There is a paragraph in Article 4 of the civil-service laws which reads: "Civil servants whose political involvement raises doubts upon their unequivocal commitment to the national State can be removed from service. Standards of judgement for civil servants in managerial positions of responsibility are to be applied on a stricter scale."

It is also interesting that these efforts for Courant's rehabilitation were actually fruitful. The suspension order was cancelled. Later, Courant took retirement as an *Emeritus* and finally, with a heavy heart, migrated to America, but with a financially somewhat more favourable condition.

The grip of the rulers did not spare any of the Jewish *Dozents* of the university. Yet Prandtl did his most to counteract the injustice. There were more suspensions. On 16 September 1933, Prandtl wrote to his wife from Würzburg: "The *Kurator* writes to me

⁷Author quotes from the German translation, here verbatim from the English original Constance Reid: Courant, Springer-Verlag, New York, 1976, p. 151.

that the Minister has withdrawn Hohenemser's *Venia Legendi*. Things have thus come so far!" Prandtl had pleaded in support even for him and had tried to prevent his dismissal.

As a consequence of intrigues by another agitator in the *Institut*, some other colleagues were also charged since they had interfered in the affair through their statements. The awkward differences and accusations were reported as per rules to the *KWG (Kaiser-Wilhelm Gesellschaft)*-Administration and their opinion was awaited. The response that followed was a circular from the President of *KWG*: In order to re-establish an atmosphere of tranquility at work, the seven employees who had given statements as witnesses were to be dismissed. This was not in tune with Prandtl's line of thought.

The complications of the case in which the name of the Georgian Dr. Nikuradse repeatedly crops up, have never been cleared up entirely. Persons of different ranks endeavoured for a prosecution of the matter. I quote from the files of the lawyer to facilitate understanding of the situation that had now arisen: "After Herr Professor Prandtl had refused to follow the orders for dismissal, there took place on 29 September 1933 a meeting with Herr *Geheimrat* Valentiner, *Geheimrat* Wolff and *SS-Hauptmann* D.J.Weniger, who came in suddenly, and at which Weniger explained to Professor Prandtl that it is now immaterial whether there has been a misjudgement or otherwise, the decision to dismiss the seven men has been taken, and it should be carried out unconditionally. Herr Professor Prandtl was merely the executing organ. Should he refuse, he puts himself at the head of a revolt against the national State and must reckon with being sent to a concentration camp."

In spite of this serious threat Prandtl did not give up supporting his *Mitarbeiter* and making known to the Prussian Ministry of Education the truth regarding the events---on 4 October he had requested for a conference in person in Berlin----to fight for reinstating the innocent.

The conflict of opinions continued to swell.

28 December 1933, Prandtl to Planck:

"I should not also conceal that, through the treatment meted out to me in the new letter, in which my representations are rejected without reason, I would feel hurt in my honour as the Director of a *Kaiser-Wilhelm-Institut*. The reason: My conceptual understanding of my duties and responsibilities towards my *Institut* goes much deeper than merely standing to attention to the superior authorities and executing an order of theirs that I regard harmful to the *Institut*, without exhausting the last possibility of coming to an agreement.

29 December 1933, Planck to Prandtl:

"Would you not want to let the matter rest at last? Basically, the three men (in the meantime four had left of their own accord) will come through the terror shaken with a jolt, and for the rest they will stay for their scientific work which gives them the best

opportunity to wipe out the blot. What hurts me most in all this is the thought that you yourself believe you must invest your precious time and effort in this obnoxious matter into which you have been drawn by fault of others. May the New Year bring better days for you and your *Institut*.

With warm greetings from house to house

always devotedly yours, Planck."

3 January 1934, Prandtl to Planck:

"The reason for my not letting the matter rest, as you suggest, is simply as follows: I wish to keep faith with my people who have entrusted into my hands the defence of their affairs. And I myself have the liveliest interest in correcting the picture of conditions in our *Institut* that has arisen from the discussions."

Let the reader form an impression himself from these quotations from letters on how Prandtl conducted himself in a straightforward and incorruptibly firm manner following his own convictions. In the end, thanks to Prandtl taking a firm stand on their side, the three employees could retain their jobs that were legally theirs.

During the course of these unpleasant discussions, one was surprised to come to know that since several years Nikuradse, as a *NAZI* activist, had cultivated confidential contacts with the Party office. "In order to re-establish an atmosphere of tranquility at work and functional capability of the *Institut*, Prandtl dismissed him (Nikuradse) although by this measure he drew the enmity of the *SS-Hauptmann* Weniger. The attempts of the *SS*-secret service-man to do harm to the Professor however went without success. In spite of the irritation that the case of Dr. Nikuradse had brought to the Head of the *Institut*, Prandtl saw to it that he (Dr. Nikuradse) got an equivalent job at the Breslau University.

His conduct was similar in March 1934. Regarding the other case involving a person, I will quote from the account presented by Kurt Kraemer in his "*Institutsgeschichte* (History of the *Institut*)" [17]:

"In March 1934, the law for re-establishing the officialdom of professional civil service (that had already served as a reason for dismissal of Jews at the university) had to be applied at the *KWI* (*Kaiser Wilhelm Institut*) for Fluid Flow Research too as follows: On 10 March (confidential), the Director-General of *KWG* (*Kaiser-Wilhelm Gesellschaft*), Glum, asked for declarations of loyalty from those institute personnel who were Social Democrats earlier, and demanded dismissal of one supposed to be a communist. Prandtl replied on 13 March '... I may be removed from the directorship of the local institute if the opinion is held that I am no longer suitable to hold the position, but I cannot be asked to dismiss a precious skilled worker only because once as a young man he got attached for some time to a youth organisation that stood close to communist ideas.' On the general administration checking up with the *Reich's* Ministry of the Interior, it turned out that as a matter of principle no exception can be made, except when . . .

On this President Planck himself wrote on 10 April (confidentially!), that the coppersmith in question may continue being employed if Prandtl personally shoulders the complete responsibility and no complaints are raised by the leader of the *NSBO* (the cell in the institute). This is how it turned out to be."

Prandtl did live mostly in the abstract thought world of his research, yet he was always ready to take time to listen to the plights of his fellowmen and *Mitarbeiter*, attend to their needs and offer effective help.

In his work [46] which he has titled "*Das geistige Erbe Ludwig Prandtls* (The inheritance of Prandtl's spirit)", Professor Schulz-Grunow writes:"Prandtl's readiness to help should also not be forgotten. He literally took care of the life and well-being of his *Mitarbeiter*. During the economic crisis of the thirties he renounced his pay as the Institut's Director in favour of needy *Mitarbeiter*, and, when the war broke out, all of us were released."

There existed a totally personal relationship between Max Planck and Ludwig Prandtl. His (Planck's) second wife was my mother's friend at school in Munich (she became my god-mother), and the two companions in youth stayed in close touch with each other even after their marriages.

Even in private circles with Max Planck, one was impressed by his ethics of strict fulfilment of duties. It might be seen as very fortunate that this distinguished person of integrity who was an example to follow in every respect, was responsible for holding the office of the president of *KWG* during the first years of the totalitarian regime.

The tasks in the realm of Prandtl's *Institut* were growing. The more the leading men of technology thought along the lines of the aerodynamicist, the more did the area of work expand. When, in the summer of 1933, the 25th anniversary of the *Aerodynamische Versuchsanstalt (AVA)* was celebrated, a large number of renowned scholars and industrialists had gathered together in Göttingen. During a round tour visit of the halls of the *Institut* one could see and admire many different models: Besides the aeroplane models there were models of streamlined cars, fast rail-cars and models of transmission towers on which the wind pressure had been measured. The public also participated actively in the new research.

The generosity of the city of Göttingen was very welcome. On the occasion of the jubilee celebrations it had donated a piece of land at the airfield for erecting a special flight hangar for purposes of the *AVA*. The state secretary of the Ministry for Aeronautics had likewise chosen the time slot of these celebrations to announce in person the granting of permission of a new construction phase. A more modern, larger wind-tunnel that was urgently needed for research purposes was to be built on the land at the Bunsenstrasse. A year later, in 1934, construction was started spectacularly by the ground-breaking ceremony; and following a two year construction activity, the new wind-tunnel could be commissioned in 1936.

16. Honorary doctorates from Cambridge and Trondheim

In early July 1934, Prandtl traveled with his elder daughter to Cambridge to participate in a meeting of the Congress for Technical Mechanics⁸. He was a guest of his English colleague Prof. G.I. Taylor and gave a lecture at the Congress [20].

In 1936 he was invited again to Cambridge where the degree of honorary doctorate was to be conferred upon him.

9 June 1936, Cambridge:

"Just now I have the first free hour after I gave my talk yesterday. It went off well. The days with the Taylors were very relaxed, filled with conversations of all kinds. In another two hours the ceremony starts. I am glad I do not have to say anything since my voice is very hoarse today."

10 June '36:

"It was very festive yesterday. Lord Baldwin, the Prime Minister, is the Chancellor of the University and performed the ceremony (of awarding me the honorary doctorate). I will tell you in more detail later. Tomorrow I am in Farnborough, and in the evening in Berlin."

A note in the newspaper "*Berliner Lokalanzeiger*" on 3 July 1936:

"An English honorary doctorate for Ludwig Prandtl. Cambridge University has awarded an honorary doctorate to the President of the Society of Applied Mathematics and Mechanics (*GAMM- Gesellschaft für angewandte Mathematik und Mechanik*)."

Prandtl had been invited to come to Trondheim in Norway on 15 September 1935 to receive an honorary doctorate from the *Technische Hochschule* here. The decision to award him an honorary doctorate had been taken a year earlier, but he could not be present in person on the festive occasion then. The scroll, and the ring that came with together with the document, were therefore sent to him. It was only two years later, in September 1937, that Prandtl could meet the Norwegian colleagues in Trondheim; he delivered a lecture to express his thanks for the honorary doctorate. He was then invited to Oslo also.

The friendship with the Trondheim colleagues was very sincere. In the post-war years of acute shortage (in Germany), Professor Brün from Trondheim sent us several bottles of valuable fresh cod-liver oil through a private courier, although during the period of Occupation he had himself stood against the Germans and worked for the underground.

⁸Translator's note: This must have been the Fourth International Congress of Applied Mechanics, held in Cambridge, England

17. The house in the mountains

At this juncture I wish to write about an event still from the year 1935. It is of a more personal nature that came by mostly due to the initiative of my mother. My parents bought a site in *Kleines Walsertal* (name translated: Small Wals Valley) in Austria, and got a modest wooden house (chalet!?) built on the same. They had always refused to move towards possessing a house of their own in Göttingen, in contrast to what most of their colleagues in the thirties did. For them it was more attractive to have a small property of their own in the south German area. We knew the place *Mittelberg* for some years. In one of the homes for children there, my sister had spent some time of repose. Later, we had been several times to this high altitude valley for our winter holidays. From the diary of my mother:

"In the year 1934, when we spent Christmas again in the House Schaule in Mittelberg and Ludwig reconvalesced there so well from a severe attack of cold, the wish was born in me to buy a small house of our own in this beautiful and healthy spot on earth. In Easter 1935, I already conducted negotiations on the site and construction of the house, which slowly sprouted out of the earth in the summer."

My father drew up the plans for the house himself, according to which the work was done. In December 1935 already we spent our first winter holiday in this cottage. From the diary:

"During the first few days there was not much of coziness when the heating system did not function properly. Later, the house owner was sufficiently experienced to give up this expectation. He liked looking after his house and once said, it is a wonderful toy. Many times during the day he was seen going around with a saw and hammer to put things in order."

They had meant to move in there into that house after retirement, and had nurtured plans for the same. But things took an entirely different course.

Friends and relatives visited us in the remote valley, and shared with us the joy of skiing and mountaineering. The clear and delicious mountain air refreshed young and old, and the informal evenings with games, chat and gossip, and useful occupations, mostly with the warm-hearted host, have remained in the pleasant memory of everyone.

It could happen that, when my mother held knitting material in her hands with the yarn in a mess, my father observed her pulling it up impatiently. It had got into a hopeless tangle. He looked up from the letter he was writing, saw for awhile, and then said: "Let me try once to put it in order." However my mother found that he could spare himself that trouble. But he didn't let go from what he had undertaken to do and merely told: "It is fun doing it!" The difficulty in solving a problem had an irresistible attraction for him. He wound the wool, put it through and untied the knots with care, and everyone followed his manipulations attentively. He applied himself to this simple occupation with patience and

quiet eagerness, and one was thoroughly entertained as an onlooker. One watched intently success coming in gradually that he finally brought to an end as in a game.

I wish to supplement my description by a passage from a letter written much later. Prandtl wrote on 17 April 1952 to Professor Marguerre from whom he had obviously received a book: "The packing of the book, it appears to me, is your own work. I found it noteworthy that the knot, that was indeed tied securely, could be undone to recover the single thread undamaged. This is a kind of game for me (it could also be said it is a game of patience). The solution turned out to be unique without searching, and the thread was put away in store for further use."

I wish to mention an incident that has remained in unforgettable memory of a young cousin of mine. Visit on holidays! The beds for the several guests were arranged in such a way that my father shared a room with his nephew. At four o'clock in the night my nephew was woken up gently by him (my father). My father asked him to get up and took him to the open window. There he showed him a star that shone standing out brightly in the sky above the mountains, and explained to him that it is Venus, a planet of the solar system. In this quiet night, both enjoyed the beauty of the clear starry sky and were absorbed in meditative watching at the sight of the morning star sending across its greetings with twinkling light.

A friend of ours also remembers even in her advanced age a noteworthy saying of Prandtl. In those days in *Mittelberg*, when she accompanied him on a walk, they saw at the edge of the meadow a grasshopper taking its tender jumps. "Something like this original small creature the human being can never reproduce in spite of permanent technical progress. It is a marvel of creation."

Of the many visitors who stayed in that cottage in those years, there is one family of which I wish to make at least a mention. In the autumn of 1936 my parents placed their new vacation domicile at the disposal of a friend and colleague, the philosopher Georg Misch, for whom the commission to teach at the Göttingen University had been withdrawn due to the "Arier"-Clause. They had also been given notice to leave the housing, so they were glad to accept my father's offer. Austria had not yet become part of Nazi-Germany by the "Anschluss", so there was no cause to fear investigations there. Misch's grown-up children were forced to leave Germany, and before they migrated into a foreign country they visited their parents once again there.

Their son Peter had accepted a professorship in Canton (China). He wrote in our guest-album: "19 September 1936: Just before departure to Canton for the last time in our German mountains, to take leave of parents who, it is comforting to know, are well taken care of in the cosy Prandtl-House. It was nice to be together for the last few days." Their daughter Lore (later wife of the Nobel-Prize winner Felix Bloch), who came from Denmark, traveled over *Mittelberg* to Switzerland; the youngest daughter, my friend Lilli, traveled from there to England. Later all the three children, brother and sisters, lived in America.

Professor Misch wrote in our guest-album on 7 March:

September, October, November
and almost the whole of December,
then again in the new year
until beyond the end of Februar'.
Thus we lived for 6 months
in Prandtl's house on the mountain slope,
two together in solitude;
the mountains rise over happiness and misery.
Some come and knock,
whether one can live here?
Yes, comfortably! But not everyone.
The lady of the house, she has the say!
She let it for friends for a long time,
she is indeed always ready to do good." ⁹

Misch left Germany at the end of 1937 and went to England, whereas his wife, daughter of Wilhelm Dilthey, stayed back in Göttingen due to her delicate health. Her husband rejoined her in Göttingen after seven years of separation in May 1945.

Extract from the "*Universitätszeitung*" no. 2 of the year 1946:

"On the return of the Göttingen philosopher from emigration: With the return of Georg Misch, one of the most significant personalities of German philosophy has come back to Göttingen from emigration. We have every reason to be grateful to him for having taken up his earlier teaching position again."

In February 1938, my sister Hilde got engaged with the legal intern (*Gerichtsreferendar*) Wolfgang Weber. The head of the family, Rudolph Weber, was a critical person of high character, who had relinquished service as a minister in Oldenburg since he was

⁹ German original:

*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."*

unwilling to enter into any compromise with the NAZI-government. Wolfgang's sister, Dr. Sophie Weber, was a pediatrician, later the trusted doctor of my children who stood by the side of all of us for advice. Destiny however took away from the bride this happiness, bringing in sorrow for all of us. On 16 September 1939, the war-time wedding ceremony had taken place in our home, and soon thereafter followed, with the calling of the young husband for service, the agonies of separation. On 29 June 1941 Wolfgang Weber fell as lieutenant still before reaching Riga.

18. Pleading for W. Heisenberg

For a long time, there had been a burning controversy in physics between adherents of a so-called "*arisch* physics"---supported by Alfred Rosenberg---and those of modern physics. The representatives of the first group, who stood against quantum theory and Einstein's theory of relativity, demanded that physics should have a more "pragmatic character". Since, over and above this, these experimental physicists (Johannes Stark and Philipp Lenard belonged to this group) regarded themselves as a political movement, they tried to rule over the entire community of physicists in Nazi-Germany through intrigue. In 1937 they directed massive attacks against Werner Heisenberg, then a young professor of theoretical physics.

Following these attacks, many colleagues of Heisenberg who held him in high esteem rallied together and dared to take the risk of defending him through written protests sent to the ministry. Even Heisenberg's own action - he wrote a letter himself "to reestablish his honour", which he sent to the *SS- Reichsführer* Heinrich Himmler - had not borne fruit. A thorough and detailed account of this incident which stretched over a year, is in the (German) book with the title "*Erinnerungen an Werner Heisenberg*" (Memories of Werner Heisenberg) authored by Elisabeth Heisenberg [12]. Here it suffices to note that Prandtl also stood up openly on the side of Heisenberg in this dangerous affair, defending him vehemently against the charges made. Thus, Prandtl helped Heisenberg greatly in the process of rehabilitation.

In his book "Scientists under Hitler" [7], the author Alan D. Beyerchen, who deals extensively with "the Heisenberg affair" and its complete history, writes about the way in which Prandtl tried to help his young colleague get out of this situation:

"The case of Heisenberg remained unresolved until the peak of the summer (1938). In July there came in important support from Ludwig Prandtl, the Göttingen specialist in aerodynamics, who was seated next to Himmler at a gala-dinner organized already some time ago by the German Academy of Aeronautical Research (*Deutsche Akademie für Luftfahrtforschung*). Prandtl had waited until he thought the *SS-Führer* was free from urgent commitments arising out of annexation of Austria in order to get a hearing for his defense of Heisenberg."

On 12 July 1938, Prandtl reminded Himmler of their talks in a letter. "When I was seated next to you on the occasion of the festive meeting of the German Academy of Aeronautical Research on 1st March of this year, I brought up the matter of certain difficulties faced by Germans in the field 'Theoretical Physics' due to the unjustified attacks made by a group of experimental physicists, and mentioned in particular the personal difficulties of Herr Heisenberg. I wish to add a few words to what I said then on theoretical physics. The difficulties people in this subject are put into are primarily caused by a small group of experimental physicists, who have not been able to keep pace with the research work of the theoreticians, vehemently opposing the new developments in theoretical physics, primarily on grounds that there are significant elements in the foundational structure of physics today that come from 'non-*arisch*' scientists.

"But there are indeed, among the 'non-*arisch*' people, scientists of a class that must be regarded as the foremost of the best. I wish to recall of the short-lived Heinrich Hertz, who proved the existence of electrical waves through arduous and imaginative experiments - the same waves that have risen high in technical importance due to applications in wireless telegraphy and radio. The physicist Einstein belongs to first class physicists through and through.

"Science simply faces the fact that laws have been discovered that in turn have led to further discoveries which cannot be ignored without dismantling the structure on which they were built. Next to theoretical physicists, there will always be experimental physicists whose strength lies in conducting experiments for which they will get the theory worked out by the theoreticians. But it is unheard of when such experimentally oriented people, because they are unable to follow the theories, simply declare them to be pernicious and reprehensible, and indulge in mud-slinging at those representing theory. In order to draw your attention to the opinion of the well-known theoretical physicist Max Planck, I wish to enclose extracts from a talk by this scholar.

"Regarding the person of Herr Heisenberg, he has indeed been grossly insulted by Stark. It is urgently necessary that the abuse is retracted, and it be made clear that officials at the Government as well as the Party leadership do not share Herr Stark's views. This is absolutely essential, since letting this slander go without a rebuttal would make it very difficult for Herr Heisenberg to be effective as an academic teacher; for the reason that the students would be taught that what they can learn from him is useless -indeed harmful---and detrimental to the development of their technical expertise,

"I think an appropriate measure would, if possible, be to let Herr Heisenberg publish an article on a subject of his choice in the journal '*Zeitschrift für die gesamte Naturwissenschaft*' which appears as an organ of the science section (*Reichsfachgruppe Naturwissenschaft*) of the Reich's Student Leadership (*Reichsstudentenführung*). I would be glad to get in touch with Herr Heisenberg regarding the choice of a suitable subject."

I will quote Alan Beyerchen again: "There is hardly any doubt that Prandtl's vehemently worded defense of Heisenberg and of theoretical physics played a decisive role in the matter. Hardly two weeks later, Himmler wrote to Heydrich saying that he concurs with Prandtl's letter and is of the opinion that the Students' Association should allow Heisenberg to publish in its journal."

However, the professor's chair for physics in Munich that had been already earmarked in 1935 to go from Sommerfeld to Heisenberg, went instead to a physicist by name Wilhelm Müller. Again, Prandtl did not mince matters while expressing his opinion: "Herr Müller does not possess any qualification whatsoever for theoretical physics. Instead, he has published a polemically worded program of work that can only be described as an act of sabotage of a subject that is indispensable for further technological development." (Memorandum of May 1941, quoted in E. Heisenberg [12])

19. Voices on the situation at that time

At this point the younger reader may find no way of getting away from the question: How could Prandtl approach Himmler, who should be held responsible for some of the most horrid crimes of the Nazi regime? That question can be asked only in a state of ignorance of the situation at that time. Most certainly, the words of the historian Christian Maier, who points at the trustfulness and unsuspecting nature of the Germans, would bear more weight than any answer I could give. A lecture given by him in Tel Aviv, with its critical analysis, aids in understanding these problems. I quote from this lecture *Verurteilen und Verstehen* (Condemning and Understanding), (*Frankfurter Allgemeine Zeitung* of 28 June 1986).

"They (i.e. a section of Germans) could indeed make out from the start the wrongdoings of the National-Socialist-regime, but could not already know on this account the gigantic proportions to which their country had set out to commit a crime of a unique nature. Had holocaust been forecast to them, they would not have believed it to be possible, and that not only because they had been brought up mostly in an atmosphere of political unawareness and extraordinary respect for the state. When does it happen that a whole generation is asked a posteriori that it should not have made use of the chances in their profession since that would necessarily bring them in close contact with those holding power? What would we of today have done in such a position? Only if we knew that we would have done better under conditions prevalent then and with the state of knowledge of those days, can we condemn Germans of those days, with the exception of those who committed offences and crimes. . . . We have every reason to resolve to do better; especially since we can know today what a totalitarian regime is and how it originates. But there is no justification for us in a much more fortunate position to put on a Pharisaical attitude."

At this juncture I wish to add one more incident from memory - a conversation from the year 1943. My father had returned from a walk that he had taken in the company of a good friend, He said: "Do you know what Frau X told me? In the East, Jews are being herded together and killed! How can one believe such nonsense! During the last war, the French also spread such tales, that the Germans committed atrocities on women and children." It was in his very nature that he was not in a position to imagine such things were possible, or even that they could be thought.

20. Congress in America

On 1 September 1938, Prandtl started on a trip to America in order to participate in the "5th International Congress of Applied Mechanics" in Cambridge, Massachusetts. He was already 63 years old then. He traveled together with Professor Blenk, Dr. Schultz-Grunow, Professor Schlichting and many other congress participants. They met together on board the steamship "Bremen" for crossing the Atlantic. My mother utilized the absence of her husband for a renewed period of stay in a sanatorium in Kissingen which was urgently recommended to her by the doctor. There, she got the following letters from her husband:

7 September 1938:

"The journey has gone on smoothly and even lively up to now. The ship is very beautiful, the meals royal, our company very pleasant. Every morning I take a ride on a camel and a horse (both living on the principle of an electric motor) and then swim. The weather has often been very nice. Now and then the day is also foggy, and there is a little stiff wind on the Gulf Stream. We are supposed to be in New York at two o'clock in the morning tomorrow. From the landing piers we will be brought to the hotel, and do not have to worry about anything for twelve days. 130 lectures are supposed to be given at the congress, three simultaneously (in parallel sessions). But even 43 is still too many. . . "

After arriving in Cambridge, Prandtl met, among colleagues from foreign countries, old acquaintances as well, like Professor von Karman, Professor G.I. Taylor, with whom some personal thoughts were exchanged. In his biography [15] von Karman tells his co-author Lee Edson on the conversations in 1938. He (Lee Edson), however, published the book on his own only after Karman's death. In this, certainly, not sufficient care was taken in differentiating between what was really said, and what Karman interpreted with hindsight.

In professional circles that have come to know of Karman's book "The wind and Beyond", the view is held that this biography should be read critically. In a meeting of the recipients of the Ludwig-Prandtl Ring on 9 May 1972,¹⁰ Professor Blenk expressed his view as follows: "The Autobiography of Karman cannot make any claims of historical correctness, which should be kept in mind by every reader of this otherwise interesting book."

Prandtl, who had been sought by the ministry in Berlin to recommend a venue for the congress to be in Germany, had agreed to place before the foreign colleagues an invitation from the German government. Through this he had hoped to continue cultivating scientific exchange with the other countries in peaceful coexistence. The invitation triggered excited political discussions between the colleagues from the different countries in Cambridge, which has remained in the memory of the participants in the congress who are still living.

¹⁰Translator was present at this meeting.

Professor Blenk wrote Dr. Rotta on 9 July 1987: "I remember well the tense, in part quite unfriendly atmosphere at the congress that was prevalent between the German and the other participants. There were many small discussions on the necessity or the likelihood of the second World War, at which we Germans did not mostly see its necessity. In these discussions we defended the policies, not the ideology or the crimes of Hitler, insofar as they were known at that time at all. What we believed we were right to defend were: 1. abolishment of the Versailles proclamation, 2. reinstatement of the right to arm, 3. the union with Austria to form a "Grossdeutscher Reich". It is interesting to read what a historian like Sebastian Haffner writes on these themes in his book "Anmerkungen zu Hitler" ("Notes on Hitler").

Prandtl also had attempted in discussions with the foreign colleagues to defend his country against derogatory judgments of current Germany. At that time he believed, without being at least critical, in the good intentions and straightforwardness of his government.

Men, who like Prandtl, had grown up in Kaiser's Germany, and in whose thinking loyalty towards the powers that be and patriotism were closely knit with each another, felt it as their duty, particularly in interactions with foreigners, to justify the political events at home through defending their country against slander. This attitude is visible in his foreign correspondence too. Soon after taking leave of the German group, G.I. Taylor wrote in retrospect upon these talks:

27 September 1938 (three days before the Sudetenland 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 be unchanged. I realized that you know nothing of what the criminal lunatic, who rules your country, has been doing, and 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."

Later, Prandtl had of course to see his political mistakes that Taylor was referring to here.

After the congress closed, there was on the program for the participants a visit to the World Exhibition which was in the process of being put up at that time.

During the Atlantic crossing that the German scientists' group had undertaken aboard the American liner "New York", the news came in of the occupation of Sudetenland by Hitler that was to come. This made the ship's captain take a detour in order to avoid getting into a possible war-zone. The ship headed towards the Norwegian coast; but since the crisis had been overcome in the meantime through the Munich agreement and the situation had calmed down, the passengers on the ship could be landed on German soil, although with some delay.

It appeared now that the judgment of the German government having peaceful intentions was confirmed, and that predictions of the bad had rightly been refuted. In his reply to Taylor, Prandtl indicated that he had not given up his earlier standpoint to defend the German position as it stood. His reasoning, however, remained not understandable. Prandtl, who, as said earlier, trusted the news appearing in the papers, could not imagine that already one year later it would be a state of war.

When after all this, war broke out on 1 September 1939 with the attack on Poland, my father had painful thoughts, after all this generation did know enough of the miseries of war. "Work will go on as up to now", that was his laconic directive to the personnel.

The first winter of the war saw the people in Göttingen having to put up with some restrictions. In February 1940, families in "Saarland" were evacuated as a measure to protect them from the fighting in the war with France. The occupants of the more spacious floors in our building were asked to house some refugees, around two or three in every floor. The family of a mine-worker with its seven members came in to the house where we were living, and they were accommodated by three tenants. My mother was full of sympathy and kept our spacious kitchen at their disposal for the evening get-together by the family. My father also took time to go there to speak with them a little longer now and then. Some other apartment owners moaned over the burden of having to house another. The people from Saarland stayed for around three months in their quarters before they could return to their home villages.

Our family was hit by several severe blows of destiny in the years 1940 and 1941. At the end of July, my sister lost her baby soon after birth. In December, my mother died. I have already referred to the death of my brother-in-law who fell in the war close to Riga.

These were difficult times for all of us. Since her marriage, my sister was not living with our parents, so, after my mother's death only my father and I were left in the big apartment. My father missed the care and refreshing liveliness of my mother with which she was participating in everything. It was often very quiet in our place. I continued my studies of language and literature and concentrated, with the best I could, upon the lectures. The housekeeping work ran well and smoothly, thanks to a reliable maid. Regarding the rest, I tried to adjust myself to Father's habits so that he should not miss anything in day-to-day life.

As usual, my father took a longer walk every week-end at which I accompanied him. During the Easter holidays of 1941 we traveled together to visit our South German relatives in Munich and his cousins in Schleching. With the help of these lovable people we finally succeeded in gaining a little more distance from the latest events.

Ingenieur Müller remembers a sentence of Prandtl from this time: "Do you know, it is difficult to bear such a loss, but life goes on; so let us work." He was totally engrossed in work again.

21. Physicists' dispute

Although Prandtl was swamped with work as before, he once more took the initiative for a statement against the NS (National Socialist) scientific policy of that time in the spring of 1941. This time, the purpose was to let those men in power know his views regarding the disastrous dispute among physicists.

In the year following Heisenberg's rehabilitation, the swelling fight between representatives of the so called "*arisch* physics" and those of theoretical physics had taken a ruthless turn again. The main attacks came repeatedly from Professors Philipp Lenard and Johannes Stark who, on 1 December 1939, had succeeded in getting a person, who subscribed to their philosophy, appointed to the Munich Chair for Theoretical Physics, that was originally intended for Werner Heisenberg. Since this person was an aerodynamicist, Prandtl was consulted. He (Prandtl) expressed his opinion in words that were remarkably clear: Wilhelm Müller is anything but a creative spirit, and (his) appointment to the Munich chair was a mistake. He called the appointment an act of sabotage against further technological development.

Prandtl wanted to stand up against this all-powerful Nazi group. He wrote a memorandum of defense of theoretical physics which he sent directly to Hermann Göring in Berlin. It is not any more imaginable these days how much courage this step called for; a step that spoke out the truth which exposed the incompetence of the NS leadership at judging the meaning of scientific knowledge, and which stamped its faithful supporters as incapacitated bunglers.

A contemporary colleague, the aged physicist Friedrich Hund,¹¹ whom I met recently, brought up this point in conversation. He remembered the courageous step of Prandtl with much appreciation.

Following is the text of the letter of 28 April 1941 to the then Reichsmarschall Hermann Göring:

"Warding off of a serious danger to the rising generation of German physicists.

"In short, it boils down to one thing, namely, that a group of physicists, to whom the *Führer* listens, is raging against theoretical physics and defaming the most meritorious theoretical physicists. This group forces the award of professorial positions, and does so by reasoning that modern theoretical physics is a Jewish invention which is to be eradicated and replaced by "German Physics"--- something they cannot do quickly enough. I have explained what this means in the accompanying annex. It is indisputable that theoretical physics is an indispensable subject for training the *Führer's* rising generation of physicists. It is up to them to arrange the entirety of physical facts into a logical order and consequently to develop laws. The technical physicist can then produce new designs methodologically and make predictive calculations regarding its working.

¹¹ Translator's note: Friedrich Hund died in 1997 at the age of 101

The training of physicists without theoretical physics is apt to produce efficient, average workers, but not leaders who have an overview and mastery of the entire field.

"The common characteristic among the group of physicists mentioned, who are led by Professor Lenard, is that its members lack the capacity for precise critical thought based on mathematical foundations. Insofar as they are not in a position to judge works of modern theoretical physics critically, which would require a relatively advanced level of mathematical expertise, they are uncertain about the indispensability of the subject. In contrast to this group, the necessity of theoretical physics is recognized unequivocally by all physicists who have a sound knowledge and understanding of the subject, who possess the necessary mathematical tools. I would like to ask you, respected *Reichsmarschall*, to consult, on the basis of what I have written (in the annex), two well known physicists who work in industry, Professor Ramsauer, Head of the research laboratory of AEG, and Professor Joos, chief physicist of Zeiss-Werke, who, by virtue of their positions are sufficiently unaffected by the terrorizing behavior of the Lenard group. As far as I am concerned, since objections could be raised that I am not a physicist, I would prefer to remain anonymous in this matter (when I was younger, however, I completed a doctorate in physics and since then have followed its development with great interest, which means that I am not entirely lacking in understanding of the subject).

"The harmful sloganeering of the group of 'German physicists' that I mentioned earlier, namely that modern theoretical physics is a Jewish invention, has caught the attention not only of the Ministry of Science, but also of the leaders of the student body; as I suggested earlier, it has engaged in violent attacks on the most meritorious and esteemed representatives of theoretical physics, and drives students away from the subject. In the immediate past, it has sought to assert itself by bringing about a professorial appointment that is so unbelievable that it cannot be said to be anything but meaningless - except when 'meaningful' is understood to mean destruction..."

Attached to this letter, in which he requested that Hitler be informed about the matter, Prandtl had enclosed an eight-page paper on theoretical physics explaining its scientific foundations. This paper is given unabridged in the annex. Copies of this manuscript were sent to several people belonging to the circle of physicists. Here is one reply:

Professor Dr. Joos, Chief Physicist at Zeiss-Werke, Jena, wrote on 5 May 1941:

"For a long time I have not had such joy as I had through the letter a copy of which you sent me! At last one has the hope that the top echelons see the danger. You have earned a position of merit for championing the cause of physics, regardless of whether your paper will be effective immediately or otherwise! I, for one, find your account of theoretical physics simply wonderful!"

Prandtl's letter of attack had been a certain kind of a signal. The physicist mentioned in his letter, Carl Ramsauer, who had been elected to the chairmanship of the Physical Society (physikalische Gesellschaft), sent to the Ministry of Education an extensive cleverly worded memorandum on 20 January 1942, in order to counteract the misdoings

of the favored "Lenard Group". His arguments were respected and were indeed successful.

A. Beyerchen [7], reporting on this, writes: "Since summer 1942, Göring's ministry lent its support to keeping the physicists working in this area free from further political interference."

22. Journey to Romania

From 29 April up to 14 May 1941, Prandtl followed an invitation from Professor Valcovici, an earlier doctoral student of his, and undertook a journey to Romania to give several lectures there.

From Prandtl's report: "Considering that the journey to Romania would necessarily retard some very urgent work, I had considerable reservations against this journey prior to starting, and was afraid that its outcome would not compensate for the loss of time."

In spite of this doubts he started on the journey on 29 April 1941. He flew from Berlin to Bucharest.

To his daughters on board the aircraft: "We are traveling very comfortably over an enchanting landscape of white cotton-wool, with cloud towers scattered here and there; over us the blue sky. Now, mountains are coming again, behind which the sheet of cloud is torn apart. Now without clouds, (the river) Elbe, mountains, then Prague, friendly landscape, dam with romantic forts, wavy land, long villages."

Professor Valcovici received him at the airport in Bucharest.

Excerpt from the report: "1 May: Today is first of May. All shops are closed; but there are street vendors with flowers, oranges and the like (sitting on the pavement or standing bare footed). The street scene is not uniform in appearance: civic buildings in European, and commercial buildings in American style (7 to 10 floors), many broad roads. In the afternoon, during the strolling hour, there are so many people going about their way that one can move forward only slowly. Added to that there are many cars (gasoline is in surplus).

On return he wrote the report on his lecture tour mentioned earlier. From this report, I will give some excerpts that appear interesting to me:

"My journey to Romania, on the orders of the Reich's ministry for Science and Education, was undertaken from 29 April to 14 May. The following lectures were given:

- 1) A general lecture "On Fluid Flow research (Strömungsforschung)" at the Faculty of Mathematics and Sciences.
- 2) 3 lectures, each of two academic hours, for students on the subjects "Compressible flow", "Small viscosity, particularly boundary layers" and "Turbulence". All the lectures were supported by a number of slides and two by a movie film.
- 3) On 9 May, a general lecture at the Technische Hochschule (Technical University) in Temeschburg.

The 10th of May was a Romanian national holiday (Unification Day) celebrated by a big march of school-children and a military parade that I witnessed, in accordance with the wishes of the Romanians.

The lectures that were announced through posters and in newspapers, and by invitations sent out, were well attended in both places. There were speeches in German first, in Bucharest one by the Dean of Science Faculty, and one by my earlier doctoral student Professor Valöcovici.

Welcoming speech by the Dean, Professor San Jonescu:

Ladies and Gentlemen, The Science Faculty of the University of Bucharest had the honor up to now to receive two esteemed German professors as its guests, Professors August Sieberg and Adolf Butenandt, whose very interesting lectures have left behind a lasting imprint.

Now, Herr Dr. Ludwig Prandtl, *Doktor honoris causa*, *Director of the Kaiser-Wilhelm Institut for Fluid Flow Research* and Professor at the Göttingen University, has been kind enough to follow our invitation.

Herr Professor Prandtl will be giving a series of lectures in his area of research during his period of stay in Bucharest.

Today's subject is fluid flow research. Respected Herr Professor and Colleague, Your lecture is of interest not only to mathematicians and engineers, but also to us biologists, since the same principles and laws that guide movement in the inanimate world, also govern many aspects of life in the world of living organisms, animals as well as plants. And even more, I could assert that finally these principles find application in matters concerning settling and organization of the different arms of a society or a nation. I am therefore convinced that the important messages in your lecture will be followed with much interest and attention by the audience. As Dean of the Science Faculty I have the duty to draw attention with a few words to the necessity of closer and closer German-Romanian scientific co-operation. As I have often said on such occasions, and I repeat with the same conviction, it is primarily working together in science that unites different people and nations with each other."

Report on Temeschburg:

"In Temeschburg there were, besides secular dignitaries, clerical dignitaries present too, among them the orthodox Bishop, who came to the reception that followed and expressed his joy over what he had heard and seen.

Professor Valcovici was kind to look after me during my entire stay in Bucharest. He showed me around the city and the university, and also his own institute of pure and applied mathematics with quite a high standing. On the afternoon of 1 May he organized in his beautiful house a tee-reception in my honor, attended by large circle of ladies and

gentlemen of whom I had the impression they were in the highest circles of the Bucharest society (many university professors, different had-been-ministers, Romanian officers). Besides these, the German Embassy was also represented, the last through Prince Solms. The gentlemen in Temeschburg also took care of me. I was received at the railway station by the dean and a few professors, and also by a delegation of "German Folk" (Volksdeutsche), and was accompanied to a small "Pension", since the big hotels were all occupied by the German army (deutsche Wehrmacht). One sees many teams of German soldiers (military) and officers on the roads and also in the pubs."

"On the streets of Bucharest there weren't any signs of unrest that could be made out. But there is supposedly much hoarding going on. Food in the eating places, and even beer and wine, that is grown within the country is very good and meets even spoiled demands. Meatless days have been introduced, but ham, smoked tongues and the like are not regarded as meat. A noteworthy way out has been found to meet the shortage of flour prevalent even there, which is that only old bread rolls (of which naturally less is consumed than the fresh stock) are permitted to be sold. Besides, rationing has been introduced, with two days of maize bread (corn bread).

During conversations with Romanians their big worry comes to the surface that they had to give away different parts of the country, and the point emphasized above all is that everything else, other than acceding such a sizable Romanian population to Hungary, would have been bearable (in 1940, an area of "Siebenbuergen", with a population of one million that was lost by them to Hungary in 1920, is returned by the second arbitration of Vienna). Their hope is that a different solution will be found by resettling. On the return journey through Hungary I had a conversation with a Hungarian from this returned area, who naturally held the opinion that even the rest past belonging to Hungary earlier had to be returned to Hungary."

The return journey by train enabled Prandtl to stay both in Budapest and Vienna. On 15 May he returned to Göttingen in a state of considerable exhaustion.

In the year 1942, on the 10th of November, Prandtl was awarded the title of an honorary doctor by the University of Bucharest.

23. The last war years

At this juncture it appears important to me to characterize Prandtl's attitude towards awards of honor: Whoever is of the opinion that Prandtl, who received honors among others from the NAZI-government too, and therefore felt very close to the government on that account, would not be in a position to convince those who knew him of such guesses, whether they belong to the circle of his colleagues, co-workers or friends. He did not attach much value to these certificates of honor. They came in to his residence and were stowed away in drawers without his ever mentioning them again later.

Let a few words I remember well from those years testify as to how little such honors meant to him. There was a "Ludwig-Prandtl-Prize" instituted for school children who stood out at making airplane models. It was awarded annually to the most outstanding young designer and carried a sum of 3000 RM (*Reichsmarks*). At no time was there any mention of this prize at home. And so it happened that my attention was drawn to this prize from someone outside: "Your father has indeed become quite popular with the Göttingen population through the Ludwig-Prandtl-Prize that will be awarded every year. Didn't you know that? Such news appears in the newspaper even here."

Pushing the research work ahead, regardless of the political situation in Germany, was the only internal prime mover of significance that was effective. Furthermore, he was longing to be able to finally finish up a major work. In the year 1942, the third extended edition of his text book "*Abriss der Strömungslehre*" was published, a book that had appeared under the title "*Führer durch die Strömungslehre*" in Vieweg-Verlag [27]. Later, this title was retained by his former students Professor K. Oswatitsch and Professor K. Wieghardt who prepared a revised and updated version of the book. Ever increasing tasks made heavy demands upon him, yet he remained the simple and benevolent person he was, always ready to stand up for a good cause. Just to give an example, in spite of the load of work he was carrying, he was committed to seeing through the dissertation of a doctoral student who was sent to the Russian front. The reply of the doctoral student, Hans Böhm, is available.

17 January 1943:

Respected Herr Professor:

Just now I came from guard duty. A delightfully clear moonlit night, such as this one that can be seen only in Russia, shortened the hours there and set my thoughts running. I went through your kind letter again and was very happy. Your book is now ready and I will get a copy of the same! I hope you will believe me, Herr Professor, how much happiness that gives me. I wish to request you to send that book to my home address since, finally, I will be getting leave in early February. The book will of course come with me to Russia---something else will have to make way for it in the back-pack.

I am most delighted that you want to go through my dissertation, since I need not emphasize how dear this work is to me! You may want to make changes to the same,

hopefully there aren't many corrections. Actually I often think on what I ought to have done differently. But errors and improvements are seen only in hindsight."

2 February 1944:

"The permanent migration and disrupted life at the front made it impossible for me to write a reply to your kind letter, and I am hurrying to thank you for your response to my comments. I hardly venture to think of success whilst I wait for the decision. . .

Your Hans Böhm"

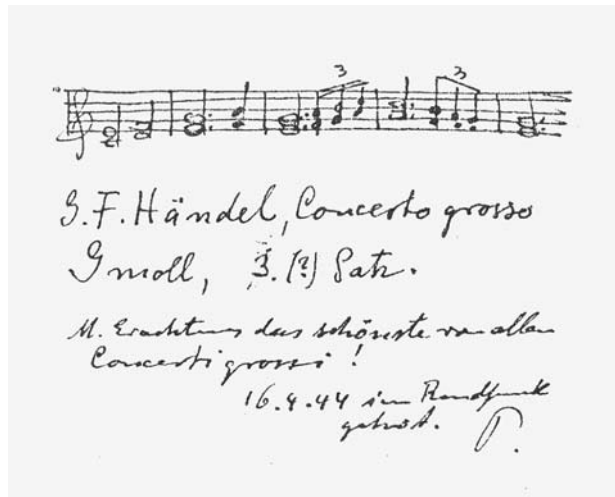
In the year 1943, in several letters my father writes about his trips to Berlin where he paid visits repeatedly to his higher authority, *the Kaiser-Wilhelm-Gesellschaft*, since discussions in person were preferred. On 4 March he had the experience of an air-raid. The path to an air-raid shelter in a basement leading through a flight of stairs in darkness proved to be a stumbling block for him. He fell and was injured on the head. He was then taken to a doctor who had to stitch the wound without anesthesia and wound a big bandage around his head. We were shocked to see him when he returned to Göttingen with such a bandage on his head. But he only laughed a little and said there is no reason any more to attach importance to the injury now. However, he had a certain feeling of being satisfied with himself that the doctors, after putting on the stitches, had expressed admiration for his courage that they had not expected of a man of his age.

In spite of his advanced age, he was deeply engrossed in his profession. His guiding principle was to put his faculties for work towards the cause of progress in science as of date, although there was steadily increasing uncertainty regarding the near and distant future.

We had yet to survive the last months of war, of course naturally with night air-raid alarms sounding frequently. Although Göttingen was mostly spared from destruction, the many hours that we spent at night in the basement brought in much unrest to our lives. Göttingen saw the first bombing on its city area in November 1944, and the order to seek shelter from air-raid in the basement was naturally taken seriously. Every further raid was a new warning.

With the optimism of youth that does not weigh the uncertainties associated with the of passage of time when their meetings appear to stand in the course of destiny, my friend at school Helmut Vogel and I decided to enter the bonds of marriage. There were therefore wedding bells ringing again in our house in the year 1944. Already during the engagement period a warm hearted relationship had developed between the father-in-law and the son-in-law. The relationship with my husband's mother and sister, a talented painter, grew soon to be equally warm. They came down from Bremen to visit us often. I have still in front of my eyes my mother-in-law and my father sitting at our piano, rehearsing to play music for four hands. He liked the cheerful and lovable nature of the Bremen lady who had a very sympathetic understanding for every one of us.

The spontaneity with which my father could catch a musical phrase is evidenced by a small record that he has kept. He had noted down the score quickly on listening to the music over the radio in order to retain the entire movement in his memory.



G.F.Händel, Concerto grosso g-minor, 3 (?) movement.
 In my opinion, the most beautiful of all concerti grossi!
 16.4.44, heard on the radio. (signed) P

In the last year of the war, 1945, one hardly undertook any travels for visits. On 4 February 1945, when he completed 70, there were only a few who had come in person to congratulate and extend their best wishes. I well remember how Professor Schulz-Grunow had not shied away from traveling in spite of the difficulties and risks involved at that time in order to congratulate my father, and how he (my father) was pleasantly surprised and welcomed him in our home.

Several former students and colleagues of his honored him by a *Festschrift* [51] that contains 20 technical articles on applied mathematics and mechanics. Due to the then prevalent circumstances of war, the *Festschrift* could be released only later. Professor W. Tollmien of Dresden wrote an article of introduction that can be given here only in excerpts.

"It is in deep respect and love that a person whose influence on mechanics during its long and illustrious history has been epoch making is being felicitated on 4 February. On this day Ludwig Prandtl is completing his 70 years of life. . .

The work of Prandtl could not have unfolded itself with the glory and made the impact it did, if he had not, out of his own passionate commitment to science, aroused in his pupils and co-workers in large numbers a similar passionate commitment to scientific research. His goal was not so much a brilliant "*Apercu*" but a systematic study in depth to illuminate an entire range of questions involved, which could be achieved only by the

building up of a school. With the steady building up of the Göttingen institutes a large number of co-workers joined the many doctoral students who worked with Prandtl over the years, and they shared the benefit of stimulating exchanges of thought with Prandtl in personal contact. During such discussions Prandtl consciously avoided arresting the development of potential research workers through his towering scientific personality. A meaningful question the answer for which appeared within reach was raised, and some possible routes for finding the answer for the same were presented for discussion. For the rest, Prandtl, with the patience characteristic of a true pedagogue, let the research worker develop his individual abilities in his own way, sharing the inevitable setbacks and encouraging him to overcome the difficulties. The levels Prandtl set for the research work were very high, true to the Georgia Augusta tradition. A brief word of appreciation by him was the highest reward that could be earned by a young research worker. Everyone who, like the author of these lines, was fortunate enough to work with him for some time, will recall with gratitude the common intellectual bond that unified the cause pursued and the respect for the personality of the Master.

Unequivocally but also without envy, Prandtl is regarded by experts since a quarter of a century as THE leading research worker in the field of mechanics. It is no less a surprise that, after such a monumental performance, he has not in the least turned away from active scientific life on the threshold of his eighties. In contrast, in the last few years Prandtl has taken over new responsibilities of leadership in the organization of scientific activity of his country, and his own pioneering research work is not taking rest.

What could his colleagues and friends therefore wish better on 4 February 1945 for themselves and for the person to be felicitated than that his creative powers remain undiminished for quite a long time to come!"

Professor J. Ackeret (ETH Zürich) also wrote on the same occasion an article [2] from which I am quoting only excerpts.

"Prandtl has enriched technical mechanics with entirely new features of his own. When a layman speaks of research, he does so usually in the sense of a confusing array of complicated apparatus and costly instruments. But Prandtl made his biggest discoveries with surprisingly primitive facilities. His Boundary-Layer Theory that removed the traumatic difficulties of mathematical unsolvability of the viscous flow problem at one stroke, Prandtl found with an apparatus that perhaps cost 40 Francs (Swiss currency) and was driven by hand. How right he was when he told his co-workers on one occasion: 'It is nice to have such a big telescope, but the main thing is the man who sees through it.'...

In the era before Prandtl, hydro- and aeromechanics were in a state of incipient petrification: it looked as though nature was hiding herself behind mathematical difficulties. Keeping steadily in touch with experiment, Prandtl found the way-out. With a sense of unbelievably imaginative intuition, he dropped from the general problem just so much that the essential features were retained and the mathematics just sufficed to solve the remaining exactly and neatly, and all this in a way that led to results usable in practice... His wealth of ideas was so profound that he gave them freely without fear of

losing priority, and it is easy to overlook his contribution entirely when the contributions of his numerous pupils are somehow put together. . . Those who were fortunate to study and work with him would remember him not only as a great scientist but also as a basically kind and benevolent person and a fatherly friend... "

The journal *Luftfahrt-Forschung* (Research in Aeronautics) published an article "Ludwig Prandtl 70 years" [19] without naming the author, from which I quote:

"On 4 February Ludwig Prandtl, who is not only the most well-known and successful scientist in aeronautical research but is also heading its organization for a few years now, celebrates his 70th birthday. The festivities are held at a lower key due to the times and according to the wishes of the felicitated, than they would have rightly been during peace times. But it is a day for everyone in aeronautical research to reflect for a while on how decisive an influence on modern aeronautics his thoughts have exerted. We are grateful and happy that Prandtl is crossing the threshold of Biblical age as an active researcher. . .

One would probably expect that Prandtl, in his seventies, would gradually hand over the duties in the profession to the younger generation in order to devote himself to tasks close to his heart or to tackle the hard problems that were left unsolved. He could have time for all those who felt the need for discussions with the most experienced expert. They would probably wish to go over with him again the thoughts that were occupying him at the time of birth of his theories, which today, bear the stamp of the reknowned name, and are used more as a catchword than with deep understanding. In spite of the keen interest of all nations engaged in aeronautics, Prandtl remained during all the decades the leading figure in further perfecting his theory postulated in 1904. Besides, he answered many questions arising in aeronautics that did not have an immediate connection with boundary layers. We wish to mention wing theory and airfoil theory at high subsonic Mach numbers, the so-called Prandtl's rule...

In addition to all this he was working on his text book that, in its revised 3rd edition, was given the title "*Fuehrer durch die Strömungslehre*" (Guide to Flow Theory). Even here, where Prandtl does not make demands of a very advanced level of knowledge on the part of the reader, he does not indulge in treading in side alleys that lead only to limited heights but charts out routes that always lead to the highest. His vividness of presentation and comparisons capture even the advanced student, just as his lectures. It was particularly so when he took a pause or strayed away when it often offered the advanced student more than the beginner. The goal he pursued was to arouse in the other a feeling for precision in the formulation of concepts and a critical attitude.

He owes his success to his conducting experiments, so to say as if it were in a play, many times in a broader framework than was necessary to answer the technical point in question. Thanks to his attentive observation and his insight feeling forward its way, a baffling phenomenon was dissected into its essential elements often in a simple experimental facility. In contrast, where conducting a tiresome experiment in small steps was unavoidable, he freed as far as possible the technical task from everything of the nature of a chance. He thus, stripped off the problem from its inessentials leaving only

the bare essentials and treated the idealized case lying close to the original technical problem which appeared amenable to a later theoretical treatment. Thus he separated the technical need from the gap in the structure of knowledge in physics, and directed his efforts more towards closing this gap than investigate case by case in the technical task. We find in his whole way of life this basic attitude of serving the whole selflessly instead of the particular individual, which might fetch better rewards. Although recognized as the expert, he remains very simple in his personal wishes. He remains true to the small university town of Göttingen, and how stimulating for ideas the leisurely walks back home in this town must have been, which is unknown in a large city with its time consuming traffic problems! He could have had the final say in appointments to chairs, but he exerted his influence only where it was asked for and where there was a fear of wrong appointments being made. This attitude has borne fruit. His research laboratory stayed alive in the worst of times, not only by its being the only one of its kind but also by the reputation earned by Prandtl and his co-workers for their selfless readiness to help."

Besides the above, on the same occasion Professor A. Betz wrote an article with the title "*Ludwig Prandtl zum 70. Geburtstag*" (dedicated to "Ludwig Prandtl on the occasion of his 70th birthday") [6] that however appeared only in April 1947 in the journal "*Forschungen und Fortschritte*". I will quote one paragraph:

"Prandtl always strives for a penetrating treatment of the problem on hand, which has almost always led to the goal of really understanding the phenomenon and trace it back to the basic physical laws. Furthermore, Prandtl has the capacity to be acknowledged unreservedly as the leader by co-workers and outsiders alike, and so chart out the route for scientific work for the whole world. Unusual clarity of thinking and selfless devotion to the task, free of all selfish thoughts, are the foundations that enabled this way of working and the big successes."

24. The end of the war

I wish to write here of an event in the family: A few months before the end of the war our daughter Agnes was born. The grandfather was extremely interested in the development of the grandchild. When he came home, he never failed to see how she was and observed her characteristic movements with loving attention. He often sat beside her with a sketching pad and drew the small head of the baby. He also kept a table to monitor the increase in her weight. The young father could take part in the happiness of the family only during a short leave from the front, and so the grandfather took over upon himself to be a little of a substitute for the father. He wrote to my sister in Munich: "Our small one gives me lot of happiness by its liveliness and intelligence and its cooperative nature".

In the meantime the last phase of the war had set in. We confined ourselves to one of the three big living rooms in order to save fuel for heating. Of course my father was not willing to do away with the piano that was in the drawing room. We therefore moved it to the office furnished as a living room. Hardly did a day pass by, without the beautiful instrument being played by him. Everyone who had heard Prandtl play once, listened to his musical ideas with rapt attention. Once, when very special harmonics blossomed from the different keys, there were words of appreciation from us. He waved aside our applause only saying: "I played it only for my dear Gertrud."

The war was coming to a close. As the front of the enemy's troops closed in, the district authorities planned the blasting of all scientific institutes. In order to prevent this, some professors who were conscious of their responsibility decided to arrange for a meeting with the *Gauleiter* Lauterbacher. An agreement had been reached between them that he should be approached in order to negotiate with him. Göttingen was in an especially critical condition for another reason. Twenty four military hospital divisions had been established there, which could not be possibly evacuated. The book "Göttingen 1945 - End of the war and new beginning (*Kriegsende und Neubeginn*)" [11] reports on this mission, of going to see the *Gauleiter*:

"On 31 March 1945, in the afternoon, Professor Plischke went with Professor Prandtl, a colleague from Königsberg, Professor Baumgarten and a Göttingen lawyer, Dr. Beyer, to Lindau near Katlenburg, where Professor Osenberg of the *Technische Hochschule Hannover* was the director of the Four-Year-Plan Institute for Fabrication Processes (*Vierjahresplaninstitut für Fertigungsverfahren*). In the morning of the next day the four gentlemen traveled with Osenberg to Rothenkirchen near Einbeck to see the *Gauleiter*, but could talk with him only at noon. They expressed their concerns about defending Göttingen and the consequences arising therefrom. Lauterbacher promised he would get in touch with the *Reichskanzlei* to pass a declaration that Göttingen, as a town of science, should be left out of the battle area."

When the men, immediately on their return, looked up the *Kreisleiter*, he had already been directed not to revoke the order to blast. The professors were stamped by him as "liberal defeatists". I remember that my father returned home very tired from this venture, being taciturn and laconic.

Through the initiative of courageous citizens and sensible civil servants of the city administration the city was handed over without a fight.

The day of 8th April, a bright Sunday, is still vivid in my memory. The latest instructions we were given, had asked us to stay in our basements, after the previous plan calling us to assemble in open air far outside the town, had been given up. The previous evening a fellow resident of our building, Frau E. Oesterheld, who had fled earlier from Berlin, came to us. She has made a note in her diary of this visit to Prandtl on the day before surrender.

7 April 1945:

"He was sitting in his office-room at home that had nothing of a home-like coziness. It was furnished soberly and office-like, with big card-board boxes on the walls. Only a big piano and a few good oil paintings lent the room some glamour. He was sitting at the table which was covered with a table-cloth made out of oil-cloth, and had just heard the news over the radio. His expressive, venerable, scholarly face was filled with sorrow and worry. I told him of the call of the Party asking women and children to assemble on the Rohns hillock at five in the morning, and asked him what he would advise. I did not get any sensible reply at all. Obviously he was strained by the events rushing in, and was totally incapable of taking a decision either for himself or others. His daughter Frau Vogel came in, and we finally decided, after some dilly-dallying, not to join the women and children leaving the town, but to stay in our air-raid basement-shelter and await the surrender."

E. Oesterfeld writes on 8 April as follows:

"Sirens announcing the alarm about the enemy sounded around noon; all the inmates of the house went into the basement. We sat there anxiously for a long time without anything happening. After all, was the town handed over without a fight? Suddenly something crashed, the building shook and the window panes came down with a rattle. The rumble still continued, the impacts could be heard clearly. Suddenly everything became quiet again. Professor Prandtl said: 'I will go up now and see how things look up there. And, if something happens to me---I am already old, I do not matter any longer', he added in modesty.

The old man then came down again. 'It looks terrible, it was good you didn't stay upstairs, otherwise all of you would have been buried underneath the rubble' he said to the family that lived in the 2nd floor. 'Obviously it was a grenade, it must have hit the gable first; there is debris on the whole staircase.'

Although, as said earlier, it had become quiet again, we were under shock and remained sitting in the basement for quite a long time. From there, through the window at the ground level we could see the never-ending chain of tanks rolling by. Had the war really

ended for us? We saw the occupation by Americans, as a fortunate lot. We mustered up courage afresh and returned to domesticity in order to prepare food.

The next day it was of supreme importance to my father to go to the Institute. What he experienced there on that and the next day is something I didn't get to know. He was very silent and introvert. He was missing, as in all these years, his companion in life to tell her what he had experienced.

Very much later, I did learn through the narrations of others that the Americans, before they occupied the Institute, got handed over to them all the scientific results that were kept secret during the war.

Then they took over the Institute completely under their power. My father was denied entry for several weeks. However, he was required there, once during the first week. He was picked up at home and was taken in an open military vehicle, guarded by six American soldiers. Neighbors who saw this, were asking with concern, where the Professor could have been taken. After the elapse of a few hours, he was brought back in the same vehicle. There is a report of Prandtl himself on this incident [5]:

"One day I was taken in a van to the *AVA* grounds by armed soldiers. The leader of the soldiers, a German-speaking Jewish officer, wanted a statement from me as to what was there on the grounds, and was at first very much disappointed on what I could tell him. He wanted to know about the prototypes of the airplane engines that we were supposed to have built in Göttingen. I had to tell him that we had only conducted studies of parts - for instance compressors - regarding the lay-out of their best shape."

But for the rest, apart from these incidents, for the first few weeks my father and I, like all families those days, had to procure food, which took much time. In order to buy bread that was allotted to us on the ration stamps, one had to start out early at six, at the hour of lifting the curfew, to queue up at the bakery, since bread was sold out shortly after eight o'clock. How often did my good father go on this errand for us both since I had to look after our baby daughter. The maid who was helping us in our household, had returned to her village even before (Göttingen's) occupation by the American troops. Carrying on our small household, required much common effort. Since neither gas nor electricity was available, and there was an urgent need for firewood, I got a first stock of wood in a wheelbarrow from the nearby woods of Hainberg. No one cared for the problems that the other person had. In all households, just as in ours, the shortage had to be met through full use of effort and time. In the courtyard we then sawed the round logs into small pieces in arduous teamwork.

Shortened hours of curfew and regular supply of food stores brought some relief already in May. In spite of it, the situation was still tense. The military government had suggested to the mayor to get loudspeakers installed in the town in order to keep the public informed of the news, and mayor Schmidt wrote in reply: "The people are very hasty and not in a position to listen with attention or read the announcements posted. Standing in the queue at stores takes several hours of the house-wife."

Professor Nikuradse turned up unexpectedly at our house and announced he would arrange for a cart-load of wood. The wood was really delivered at our door the next day. Soon thereafter, young people from *KWI (Kaiser Wilhelm Institut)* who were unemployed came and sawed the wood into pieces. The firewood stock that was piled up in our yard at that time was substantial.

It was strictly forbidden to continue research work in aerodynamics. Instead of resigning, Prandtl now started addressing meteorological problems. Meteorology had indeed been one of his special fields of interest for a long time. He used the weeks at home for working intensively. Now and then, a colleague came home to tell him where matters stood and to talk over the possibility of a new beginning.

Ministerialdirigent A. Baeumker was among these visitors. There was a long and lively talk. The guest had to make do with soup for lunch that I had boiled in the same room on the oven. Baeumker who was an airplane spotter in the First World War, and then a delegate at the disarmament conference in Geneva had a vast organizational experience. Now he was already thinking of new plans for the distant future of the Aeronautical Society (*Gesellschaft für Luftfahrt*).

In the year 1949, A. Betz and L. Prandtl wrote, from their memory, a comprehensive report on the matters of the Institute in spring 1945 [5]. Here are some excerpts:

A. Betz: "An important event was the visit of Professor v. Karman on 14 and 15 May, who came to the *AVA* with a group of esteemed research scientists. It is perhaps here that the possibility first came up for discussion, to allow the Directors and their personnel to enter the Institute premises once again. Since research work was forbidden on grounds of principle, v. Karman saw an alternative way for keeping the scientists occupied again. He suggested that they write reports on their research work during the war years in the service of the occupying power." These monographs were later translated into English.

L. Prandtl: "Visits of American experts started to be rather frequent, and I had to show and explain to them my special institute, Building no. 3. ...I requested them to mediate for us to be permitted to move about more freely within our own Institute. But matters stayed where they were, in that we had to be accompanied by armed soldiers in our Institute."

Later, I was told of a statement by Prandtl that characterizes the absurdity of the situation to which he was exposed: With a smile he spoke to the soldier who was always following him with a machine gun: "Is the soldier perhaps afraid of me?" Embarrassed, the soldier explained to him that the rules were so.

Prandtl: "The scholars and the experts came in increasing numbers, and I felt more and more like a museum attendant, who had to explain in roughly the same words, the same thing again and again (and of course according to the context told the same small jokes)."

According to the statement of a *Mitarbeiter*, one day documents were searched that a young scientist had hidden in a secret location. He (the young scientist) was rather alarmed, and had probably every reason on imagining the consequences if he would have to confess to the military power. "Regarding the documents I will take it on myself", Prandtl told him, "they won't behead me as easily as perhaps you."

Professor Betz too was called equally often for guided tours around the *Institut*, for answering questions and giving explanations.

Betz writes: "The questions asked during these guided tours often gave us an insight into matters of fact that were surprises to us. For instance, most of the Americans could not understand that we were mostly doing fundamental research. Even the big difficulties with manpower and material during the war were often unimaginable for them. The question was asked several times as to why such an important facility as the big refrigerated tunnel was not completed fast.

Some other questions indicated an ignorance of many matters known in Germany although the people asking the questions gave an impression of being capable scientists. For instance, the question came up again and again, as to why we built swept wings, and it required long and repeated explanations until the advantages of this type of wing on approaching sonic velocity were understood. Now swept wings are foisted as a big American invention."

Prandtl was very happy when the occupation authorities permitted him to enter the *Institut* premises regularly again, after being forbidden from entering for eight weeks. However he was required to obtain a permit at the hour of commencement of work, and one again at cease work. A grotesque requirement for the Director of the Institute! One day Prandtl innocently asked: "Could I also get a permit valid for the whole day, like the one our Institute's messenger gets?"

On 8 June 1945 he wrote to my sister in Munich:

"In my Institute, work has begun again on a small scale with a third of the personnel."

A few of the talented younger scientists soon found positions for work in America or England where they were offered very good openings for continuing their scientific work.

I wish to mention here one small thing. At that time, a loaf of bread was given to the employees of the Institute every week. My father liked the taste of the "Institute bread" very much; he was keen on cutting a slice of it every day which he tasted as in a church service. Of course he distributed it too. But I observed that he was very cheerful when the bread was in front of him on the dining table. It was certainly not the plentiful supply for the mouth that gave him satisfaction, it was this "Institute bread" that had a symbolic value for him. After he had been locked out for weeks, he had a feeling of tranquil pleasure that he could work again in his spiritual home, the *Strömungsinstitut*, although under more difficult conditions.

Prandtl wrote his English colleague G.I. Taylor in detail on the post-war events in his institute.

28 June 1945*:"My institute survived undamaged through the war. However, there is now a lot of damage because American soldiers were accommodated here for several weeks. Only after the beginning of June were we allowed to enter there. The Allied Committee told us what to do. We were allowed to make some repairs and to write reports for Allied Committee. We were also permitted to continue certain projects which remained unfinished during the war, and on which reports were expected. So far we have not been permitted to begin new work. Yet we hope soon to be able to investigate problems of a fundamental nature which were set aside during the war. We have enough such problems to last a decade."

On 10 October 1945¹² to Taylor:"Any continuation of our research has hitherto been prohibited by the Director of Scientific Research in London. For a research institute whose mission is to extend the knowledge of its subject as far as possible this is a very hard demand. Indeed, we see many problems that await their solutions, for instance turbulence and near-sonic flows. Problems of meteorological and oceanographic flows in which density stratification and turbulent processes both play an essential part are also among such topics."

Although the stringent measures of the military officialdom had entirely banned scientific development, and as a consequence, Prandtl's sphere of influence had been narrowed down, his international standing continued uncontested. A Chinese scientist who had worked under Prandtl on her doctor's dissertation in the beginning of the forties and had survived the war in Berlin, came to Göttingen and spent some time there shortly after the end of the war to get Prandtl's advice for further scientific work. Ms. Lu Hsin Chen then returned to China where she became a professor in aerodynamics later. Once, in retrospect on her Göttingen years, she said, that Professor Prandtl had looked after her with fatherly benevolence. The living memory she cherished of her respected master made her come to Göttingen with her husband again and pay a visit to his grave. We stood together in front of his tombstone. They bowed thrice paying respect for the dead as they do in China to revere their forefathers. In 1984 she sent me her translation of *Strömungslehre* into Chinese. She wrote in the accompanying letter:

16 November 1984

"I am taking the opportunity of a colleague of mine in my institute who is going to Göttingen to carry on scientific co-operative work in *DFVLR*, to request him to give a book to you. It is a translation of the book *Führer durch die Strömungslehre* of my highly respected teacher Professor Ludwig Prandtl. I have done the work of doing the translation in memory of the greatest teacher of fluid mechanics in the world.
Lu Schang (nee Hsin Chen)."

¹²These translations have been taken from the book G. Batchelor: "The Life and Legacy of G.I. Taylor", Cambridge University Press, 1996, page 187.

25. New beginning at the university

Efforts were already under way in July 1945, at the university, to restart teaching. Due to the denazification procedures ordered by the military government, a number of former professors were dismissed. So, only a part of university teaching staff was available for a new beginning. (From the "War Diary" of the military government of Göttingen, 8 August 1945: "None of the 60% of the dismissed university professors filed an objection.")

There were of course many other difficult problems that had to be solved, e.g.. working out rules of admission of students, re-equipping the *mensa*, measures for procuring housing for students. In the course of this an appeal was made to the population to register rooms for students in private homes, asking everyone to forego rooms that were owned but could be spared. We too, with only three of us living in our house then, registered two of the rooms that were empty as "student rooms (*Studentenbude*)" and accepted the disquiet brought in by these young people. Soon there was hardly a house in which no student was housed, at least in the attic.

On 17 September 1945 preparations had advanced sufficiently enough that Georga Augusta could open its doors to students as the first in Germany. The British Military Government had fixed the number of students as 3500, but this ceiling was soon crossed since it was decided to enable the combatants at war, who were released later, also to begin studies.

Prandtl, although seventy, gave lectures as until now. Generally the students' eagerness to learn was favorably recognized. The city had transformed itself within a few weeks, and a new spirit of freedom was perceivable in spite of the occupation forces.

In 1946 *Neue Physikalische Blätter* wrote: "With 4775 students registered in the summer-term, Georga Augusta is at the head of German universities."

Now, after the truth had come out to the full extent, Prandtl, who was deeply hurt, tried to introspect upon the happenings of the immediate past. He decided to formulate coherently in writing, the conclusions that he had come to, particularly with regard to the prospect of further scientific work. He addressed a letter to the Education Officer, Mr. Bird, to whom he wished to communicate his reflections. He called his memorandum: 'Thoughts of an unpolitical German on denazification.'

Prandtl himself had, as already related, refused outright every kind of membership of the Party, and so had no incriminatory charges against him that could come in the way of a fresh start. But he could not, as it was in his very nature, ward off feelings of sympathy for some of those who were indiscriminately sentenced only on reasons of their party membership with no political interests or activities. In his always humanitarian stand, he considered it necessary to give clarifying explanations to the occupation power on the coming into existence of the NS-State and its consequent development mechanisms.

Possibly these explanations enabled a more favorable judgment to be passed in some cases of incrimination.

In the meantime there have appeared many publications on this subject which have been keeping our (particularly Germans') thoughts increasingly occupied although 40 years have passed since then.

Below is the letter of 14 March 1946:

"Respected Mr. Bird,

Following your suggestion I have drafted a memorandum on the question of denazification that could be suited for publication in an English newspaper... Should there be some point which you wish to talk over with me I will be glad to be available to you at any time.

Respectfully yours,

Ludwig Prandtl"

"Thoughts of a nonpolitical German on denazification"

Preliminary remark

The question of future political development of Germany, and in particular that regarding the best procedure to eliminate all elements that could obstruct this development, is occupying the thoughts of many in Germany today. The author of this memorandum is a professor at a German university. He is an engineer and a physicist, and is most probably known to the English specialists of his area. He is more than 70 years old. His age and the fact that his life has been dedicated to scientific work, probably protect him from suspicion of being an extremist of any kind. Indeed he has never wanted to have anything to do with politics, but on the basis of the sources available to him, has tried to form an impression on the questions mentioned above that he would like to share.

The state of affairs in 1932

According to the Weimar constitution, the German parliament was elected through lists of the *Reich (Reichlisten)* that were presented by the individual parties. This procedure encouraged the formation of a huge number of small parties, and this was reflected in the results of the new elections. In these circumstances, a parliamentary majority could be formed always only through co-operation of parties with programs widely differing from each other. The governments so formed stood, therefore, mostly on a very weak footing, and had to work their way through permanently through some compromise or the other. It is therefore understandable that the Government (of the day) was not up to the task of dealing with the problem of as many as seven million unemployed in the ultimate stage, and a further seven million underemployed. Besides, the rural population was strongly in

debt due to forceful imposition of artificially low prices for long, coupled with high rates of taxation on its products. They were also severely oppressed by the harsh methods of collecting these taxes, which they could not resist, being still divided and so in the minority relative to the industrial and other urban population.

With this economic misery thus ruling in both cities and villages, it was not a surprise that the extreme parties---the communists on the left and the national socialists on the right---steadily gained power, with the two often in violent conflict with each other. The rural population, to whom Hitler promised deliverance from debt and protection of inherited property, followed him in large numbers. Many of the unemployed, who did not like the communists' methods, also turned towards Hitler since he promised creating employment for them. These developments headed towards a duel between the two extremist parties. Many followers of the centrist parties considered National Socialism to be the lesser of the two evils; they were afraid of a Bolshevist rule along Russian lines if the communists came to power. It was thus that it happened that Hitler could gain the support of a majority to form a government in 1933. The *Reichspräsident* Von Hindenburg, who was a man of honor, asked him (Hitler) to be the Chancellor of the *Reich*, in accordance with democratic processes; but this earned further sympathetic voters for Hitler.

The psychological situation after NSDAP's take over of power

In the beginning, Hitler exercised considerable restraint, obviously influenced by Hindenburg. Many of those who did not like Hitler's earlier ways, hoped that the numerous moderate elements that had helped Hitler to attain his majority, would have a salutary influence on the way he conducted the affairs of the State. This is how the large number of votes that Hitler gained at the plebiscite in March 1933 can be understood, whereby the political pressure, that was occasionally applied, hardly improved this number.

There was a large increase in the Party's rolls during this period. During the first few years after 1933 the Party's composition can be characterized as follows:

1. There were Party members of many years' standing, the so called "*alte Kämpfer* (the old fighters)". (There were many among these who were failures in their profession due to their own inadequacy, but there were also many idealists who had set themselves the goal of fighting against the danger of Bolshevism).
2. There were other discontented people who, partly out of a craving for recognition and partly for selfish reasons, wanted to gain influence through the Party.
3. The unemployed enrolled in the Party hoping for a betterment of their situation; and the same was true with many in the rural areas.
4. There were also many earnest men who were aware of the shortcomings of the Hitler system but believed that they could correct the damaging influence that primarily the old fighters would exert; many in this category also had the idea that Hitler should be supported in order to save Germany from Bolshevism.

Men belonging to the fourth group above could achieve something good in isolated cases, but they soon came to realize they could not exert any influence on the bigger political issues. The step of demonstrative resignation from the Party that some of the more courageous among them took, served only to teach the rest that they will only be exposing themselves to the most severe persecution and losing all further influence in the Party. Whoever believed that he should try to do something good in the small circle around him had, therefore, to stay in the Party, and accept that sometimes he had to say things that were going against to his true attitudes.

As these developments were taking place, Party authorities put increasing pressure on the people to enroll for the Party and its sub-divisions. In fact, Party membership was categorically demanded of persons aspiring for civil-service posts. Whoever who could not afford to renounce aspiration for such a career, for economic or other reasons, had to bow down, even if it ran contrary to his beliefs. It was much the same even with the timid people of the older generation. And it was not rare for private employers to exert pressure on their sub-ordinates to follow the same direction. The large number of "camp followers" that emerged thus becomes understandable.

Conclusions regarding the denazification procedure that is to be aspired

This wide spectrum constituting the Party makes it inadvisable to choose a purely formal procedure laid out schematically going by the particulars given in the Party-book or in a questionnaire. Rather, it is necessary to base judgment upon the actions of the individual and his overall influence. Of course, such a system is more cumbersome to handle, but destinies of human beings are at stake, and so the bigger effort is probably worth undertaking. The new Denazification Law in Bavaria already adopts this course. If one's own people are involved in the decision making, the danger of individuals trying to pull themselves out of the noose through lies is not very large. One knows one's people, and is in a position to distinguish between "followers" and the real *Nazis*. Every German concerned about the future of his people expects that those who have a heavy burden of blame to carry because of their doings during the past twelve years should be punished severely. In much the same vein, severe punishment should also be meted out to those who used their privileges as members of the Party or of other organizations for their own personal advantage or aggrandizement; and also to those, who inflicted much harm on some fellow human or other through slander or denunciation. But the German people also have a right to retain in their midst those precious people among the Party members that should continue their work without disruption, freed of the odium of being a *Nazi* that is still stamped on them.

I do not regard it as my task to talk about the most purposeful kind of punishment (for such people). I only wish to say that the punishment, in terms of both location and duration, will have to be graded according to the gravity of the delict or the crime. Possibly, withdrawal of the active and the passive voting right for a probation period could suffice as the mildest punishment. Through this measure, we can prevent immature or incorrigible elements from disrupting the new political advances. It would also suffice as a measure that takes into account people's feelings against the harmless followers.

Denazification in the universities

It should be understandable that for the author, it is the inner circle of his own activity that is of primary concern. Here, the *Nazi* regime has done much damage through the entry of persons totally unsuitable for the teaching and research profession into the *Hochschule*, and their arrogant assumption of power. These people, often *Dozents* who were failures in their career due to incompetence, distributed leading positions in the *NS-Dozentenbund* (National Socialist Association of *Dozents*) among themselves. They exercised considerable influence on the new 'calls' (appointments) in which they tried to accommodate more "*alte Kämpfer* (old fighters)". Apart from a few highly talented individuals, only those who were acceptable to them---through becoming a member of the Party, or was in the *SA* or some similar organization---could from then on become a *Dozent*. The *Reich's* Directorate of the *Dozentenbund* in Munich also exercised authority over the *Hochschul*-division of the Ministry for Education, which often thought more sensibly in matters regarding the choice of suitable teachers: the *Reich's* Directorate, however, could block every 'call' unacceptable to them since they were given vetoing rights by Hitler. One can thus imagine how all young aspirants, who either could not or did not want to forgo their scientific careers, had to pay their tribute to the Party in some manner, often in great mental agony. Those who were particularly timid permitted themselves to be coerced to going further than necessary and became leaders of blocks or the like, and have difficulty now in making their non-Nazi disposition believable.

The universities should demand that all those young researchers and teachers who are valuable from both human and professional points of view, and were not activists but only wished to serve the cause of the state and their science should be taken back on compassionate grounds. They should not be penalized, for they had no other way to make a scientific career than through the Party that was totally assimilated into the state.

The future of the whole rising generation of German university teachers depends upon the adoption of a policy decision in this spirit.

I can very well understand that the English, who have been used to a democratic form of government for centuries, will have much difficulty appreciating such thoughts. Only those who have lived under a dictatorship may be able to understand the present situation in Germany."

After this open admission of guilt that pointed out to the wrong conduct of the unpolitical German, Prandtl, however, suggested that judgments regarding denazification be given a second thought according to his explanatory observations. Again and again, he stood up to help a colleague to have his past rated more justly, when they were accused of complicity by the military government and sentenced accordingly.

Prandtl tried again to make the authorities of the British occupation forces understand how differently such memberships should be judged. In this spirit, for instance, he wrote on 14 April 1946 to Mr. Bird:

"It is about Professor Osenberg from the *Technische Hochschule* Hannover, who, as you would know, had developed with great success, the work of the planning office of the Reich's research advisory body (*Reichsforschungsrat*). In the course of many years of work, he got it approved, against much resistance, to have important scientists released from the front for research work in a planned manner. ...

If there is a way to free him and other professors from internment... much good would be done in a humanitarian spirit and for scientific occupation of these scholars."

I wish to quote another letter in which he stood up, speaking on behalf a colleague. On 13 January 1946 Prandtl wrote a conduct certificate in the matter of the trial court case against Professor H. Schaefer of Bad Nauheim whose past history as a member of the Party was under investigation.

"I came into personal contact with Professor Hans Schaefer in the year 1943 in my capacity as the president of the research leadership body (*Forschungsführung*), because the matter under consideration was issuing a call to Professor Schaefer to take up a position to be newly established at the Munich Aeronautical Research Centre (*Luftfahrtforschungsanstalt München*). At that time, he was suffering due to the enormous pressure exerted by the Frankfurt *Gauleiter* who had set everything moving to remove him (Professor Hans Schaefer) from Nauheim. On the occasion of a visit by Professor Schaefer to Göttingen, I myself had a longer discussion with him. He told me in detail, during this meeting, of the efforts of the *Gauleiter* to remove him from Nauheim. Extract out of my report to the research leadership body (*Forschungsführung*), 8 June 1943: Professor Schaefer is trying his best to leave Nauheim since it doesn't suit the Frankfurt *Gauleiter* that Schaefer is a Catholic who goes to church.

My personal impression of Professor Schaefer is entirely one of a serious scholar full of scientific ideas. Therefore I do not have any doubts that every word in his statement can be believed."

In his biography "Perceptions and Confessions of a Scientist" (*Erkenntnisse und Bekenntnisse eines Wissenschaftlers*), the physiologist Professor Hans Schaefer himself writes of his above mentioned visit to Prandtl at Göttingen [45]¹³:

" In spite of many trials, my attempts to tread the easy path on a different occasion, ended in a failure, of course during the war. I wish to describe one of these trials since it permits singing a song of praise of a great scholar.

In the meantime, I had made friends with Theo Benzinger. He thought that (my) being taken over in the position of a Government Medical Officer (*Regierungsmedizinalrat*) would be possible, and had paved the ways for the same. The person who finally mattered was Professor Ludwig Prandtl, the great pioneer of fluid flow research in

¹³ No translation of this book is available in English.

Göttingen. I had decided to visit him in order to promote the plan of working at the biological institute of the Aeronautical Research Centre Munich (*Luftfahrtforschungsanstalt München*) under the directorship of Benzinger that was still to be founded. During the visit, that took place on 7 June 1943, I found Prandtl rather disapproving at first. He did not understand why I wanted to go to the Air Force (*Luftwaffe*) now, didn't I read any newspaper? My hint that I was being forced by the *Gauleiter* to look for a position, and that I was rather stuck in political difficulties, changed the old and surly person into a lovable fatherly advisor. His advice: Stick it out in Bad Nauheim. It was the same advice I got from my colleague Hermann Rein too. So I saw the end of the war in Bad Nauheim. With the moving in of the American tanks in our town the most deadly nightmare of my life came to an end."

Dr. Hans Schaefer wrote on 17 November 1946:

"Respected Herr Prandtl,

I have received your certificate, issued in my case, and wish to thank you from the bottom of my heart. The letter will most certainly make an impact."

26. The first post-war years

The British occupation authority had prohibited the continuation of any research work in the individual institutes, but the Kaiser-Wilhelm-Society (*Kaiser-Wilhelm-Gesellschaft*) existed further on as an umbrella organization. In arduous discussions with individuals, its General Secretary Dr. Ernst Telschow succeeded in keeping this society continue its existence as a registered society. This far-sighted man had already transferred a part of the general administration from Berlin to the undestroyed Göttingen before the end of the war, and had thus laid the foundation for further work.

Even for Dr. Telschow, whose significance and influence in the years following simply cannot be overstated, Prandtl could influence the authorities to issue a "no suspicions" certificate (letter of 7 June 1946 to the occupation authorities).

Dr. Telschow conducted transactions with the military authorities in Hannover and orally reported to them on his visits to the different institutes that were in the other zones, the American, the French and the Russian.

However, a clear directive, defining the purpose, was still absent. When Max Planck came to Göttingen as a refugee seeking shelter with relatives in Göttingen, it was an obvious thought to suggest to him to champion the cause of the research society continuing to exist. It was known that Planck was held in high esteem by the victors, due to his unassailable clear stand against Hitler. He was requested by a committee to take up again the presidency of the society in spite of his advanced age (87 years). Later the society was to be named after him as Max-Planck-Society (*Max-Planck-Gesellschaft*). Planck agreed and was ready to dedicate himself to the task of rebuilding this society. Thus the responsibility for the many German research institutes was lying again in one hand.

In April 1946, when Prof. Otto Hahn was released from imprisonment and came back to Göttingen, he could relieve Planck through assisting with the difficult administrative matters. Hahn was then elected to the office of the new President.

The fluid flow research institute could be run further in this way, but not the *AVA, die Aerodynamische Versuchsanstalt*. It was denuded of all its equipment---the wind-tunnels were partly destroyed, partly dismantled and shipped off to England. However I cannot remember my father telling me of this. It must have been very painful for him to witness the experimental facilities that were a product of years of planning being converted into wreckage, his life's work being destroyed through demolition. He did not live to see a generous plan bringing new wind tunnels back to the laboratory halls. Sometimes my father described himself as a stoic; subscribing to the philosophy of a basic ethical attitude that teaches not to let emotions rule.

In the scientific arena, as a whole, there were on the other hand new beginnings. It was possible to accommodate other institutes in the empty buildings of *AVA*. W. Heisenberg had moved his Kaiser-Wilhelm-Institute for Physics there and shared the space with C.F.

von Weizäcker and K. Wirtz, who in turn built up their own departments. It was therefore not a surprise that the first Physicists' conference after the end of the war took place on 4 October 1946 in Göttingen. Although the number of participants had to be restricted due to catering difficulties, around 80 physicists had gathered together for the conference. One was happy that the pleasant custom of exchange of scientific ideas could be revived again, regardless of the poor state of goods supply.

Prandtl's interests were now consciously directed towards politics. Against the background of the lapses in the past, he felt it a duty to reflect independently on political happenings and draw consequences from them. After the political parties had established themselves afresh in 1946, he became a member of FDP (Free Democratic Party).

On the domestic side, at home in Calsowstrasse, things brightened up a little for us when my sister returned to join us in Göttingen in the autumn of 1945. She had lost everything in Munich during a bomb attack, and we were happy to see her again in good health. She herself was happy to be with her family again, put herself entirely at our service for running our household, and she was very keen to look after the aging father at the best possible. It took a lot of time those days to procure enough food for a family. For the little that was available on ration stamps, one stood in a queue, and that, too, in different shops. In autumn, we collected beechnuts to extract oil, and gleaned potatoes from harvested fields, since the main food: potatoes, was never available in sufficient quantities. Sometimes we were fortunate to obtain precious food in exchange. With all hands pulling together, it was easier to cope up with everything.

Even my cousin Hermann Föppl, who wanted to study in Göttingen after being discharged from captivity, could be accommodated with us. He remembers the evenings when he sat with his uncle at the big kitchen table and how he (his uncle) sat late into the night going through his work. Consumption of electrical power had been rationed in such a way that power was cut off at ten at night. But in the kitchen we had, besides the electrical power connection, an old fashioned gas lamp. The rays of light passing from our kitchen over to the other houses shrouded in darkness might have surprised some citizens of Göttingen.

Then, in April 1946, my husband, too, was discharged from American captivity. He had remained in good health; there was enough food with the Americans. Our small daughter, then one-and-a-half years old, made friends quickly with the young father.

Now we all lived, though under somewhat restricted conditions, in the same apartment. But things could be arranged in such a way that our father kept two rooms for himself. Shortage of space to live in was general in Göttingen so that everyone had to get used to doing with less space for living.

The meager food with which all of us fed ourselves for good, was always less than sufficient for a whole family. We still remember the piteous mealtime when nothing but a few boiled potatoes could be brought on the table. In order to roast it, we poured a little cod-liver oil into the frying pan. The product of our art of cooking did not agree with any

of us. So one can imagine our bright cheer on receiving on the next day from Professor Courant from America a Care parcel with its rich contents on which we could run the household for a long time.

Later, a few other colleagues living in America also thought of their teacher and friend Prandtl. So almost every month, we received one such precious packet from overseas. With these we had been generously favored, and the anxious question as to whether we would perhaps be without stocks the next day, never came up again.

Our father took part happily in our family life. The son-in-law who used to bring in themes on human problems in conversations, exercised a stimulating influence on the traditionally scientific atmosphere of our house. There were then talks of a more general nature. Occasionally, my husband noted down what appeared significant to him.

One day he asked his father-in-law in a manner that was easygoing to a certain extent, whether he (Prandtl) understood the Theory of Relativity that he (the son-in-law), a philologist, knew so only by name. Our father replied, with a little smile "Yes, really---it appealed to me straightaway so that I also became a relativist. On my reading Einstein's first article, right at the outset I had the feeling, in fact the conviction, that this was correct."

The reply was characteristic of Prandtl's forbearing attitude and helpful attention, even towards one not very knowledgeable in science. He took the other seriously enough to convey his appreciation through a tangible reply. This attitude of always paying respect to the other becomes clear in a basic statement of policy to the authors, which he worded as follows: "The reader must be treated obligingly in order that the sections, difficult to understand, are bearable."

My husband has often heard the father-in-law "preluding" on the piano, as he (Prandtl) called it himself. One day, when he asked him whether his music was, for him, an occupation with higher mathematics in a certain sense, a sublime game with proportions and ratios of numbers, Prandtl replied: "No, nothing of the kind, most certainly not, but I play guided only by my feelings. However, when an unexpected chord happens to be struck, or an unintended harmony, I am inclined to follow that direction consciously." Basically, it is all dependent on moods. According to his own statement, he succeeded best in improvising when there was a particular occasion, such as on days of commemoration or bidding farewell. (In fact I can very well remember that he delighted us touchingly with his music on family festivities: birthdays and days of baptizing, again and again compositions of surprising mastership.)

In the course of a general conversation on outwardly success, he said he had been specially favored in that "what was close to my heart also happened to be of interest during the times. One should after all profit by what one has, to the best possible. For the rest, I have my professional ethics that makes me strive for leaving behind a work as complete as possible and to attracting a class of pupils who would continue this work." It is proper to include at this juncture what he said about himself when my husband related

to him once that an English professional colleague described him as "a marvelous sort of man". "He was surprised that someone, whose scientific success is the subject of talk of so many kinds of people, appears to be not proud of it at all. I think, I can say of myself that in spite of so many honors over all the years I am not conceited. " But, after a small pause he added, in a conscientious self-searching way, as it were, "But when I say that I am already demonstrating that I am after all conceited. I am indeed proud of what I have achieved, but I never make use of it." On a different occasion, he expressed his opinion on his attitude in situations of conflict: "Apparently the human being has often to sacrifice something when suppressing temperamental outbursts. I am very fortunate in that I am very slow in such thoughts. By the time I have a grasp of the whole situation everything has calmed down so far that I accept it calmly."

This composure was for him the essence of an appropriate fundamental attitude. To the question as to what enabled him to withstand painful things, he replied again: "Composure!" He said he underwent a very difficult time after an operation. Sleeplessness and inner unrest had tortured him. He said he then told himself: "I must regain this composure." Whether he feels bound by the stoic ideal? "Yes, stoic teaching has always appealed to me- not only not to expect anything at the time of death, but also in life. I do not believe in immortality, but I do believe that one has to lead a morally righteous life. If there is no cause to blame oneself, then this composure becomes a part of the person. One should have sympathy for and be good to the other. One should help, but do not expect anything, on the whole in a certain sense a stoic moral." In reply to the question if his humanitarian upbringing had prepared him to acquire this attitude, he said: "Yes, it is quite possible. But it needs a certain strength to make this attitude one's own." This strength is perceivable in his detached attitude towards death. In the context of a conversation on the question of life after death, he said: "I do not expect anything for myself (*Ich erwarte mir nichts*). I know that one day my heart will cease to beat and my breath stops. I have had enough time to get used to this and accept it." Through his occupation with the sciences he said he had gradually moved away from the Catholic teaching in which the thought of immortality connects itself with the thought of God. Finally, on the thought of Genesis, he replied: "A Creator of the worlds? Well, how should I imagine that? I do not formulate that for myself, neither do I feel a need for such a formulation." In this spirit he subscribed expressively to Goethe's words: "The most beautiful fortune of the thinking human being is to have researched into what is researchable and quietly to worship the unresearchable."

In the course of a conversation on the last war, the very earnest foundation of his philosophy of life became clear, as also his strength to stare into the eyes of recognizable truth relentlessly. "It is an old wise saying: The world is after all a valley of wretchedness." My husband adds here from his own philosophy of life: "It stands for Ludwig Prandtl's deep humanitarian nature that together with the tough decisiveness of such a consequent realism regarding *conditio humana*, he was all the same very soft to fellow human beings, full of consideration and kindness."

In the winter-semester of 1946 Prandtl was made an emeritus. After that, at the age of almost 72, he retired as the Director of the Institute, with Professor Betz succeeding him.

However, it was considered necessary to create three divisions since the area that had grown to be so vast in the meantime could not be handled by one single person. One division was further on guided by Prandtl. Professor Tollmien who was called to succeed Prandtl to the chair at the university, and Professor Betz were each responsible for one division. Thus good co-operative work of this extraordinary team was assured.

Since Prandtl was now freed from a few duties, he could accept an invitation to go to Switzerland in March 1947. Thanks to the initiative of Professor Ackeret in Zürich, the conditions necessary to realize the plan of undertaking this journey had been met.

Ackeret wrote to Prandtl on 30 January 1947:

'Now I must actually write you once specifically about my efforts up so far, to enable you and one of your daughters to spend a restful holiday in Switzerland.

Now, since the main problems of financing and permission by the Allies are settled, there should not be any hurdles, in principle. In response to my inquiry, the three companies, viz.

Brown Boveri Cie, Baden
Escher Wyss Maschinenfabriken
Gebrüder Sulzer, Winterthur

have expressed their willingness to shoulder gladly, the costs for a stay of about six weeks for two persons. I wish to know now what special wishes you may have regarding this stay."

What it meant in 1947 to have, all of a sudden, the prospect of traveling to Switzerland is something that can hardly be conveyed today. With the total shortage of goods of every kind prevalent, one struggled relentlessly for the most elementary things, to maintain what was extant. In our imagination we could now picture the possibility of our living in a country that was spared from the ravages of war. In early March, my father could start on the journey and I was permitted to accompany him. Trains didn't run daily during these post-war days, but only thrice a week. Finally, after many hours of journey and an overnight stop in a bunker in Freiburg which had been improvised as a lodging, we reached the station at the border, Weil, where we were picked up. Some formalities had to be attended to after which we boarded a train to Zürich. There we were sitting in our worn out overcoats in a comfortable express train amidst Swiss who, in contrast to us, were well clothed, bore an air of their natural self-assurance that we lacked, of course. A few young people, returning after skiing, with red cheeks and sun-tanned, joked in a merry conversation. The war years that had been forced on us and the general depression with the plight following it, had moved all thoughts on such pleasures of sport into a distance, far out of reach for us.

In Zürich we were very generously given a chance to improve the looks of our clothing. We were put up in a very beautiful hotel. We thus enjoyed the extraordinary paradise-like condition of being guests in unscathed Switzerland.

Professor Ackeret and his wife took attentive care of my father. Of course there was a visit to his *Institut für Aerodynamik* on the program; there followed a visit to the works of *Gebrüder Sulzer* in Winterthur and one to the workshops and laboratories of the plant *Escher Wyss*. There was also a personal appointment made with Dr. H. Gygi whose chauffeur brought us to his well kept private home in Wildegg where we spent a very pleasant Sunday with his family. Herr Ing. Gygi, director of *Maschinenfabrik Escher Wyss* was very much interested in discussing technical problems with my father. I noticed, although being not able to follow the exchange of thoughts in content, how Dr. Gygi thankfully acknowledged and agreed with the solutions suggested by my father.

I wish to mention here that I was very happy at that time to again meet my friend Lilli Misch in Zürich who had migrated to Switzerland during the Hitler-dictatorship and could study medicine there. She and her husband, Dr. Walter Baum, invited me and my father to an unforgettable evening at the theatre in the *Zürich Schauspielhaus*: "*Der Tod in Apfelbaum* (Death in the Apple Tree)" by P. Osborne was performed, with Albert Bassermann in the leading role.

At the (*Eidgenössische*) *Technische Hochschule*, my father gave a lecture on turbulence in a colloquium. On 15 March, we traveled onward to Ascona on the lake *Lago Maggiore* for a longer stay. These three weeks there were really restful for my father. We took walks every day, regardless of the weather which was not very friendly. The view over the lake in dull weather was charming again and again. On the return journey, in the beginning of April, there were several items on the program that my father was keen on doing. His interest in new projects and new publications in science had not decreased with age.

In Weil am Rhein, he visited the scientists' group of Professors Schardin and Sauer, who were engaged in building up a laboratory in the *Elsass* (in French: *Alsace*) region. From there, he traveled to Karlsruhe for a meeting in applied mathematics and physics, listened to the majority of the numerous lectures, and didn't leave the discussions that followed. After returning to Göttingen he himself noted: "It was stimulating for me, but also strenuous; and I have wasted a good part of my recovery again, but I still do not repent having taken part in this meeting."

On 3 July 1947, Professor Courant, coming from USA, visited the familiar old Göttingen. In his diary he made a note: "Arrived in Göttingen at seven-thirty in a bit of a melancholic mood. Outwardly, the town hardly shows any signs of destruction. According to Karman, the town was explicitly excluded from the allied bombing raids." His diary entry regarding Prandtl: "The *Institut für Aerodynamik* has been turned into a real fortress. Prandtl was sick and depressed, but still mentally very active. He had been studying analog computers extensively, particularly for carrying out meteorological

computations. The dimensions of the machine he designed were determined by the size of the ball bearing that he had found accidentally in war surplus goods."

For the summer holidays, my father was invited to Ammerland by his brother-in-law, Ludwig Föppl. This meant a rest in familiar surroundings, and, when needed, an opportunity for exchange of scientific thoughts. In the beginning of July our second daughter Susanne was born, and so naturally we stayed back in Göttingen.

Possibly it was during these holidays that Prandtl wrote this small article [36]:

"On mammatus clouds:

I have observed this form of clouds quite often on my occasional holiday trips on the Bavarian plateau. I concluded rather soon from the experiences of the related weather, that a threatening mass of cloud in which mammatus clouds are present, takes on a pronouncedly harmless further course. Later, in an elongated mountain valley that stretches itself in the north-eastern direction from the south-west end of the valley, I have observed there especially beautiful mammatus cloud formations out of a larger cloud when the flow was towards south-west, and which moved rapidly down the valley. From the overall form of the motion that had a certain similarity with the form of the motion that appears in a liquid heated from below, it was entirely clear to me that there is an instability present. It did not need much of further thinking to find out that obviously the mass of air with clouds should be lying over a clear mass of air. The instability is created by a downdraught within which the cloudy mass of air gets heated up more slowly than the clear mass of air. The fact that the flow was directed down the valley also provided, in this case, the explanation for the sinking as such."

These beginning lines of this article should suffice to gain an insight into how Prandtl was stimulated to think in specific scientific terms through observations of a phenomenon in nature.

In the meantime, new technically trained people were again recruited, and everyone, who was taken on, regarded it as fortunate to have found employment there.

When Frau von Stutterheim related to me how she started working as a technical assistant with Dr. Reichardt, she spoke with a deeply felt sympathy of "the sympathetic old Professor Prandtl" who came often to Dr. Reichardt's office. She had to undergo surgery of the foot soon after beginning to work at her new job, and for a considerable length of time could only walk with difficulty to her place of work. Prof. Prandtl, she said, showed very much sympathy for her painful disability. He tried to cheer her up daily. Once, he told her that he often counted his steps from home to the institute in order to ascertain if the number of steps increased after some time had elapsed. Obviously he wanted to monitor in this way, the aging that he accepted in advance.

There are similar thoughts that he expressed in a letter to Dr. A. Baeumker, given below.

“To Dr. A. Baeumker, Fairfield, USA, 14 February 1949

I have still a long way to go, working on my book, before it comes to an end. I may remark, in this context, that I am getting to feel my age in various respects. But there are still ideas in plenty so that for a long time to come, I cannot think of writing my memoirs. It is something my daughters would very much like to have. Herr Sommerfeld is now over 80 and is writing a new book again. When I am that old, hopefully I will be able to write down my memoirs, and, if that doesn't turn out to be so, that is nothing much to be pitied. Since, I see it myself in the young generation, that what interested us at our time is no longer of interest to the younger people. Only when something existed long ago does it start getting interesting."

Excerpt from the letter of 1 June 1949:

"Unfortunately, I have not understood much of your political discussion. Obviously I am very poorly informed on matters political and can understand arguments relating to this only when the matter concerned is told in clear and direct words. I would also like to say that it is indeed quite interesting that my petition to Göring, in which I complained about the loathsome behavior of some national-socialist (NAZI-) German physicists has been read in Wrightfield."

Prandtl was now working, as has already been said, exclusively on meteorological problems. He worked together with the meteorologist Dr. E. Kleinschmidt. His thoughts and results appeared in a special issue in 1949 that was published by the *Akademie der Wissenschaften* (Academy of Sciences). The introduction that is understandable to the general reader is reproduced in the following. In the meantime, knowledge on this subject has grown so stupendously that it appears rewarding to consciously recall the beginnings of this scientific approach through the said introductory passage.

Weather phenomena in the upper troposphere (presented at the meeting of 17 June 1949) [39]:

"Forecast of bad weather regions (barometric low-pressure regions) along the Atlantic coast of Europe was formerly a very difficult task, since these low-pressure regions moved at a considerable speed from the sea to the land - apart from the main maritime routes from where wireless messages come - and therefore could not be observed well in time before arriving on land. The introduction of radio-probes, that transmit to the terrestrial stations a report on the weather conditions prevailing well into the stratosphere, and, with double exposure also furnish data on the strength and direction of winds in the upper regions, has enabled considerable progress to be made here. It has been discovered that in the high troposphere there exists even in the lower stratosphere layers, a characteristic wind system with wind velocities up to over 100 m/s that travels ahead of the low pressure region. This announces the arrival of the low pressure region, so to say, whereby the wind velocity also indicates the strength of the low pressure region.

Here, let a basic thought be mentioned that provides the requirement for the real calculation, viz. that the air masses on the rotating earth drift along with the rotating atmosphere."

The co-operation with the meteorologist, Dr. E. Kleinschmidt, led Prandtl to new unsolved problems, which he addressed with verve and for which he found some characteristic solutions. Thanks to his richness in creative ideas, even in the subject of meteorology, he could present significant results for publication.

At the Physicists' meeting on 6 September 1948, at which Prandtl was elected as an Honorary Member of the German Physical Society (*Deutsche Physikalische Gesellschaft*) in the British Zone, he gave a small lecture on his way of working. Later, he was willing to put down on paper the thoughts he had expressed in the lecture, without the help of written notes, in order to make the same accessible to a larger circle [31].

"I will gladly accede to the wish of Herr B., since up to now, I have refrained from comments upon the methods that have often enabled me to pursue new ways in my problems. Especially since I believe I could give, in particular to the young colleagues, useful hints through such remarks.

Herr Heisenberg, in his kind remarks of appreciation of myself, said that I have the capability of "seeing" the solutions of equations without going through the calculations. I must reply that I do not have this capability, but I strive to form in my mind a thorough visual intuition (*Anschauung*) of the "things" governing the problem on hand and to gain an understanding of the phenomena. The equations come only later when I believe to have understood the thing; they serve to get quantitative statements that cannot of course be obtained by *Anschauung* alone. On the other hand, the equations are a good means of proving my conclusions that others are ready to accept."

Professor F. Schulz-Grunow, a former pupil of Prandtl, talked about this special starting point in Prandtl's scientific thinking when he gave a lecture on the subject "The intellectual Heritage of Ludwig Prandtl" (*Das geistige Erbe Ludwig Prandtls*) in October 1980 [46]:

"Prandtl first strove to understand the phenomena through *Anschauung* and gain a feel for the differential equations. In the process of such feeling his way through, he found a number of influences superposed on each other. He extracted the ones that matter, freed himself of the inessentials, and saw that these were the ones that stood in the way of a mathematical solution. A wonderful arrangement of nature was exposed to view. Prandtl explains in his own words: Through a systematic simplification of the *ansatz*, that can be taken to different levels depending on the problem posed, a certain agility of the method can be achieved. This turns out to be advantageous over the rigorous, but also rigid method of the exact theory. Thus he created a new eminently successful dimension of thinking."

We return again to Prandtl's own speech:

"The way of *Anschauung* mentioned earlier can indeed be learned, as I could see in several pupils.

In the old fashioned mathematics lessons that I went through around 1890 at high-school, there were no functions, but only concrete individual examples. Therefore, in the first semester of study (at a university) it was a real eye-opening experience for me that there are "variables" and "functions" of a variable. With a real craving, I plotted the different functions $y=x^n$ for positive and negative n on chequered paper at that time. . . In examples of mechanics I gradually got used to 'seeing' the forces and accelerations in the equations, or feeling with muscular sense, just as the stresses within the bodies under load and so on...

Streamlines in two-dimensional flow could be regarded as lines of constant height of a 'stream function', and through this a spatial model of this function could be visualized. So there were various ways of making sketches of the solution sought. Such 'playing around' led me, among other things, to the nice relation between shear stress distributions and soap filaments.

Regarding the special tasks that I worked on, I got the idea from published works that evoked a contradiction; but my failures, too, have made me reflect intensively."

Let the example that follows illustrate this point: "Shortly after 1900 hr. I came across several publications in which it was asserted that the exit velocity in a pressure driven jet cannot exceed the speed of sound, although the energy is sufficient for reaching higher velocities... The matter could be put into place easily. Euler's equations, together with the continuity equation for a compressible medium, yield stationary waves with supersonic speeds [34]..."

Still in the same month of September 1948, from 22nd to 24th, the first scientific meeting of the Society for Applied Mathematics and Mechanics (*Gesellschaft für Angewandte Mathematik und Mechanik, GAMM*) in the British Zone was held in Göttingen. Prandtl, who was the first chairman of GAMM since its founding in 1922, had successfully negotiated with the Occupation authorities for grant of permission for re-registration of the society. The British Scientific Adviser Dr. R. Frazer was interested. Prandtl had set one lecture by himself on the program: "Generation of circulation by shaking of vessels". He was also responsible for the course of the meeting. In this spirit he encouraged a young participant, Julius Rotta 1), to present a talk on a theme of his own. It was his first lecture in public. One afternoon was planned for a walk of the party to Nikolausberg (a hill on the outskirts of Göttingen) where an informal round of talks was held over coffee and cakes. The above mentioned participant (Julius Rotta)¹⁴ told me that the seventy three year old Prandtl was engaged in lively conversations with the conference guests. Thereafter on the way back home, he led the group in vigorous strides to the most beautiful viewing points.

¹⁴ Dr. Julius Christian Rotta is the author of the book: "*Die Aerodynamische Versuchsanstalt - ein Werk Ludwigs Prandtls, Ihre Geschichte von den Anfängen bis 1925*" [43].

Even as an emeritus, Prandtl still kept the rhythm at work that he was used to. Besides working on meteorological problems, he had undertaken to publish a new edition of his book *Strömungslehre* to bring his text book up to the current stand.

He also participated in university matters that were discussed in meetings of the *Akademie*. He also gave an address at the university celebrations held on 7 May 1949 on the occasion of the hundredth birthday of the Göttingen scholar Felix Klein [26]. I will quote from this address:

"It might have been granted to me, as one of the 'younger people' to whom Felix Klein became a destiny at that time, to talk from my memory about the experiences under his leadership. It was the time when the gigantic undertaking of the Encyclopedia in Mathematics (*mathematische Enzyklopädie*) was launched under the leadership of Klein. The fact that this work could be brought to a good finish really in accordance with his original plans, goes to the credit of Klein alone who, through the inspiring influence of his powerful, in fact kingly, personality, was in a position to spur the willing and the unwilling on to amazing performances."

Perhaps the liberty can be taken here to quote from a letter of Prandtl written on 8 March 1949 to Professor Dr. A. Sommerfeld. It is about what a friend of Klein, Carl von Linde, who became very well known for industrial liquefaction of air, had advised him at that time when funds for starting an institute for technical physics were required, and following that, for the project of a model laboratory (*Modellversuchsanstalt*): "If you, Herr Klein, want to collect funds from industrialists, you will not scrap much together. Something like this should be done in such a way that the richest of the industrialists is won over for the cause first, and then one leaves him to do the fund collection. ..."

Von Linde then introduced him to the commercial director of the company *Elberfelder Farbenwerke*, Henry Böttinger who was himself very keen on establishing close contact with scientific circles. Thanks to his interest in Klein's ideas and his selfless personal dedication for the big purpose, sufficient funds could finally be raised for technological research to be brought to the university. Thus, undoubtedly, he had a decisive share of influence in realizing these new projects. Owing to *Ministerialdirektor* Althoff in Berlin who worked in close co-operation with Klein, hereditary nobility was conferred upon Böttinger and he was given a seat in the Prussian Hall.

1950 was the year of several jubilees, all concerned with Prandtl himself. He celebrated his 75th birthday, the golden jubilee of his doctorate, 50 years of his membership of *Verein Deutscher Ingenieure* (German Engineering Society), and in July 25 years of the history of the Institute, starting from *Strömungsforschungsinstitut* (the Flow Research Institute) until the present post-war period.

Professor Tollmien wrote an article in the journal "*Forschungen und Fortschritte*" ("Research and Development") on the occasion of Prandtl's 75th birthday [49]. His career is known to the reader, so I wish to quote here only the first and the last paragraphs from

this article. Tollmien begins his article as follows: "Epochs in the life history of a great man do not keep in step with the number of years reaching a nice round figure. Such predominant data are a reminder to the contemporaries to make sure what the merits of the celebrated are and preserve the achievements." He closes the article with the following words: "This brief survey of the work of Prandtl up to now should not obscure his significant influence as a scientific educator. As the Göttingen institutes were built up and expanded, a large number of *Mitarbeiter* joined the many doctoral candidates who did their doctoral work with Prandtl in the course of years, and they benefited by his stimulating suggestions in personal contacts. After becoming an emeritus in the year 1946, Prandtl, of course, stopped giving regular lectures, but he is actively engaged in discussions in the colloquium over questions in applied mathematics and mechanics with the richness of his superior knowledge and the temperament so characteristic of himself. In the *Max-Planck-Institut für Strömungsforschung* Prandtl supervises research work as the head of his own division. His publications of the last few years of which only a few can be mentioned here go to show, not least, that Prandtl need not put on the robe of a 'historic figure', but he is in the middle of a blessed, highly attractive creative old age.

May we all, Prandtl's pupils and friends, and colleagues in all the world, have the fortune to see the man worthy of reverence live and work in our midst for long."

He also received many congratulatory best wishes from his past pupils from foreign countries too.

27. The last years of life

In order to write about his last years of life, primarily on his activities and reflections of several kinds, I have relied upon his correspondence during this time. But I will restrict myself to writing only on such matters that refer to something entirely personal.

In his correspondence with earlier co-workers (*Mitarbeiter*) who had now found a new sphere of activity in England, America, even Russia, the amicable relationship of mutual trust that existed between Prandtl and his earlier pupils becomes clear again.

In his letter of 1 March 1950, Prandtl replies to the circular of Herr Professor Bock in Moscow which had reached him. Professor G. Bock who was holding a leading position in the laboratory *Versuchsanstalt Adlerhof* in Berlin since 1936, was taken prisoner at the end of the war and brought to the USSR. After a very tough time in Lubyanka-prison he was permitted to do scientific work in the Aero-Hydrodynamic Central Institute in Moscow. He suffered a great deal from the separation from his family.

From Prandtl's reply:

"The circular gives a reasonably vivid picture of the kind of life you are leading there. Unfortunately, it also says that you have become lonely by a working group going away. Should this not change that soon, you will be conscious of your wife and children living and of your taking care of the latter.

As far as I am concerned, I lost my wife almost 10 years ago, and although I have two daughters, one of whom is childless and a war widow, the other with two daughters of 5 and 2 1/2 years and a lively young husband, this is no substitute for the wife with whom I could share everything, my joy and my sorrow, for 31 years, and whom I have missed very much since then. The saying that you quote in your letter, 'Getting used is given to us from above. It is a substitute for happiness' (*Gewohnheit ist uns von oben gegeben. Sie ist Ersatz fuer das Glueck*), applies to me too. Under the present circumstances in Germany at present, where apartments are doubly occupied, due to destruction of housing and Germans being driven out of the eastern countries, my daughters are living with me and running the household. But that happiness was otherwise.

With the state of my health, I am quite contented, as far as one can demand of a 75 year old.

The direction of work at the institute needed of course to be changed considerably from that of earlier times, and this is not yet completed. I myself still put in what I can, and I have changed to working in my pet subject, which it was earlier too, viz. dynamic meteorology. The science of meteorology is making big strides of progress, especially in America, but also in Norway, Sweden and England, and appears to want to catch up with what has been lost up to now. Partly, it is also new research equipment like radar with which wind velocities can be followed in measurements even in high altitudes. Much is

known now about the atmosphere up to a height of 20 km so that it pays to follow the processes dynamically.

With this, I have embraced again in my old age a young science in which it is really a pleasure to pursue things not researched hitherto. If this aspect of my work is looked at, perhaps I am very fortunate again in matters of science!"

Even in a letter of reply that is really formal, he valued a very personal response:

16 December 1949: To The Indian Mathematical Society, Madras:

"The Indian Mathematical Society has been so kind as to inform me that it is holding its annual meeting from 26 through 29 December this year at the University in Madras. In your invitation, you call me 'an eminent mathematician'. I can make no claims for this description of myself. I am an engineer. If you want that way, a theoretician in engineering subjects, and I have used mathematics in the different cases of problems that I have addressed. But I have never furthered the science of mathematics through any contribution. I thank you very much for your good intentions and wish your meeting all success."

Our third daughter Ruth was born in April 1950, and, of course the grandfather was happy to see the small grandchild growing up in his home again. But since then, I had even less time to spend an evening chatting with Father. But my sister looked after his welfare.

On the occasion of the Silver Jubilee of the *Kaiser-Wilhelm-Institut für Strömungsforschung* (Kaiser Wilhelm Institute for fluid flow research) that was now known as *Max-Planck-Institut*, a celebration was held in Göttingen on 15 July 1950 which was attended for the first time, after the war, by many earlier co-workers (*Mitarbeiter*) and pupils of Prandtl from home and abroad; it was also the last time when he could gather together around him his older *Mitarbeiter* in larger numbers.

In late autumn, on 19 November 1950, a Saturday---it was my sister's birthday. As usual, he took a walk through the woods. When, while bending down to pick up an ivy creeper, he was suddenly hit by a stroke of the brain. He wanted to bring this unpretentious ornament from the now monotonous autumn woods for decorating the table.

His own report on the incident is as follows: "I did note something in my head, but with the obstinacy that is mine I continued plucking." He came home limping. The doctor, whom we immediately fetched diagnosed a paralysis of the leg and the arm, and prescribed absolute rest for him at home. For several weeks he remained our patient, sitting very patiently during the day in a broad reclining chair. But it is sad that his work at the institute had to be left lying unfinished. Visits from people who knew well how to entertain him and who kept him informed of the Institute affairs were stimulating and they cheered him up. There is a letter dated 27 November to Herr Dr. Rotta that indicates he was thinking of technical problems in spite of his weak physical state:

"I have received a paper of S...for assessment...I have gone through the same from beginning to end. When you have familiarized yourself with the contents and value of Szablewski's work I would be happy if you would visit me in my sickroom."

He could finally attend to some correspondence that had been left lying. There was one matter of special urgency among them.

In a letter of 29 November 1950, Prandtl wrote to the Chair of the Catholic Church declaring his intention to quit the Church. In this year Pope Pius XII had raised Mary's Ascent to the Heavens to the level of a formal dogma.

"Delayed by pressure of work and finally by illness, I wish to declare herewith that I am quitting the Church.

I learned from the newspapers that the mortal remains of the Mother Mary had been transposed to the Heavens. This, as a fact of matter, is unimaginable for a person educated in the sciences, and consequentially, cannot be prescribed as an article of faith to someone who is pursuing the sciences with all seriousness. I wish to make the remark that I distanced myself inwardly from the Church already in 1905 when it concerned the anti-modernism vow.

Outwardly, however, I have kept my faith in the Church, since I have many precious memories of youth that have kept me tied to the same. Whereas, at that time it was gagging against the freedom of thought of Catholic priests, now it concerns my own attitude.

I would be a dishonest person in my own eyes if, through my retaining membership of the Catholic community, I would give my formal assent to the new doctrine which would probably harm the Church much more.

It cannot stand the test of time if the Church continuously ignores the ideas of science..."

Visitors in the sickroom were, as already said, always very welcome. Once the painter Wolfgang Willrich paid a visit. When my father learned from him in the course of the conversation that he plays the piano and had the habit of improvising freely at the instrument, he requested him to open the piano and play. The powerful and pleasant sound of a musical creation of one's own soon filled the sickroom. My father was much moved. I saw tears of emotion in his eyes. This way of making music in its naturalness made him very happy. And the thought that since a few days he was not in a position to form a musical inspiration on the piano himself, might have made him painfully conscious of his state.

How happy he always was to express his inside world through music. He thanked the guest profusely for playing, praised the talent of the guest who had so well succeeded in developing a charming musical theme, and contrasted his present failure.

Herr Willrichs words of encouragement that he (Prandtl) should not give up hopes of betterment, however, sounded comforting. In fact, in the course of days of patient waiting for betterment, there was some improvement. The paralysis receded gradually. As soon as he could, he went to the Institute. In the beginning, he was picked up in a service car of AVA, but soon he chose to be independent and started walking to the institute as ever before. He was impelled to make progress at the work on the new edition of (his book on) fluid flows. However, his energy for work had noticeably declined, and he got tired much faster than before.

On 7 January 1951 he wrote to Professor Grammel:

"The paralysis of my left leg has, in the meantime, receded quite substantially. I still limp a bit, but I have started again to take short walks on Göttingen's Hainberg."

On 19 January 1951 to Professor Busemann:

"In the meantime I am going through the material for a new edition of my book and attending to what is new that has happened in the world."

On 2 March 1951 to Professor Grammel:

"I note with certain sadness that one is not allowed to get 76 years old unpunished, and regarding retirement, it has to be put off for later times."

14 June 1951 to Professor G. Bock:

"The reason for my replying only today is mainly that, of late, I have to work rather hard to prepare the new edition of *Strömungslehre* (Essentials of Fluid Dynamics). The pace with which fluid dynamics is developing further, primarily through American publications, has become so vehement that one cannot even think of giving an overview of all the individual branches. My energy at work dwindles rather rapidly, and, in particular, I am not at all in a position to really keep track of the current literature on the subject. If I had foreseen this, I would probably have set my goals at a more modest level. Since, from a 'guide' that this book aims to be, at the end of the day one expects that all that is important should be mentioned. Already now, I take much help from my earlier pupils, otherwise it would be a hopeless task. It is really a blessing for me that I do not understand Russian, otherwise the amount of material to be reviewed would be much more voluminous... If the Russians want to change the state that their work is not being known, they just have to prepare translations into a Western language, and they will become known!"

In that spring of 1951, my husband procured a small car, a two-seater; but four people could also sit inside. There were now some nice car-trips for my father, which he enjoyed happily with us. Once, during a trip to the Harz mountains, when a shower of rain took us by surprise, my husband noticed how, along the left edge of the windscreen considerable

quantities of rain water climbed up slowly instead of draining off. Since he liked to ask questions, he drew my father's attention to this phenomenon. He (Prandtl) looked at it and said only one word stressing the same: "*Stimmt!* (Yes, it is so!)". One could discern the quiet smile conveying a certain humor with keeping distance at the same time, since through this one word he was expressing satisfaction that the wet element takes a course according to the rules 'prescribed' by the science of fluid flows.

For the summer of 1951, he had planned a longer period of vacation in order to relax thoroughly. My sister accompanied him on this trip to Bavaria. This was his last summer vacation.

On 10 November 1951 there was again a celebration of a jubilee in Göttingen: The Academy of Sciences (*Akademie der Wissenschaften*) had been in existence for 200 years. It was founded in 1751, 14 years after Georgia Augusta (the university in Göttingen). Teaching and research were supposed to be in a position to stimulate each other this way. And as I have been told, it is certain that the 'Göttingen way' has been influential in the shaping of modern institutions of higher education (*Hochschule*) elsewhere.

The President of the Federal Republic of Germany (*Bundespräsident*) Theodor Heuss had come to Göttingen on a visit for a few days on this occasion, which had set the whole town in a happy mood. The then president of the *Akademie der Wissenschaften* Professor Werner Heisenberg was the chairperson of this celebration. The grand ceremony took place in the *Aula* on 10 November with many scholars from home and abroad attending.

On the day before this celebration, on 9 November, Heuss had honored the *Max-Planck-Institut für Strömungsforschung* too by a visit together with the President of the *Max-Planck Gesellschaft*, *Otto Hahn*. In a ceremony, he awarded Prandtl the Federal Medal of Honor (*Bundesverdienstkreuz*).

Let me also give here one sentence cited from the speech Heuss gave in the *Rathaus* at the end of his visit: "Göttingen is a small city, but through it flow all rivers of the world. (*Göttingen ist eine kleine Stadt, durch die aber die Ströme der Welt gehen.*)"

For commemorating his visit the *Bundespräsident* planted in the presence of the entire staff of the institutes there, a lime tree sapling on a circular flower bed close to the entry gate. Since then it has grown to be a tall tree, and in well-informed circles it is referred to as "Heuss-Linde" even today.

The little that is still left for me to relate, before my father was hit by a second stroke in the beginning of August 1952 is again the few personal notes on how he felt, that he used to annex to his letters with technical content when he wrote to a friend and colleague.

22 April 1952 to Professor Blenk:

"My own energy has, unfortunately, dwindled of late. So you shouldn't expect from me any longer much of active involvement in this direction (he was elected to honorary membership of the newly founded WGL - *Wissenschaftliche Gesellschaft für Luftfahrt*--- Society for aeronautical science).

18 March 1952 to Professor Tietjens, Bangalore:

"My own intention is to go to Bad Gastein with my daughter Hilde in order to cast all the signs of aging into a milder form."

On 1 May 1952 he traveled with my sister to Bad Gastein for three weeks. They were put up there in good quarters in the house of the emeritus colleague Pröll. However, the treatments at the health resort put too heavy a strain on him, and on return he was not feeling reposed. He was sad he had not been able to regain his earlier energy and stamina.

30 June 1952 to Dipl.-Ing. R. Langer, an earlier *Mitarbeiter*:

"I cannot say things are going on well with me in all respects. I have decided, encouraged by especially good experiences of colleagues, to undergo treatment at the health resort Bad Gastein. But the healing baths have not improved the state of my health, so that I now need to recover from the health treatment. So much is said of it in Gastein that the real recovery starts a half year later. Let us hope for the best!"

My father did not recover any longer from the sudden stroke of the brain that hit him in the beginning of August. Infirmity returning led to a long period of confinement to the sick bed. We engaged a nurse at home. "*Schwester Lenchen*" was conscious of her special duties and took care of her patient conscientiously and lovingly. She remained with us until his death. How often have I heard her say: "Herr Professor is so patient and modest, he has no wishes or demands. On the contrary he is happy with everything and thankful for every help, he is so considerate as to think on how he can make one or the other small work easier for me. Never have I nursed a patient this modest and gentle."

The only embarrassment he caused to us in the beginning were his willful attempts to go as usual to the Institute despite his weak physique. But having come there, his powers of concentration were absent. His tiredness could not be covered up, and he was brought back home. Over all the years, AVA (*Aerodynamische Versuchsanstalt*) was at the real centre of his life, and he got ready to part with it only with much hesitation and sadness at heart.

His medical condition got worse, and he knew that he would not recover any longer. He resigned himself to the inevitable without complaint. On 15 August 1953 he died. Until his last day he stayed in surroundings he was used to.

Difficulties cropped up at holding the funeral service for him, since the theologians of the university denied to give a Christian prefatory note to a colleague who had quit the

Church. Without paying any regard to this fact, the vicar of the Reformed Church Pastor Th. Kamlah gave the address at the grave. I will quote from this address.

20 August 1953:"Thoughts on the last and most profound questions of life he exchanged with himself and usually did not talk over this matter. It was one of the most deeply heartfelt hours in my professional life when he came to me on the death of his wife, deeply touched, and allowed me a glimpse into his soft inner self."

In his introduction to "Collected Works of Ludwig Prandtl (*Ludwig Prandtls Gesammelte Abhandlungen*), Prandtl's former pupil and later successor Professor Walter Tollmien remembers [50]:

"It was in November 1950 that he suffered a light stroke, from which, thanks not in the least to the strength of his will-power, he soon recovered. But people around him observed with concern the continuous dwindling of his strength a few months later. In August 1952 the much feared breakdown happened after which he was no longer in a position to express his thoughts in an orderly manner. Even then his benevolence at heart shone through his behaviour. I was reminded of the aged Immanuel Kant who ended his life in a similar way.

During my last visit to Prandtl, only his eyes spoke to me until he pressed my hand and said the two words:'*Wir danken* (We are grateful)'. I know I will be acting in the spirit of the immortalized if I pass on this thanks to all his *Mitarbeiter* (co-workers), to all those who helped him at his work, and to his scientist friends."

28 Concluding remarks

Four years after Prandtl's death, an award bearing his name, to be given to aerodynamicists of later generations, was instituted to honor Prandtl and to perpetuate the memory of his pioneering work in the aeronautical sciences. A golden ring, with his name written in a highlighted script, was chosen as the symbol. It was given a name as the LUDWIG-PRANDTL-Ring. The figure of an eagle which was to symbolize the spirit of freedom was engraved in a big stone of rock crystal.

The date for granting the award for the first time was chosen as 4 February, his birthday, of the year 1957. The Society for Aeronautical Sciences (*Wissenschaftliche Gesellschaft für Luftfahrt*) gave this highest award to the aerodynamicist Theodore von Karman. Since he could not be present in person at Göttingen, he sent a letter that was read at the ceremony: "I regard it as a great honor that I have been chosen to be the first recipient of Ludwig-Prandtl-Ring... Prandtl's influence was decisive for my scientific development, and I always remember him with gratitude and reverence."

Since then the Ludwig-Prandtl-Ring has been awarded to many deserving aerodynamicists who had worked with him previously as his pupils. They were scientists of special eminence who had given new ideas for research (in this subject).

After the elapse of a hundred years since the birth of Ludwig Prandtl on 4 February 1875, a memorial ceremony was held in the *Stadthalle* in Göttingen on 3 April (1975) by the GAMM (*Gesellschaft für Angewandte Mathematik und Mechanik*) as a part of their annual conference. Prandtl had been the first president of the GAMM for over 20 years [9]. The conference was also the platform for the Ludwig-Prandtl lecture. Here, which was the 18th in the series, it was given by Fritz Schulz-Grunow. In the same year the *Max-Planck-Institut für Strömungsforschung* brought out a *Festschrift* (commemorative volume) on the occasion of its golden jubilee (50 years of existence) [18].

Appendix

Prof. Dr. L. Prandtl

Annex to the letter of 28.IV.1941 - pp. 314/41 -
to Herr *Reichsmarschall* Hermann Göring

I. On theoretical physics

The goal of theoretical physics is to formulate a logically consistent structure of thought, through which observed facts can be ordered within a framework such that even entities lying far apart from each other may be explained in terms of a common basis, and with as high a degree of precision as possible. The laws resulting from this work may then serve to predict new experimental results. A theory is required to be free of logical inconsistencies, and its results should properly account for the facts. Depending upon the hypotheses on which the theory is founded, there might be several valid theories for one and the same set of observed facts. If a new event that is observed is in accordance with one of these theories but not with the other, the latter should be discarded. This is the case that arose around the turn of the century through what have come to be known as Michelson's interference experiments. These experiments were expected, on the basis of Newton's space-time concept that had been regarded as unquestionably correct until then, to provide conclusive evidence of the relative velocity of the earth with respect to the ether in the universe. But, in spite of increasingly more sophisticated repetitions, the experiments led to a negative result, i.e. instead of the expected shift in the interference fringes there was no shift. With this finding, the Newtonian concept of space and time proved to be basically flawed. H.A.Lorentz, in Leiden, was then able to show that Maxwell's equations of electrodynamics do not lead to any inconsistency in the new experimental observations, i.e. one does not run into inconsistencies if the observed universe is regarded as made up of electrodynamic phenomena. It now became necessary to reformulate, from a rigorous point of view, the space-time concept that satisfies the new observations exactly. One such formulation was first advanced by A. Einstein. His system is free of internal inconsistencies. It is, as already mentioned earlier, not the only possible solution, but it is perhaps the simplest.

Vis-a-vis this issue of fact, the Lenard group buries its head in the sand like an ostrich, and holds steadfast to the Newtonian space-time concept, although this has been long refuted by Michelson's experiment. The Einsteinian space-time concept, which has been recognized by clear thinking physicists from all over the world as the best solution today, and which has become an indispensable foundation for further development of physics, cannot, in the opinion of the Lenard group, be correct, simply because its creator was a Jew. All further research studies, which have been conducted since then by *Arisch* scientists on the basis of this new thought, are, in the eyes of the Lenard group, merely "Jewish physics" ("*jüdische Physik*").

The matter is somewhat different with quantum theory, which also started at the beginning of the present century. The development of man's capacity for thought in

physics has taken place around the observable world. This, according to the established knowledge of today, consists of small particles (atoms), which are themselves made up of still smaller elements. In all observable phenomena, even in the smallest region of space, the number of such particles involved is still very large, and all phenomena seemed to fall strictly into a cause and effect pattern, from which a causal principle was derived. The entire body of earlier theoretical physics is built upon causal relations holding between individual quantities. Today, with research probing into the inner structure of atoms, and, so to say, into the fundamental constituents of matter (the individual objects are perceivable separately through certain methods), it has been realized that the concept of causality fails, and needs to be replaced by a statistical concept. (In the decay of radium atoms, for example, there is no way of predicting when a certain radium atom is split. But it is possible to make a statement concerning the fraction that disintegrates on average, in one hour or a year, of a given amount of radium. Such statements are not restricted to radium, but are applicable to all atomic processes.) The causality of the older point of view turns out to be the "law of large numbers", the "law" that arises when questions concerning overall statistics, of every kind, are addressed. The larger the numbers, the smaller the random deviations from the state that is to be expected from "causal" considerations. The processes of energy conversion within the atoms, of which one has no knowledge as to where and when an individual process occurs, also have the property that, depending upon the type of conversion, only certain quanta of energy are converted at a time (hence the name quantum theory). On the basis of such a point of view, it was possible to hold a considerable number of earlier and recent facts of observation within one logically consistent system. The Lenard people consider even this to be "Jewish physics", perhaps according to the principle that I have heard mentioned now and then, viz. "What I do not understand, I regard as Jewish". Of course, there are contributions from Jews to this part of scientific development, but the major share of contributions is by men like Planck and Sommerfeld to start with, all the way up to Heisenberg and Schrödinger.

II. Details of the Lenard Circle

1. Lenard has earned much fame for himself through experimental investigations that would, in all likelihood, have led him to the discovery of X-rays, had Röntgen not got there before. However, mathematical theory has never been his cup of tea, and it would have been better if he had not started a controversy on mathematical subjects. In his old age, he wrote a text book of many volumes, to which he gave the title "*Deutsche Physik*" ("German Physics"). The necessary clarity and rigour are absent in this book even when it comes to the simple laws of ordinary mechanics, so it may pass as a text book for teaching at the lower level, but in no sense does it suffice for the higher level.

2. Another exponent of this group is Johannes Stark, the ex-president of the *Physikalisch-Technische Reichsanstalt* (Physics and Engineering Laboratory of the *Reich*). I know Herr Stark from his days as a *Privat-Dozent* in Göttingen to be quite a passionate and eccentric person. Despite this, he is a superb experimentalist. He has two first-class discoveries to his credit, one of which, known as the "Stark-effect" in professional circles all over the world, has made his name immortal. He has not, as far I know, engaged

himself with theory. But this has not prevented him from heaping abuse over and over again on Herr Planck and Herr Heisenberg in unbelievably malicious articles, one of which appeared a few years ago in "*Schwarzes Korps*".

3. The group has a few followers, whose work is essentially of an experimental nature, and whose contributions are invaluable that sense. But there are quite a number of people who consider themselves to be unrecognized geniuses, but who, due to their poor performance in the early days, could not make a mark; and they have poisoned the air with that disdain for the past which is so fundamental to National-Socialism (Nazism). Some in this circle engage themselves copiously in reforming the philosophical foundations of physics, and in particular the space-time concept. For all these people, the Michelson experiment is of no consequence whatsoever in this venture; or in other words, they stick to the Newtonian space-time concept.¹⁵

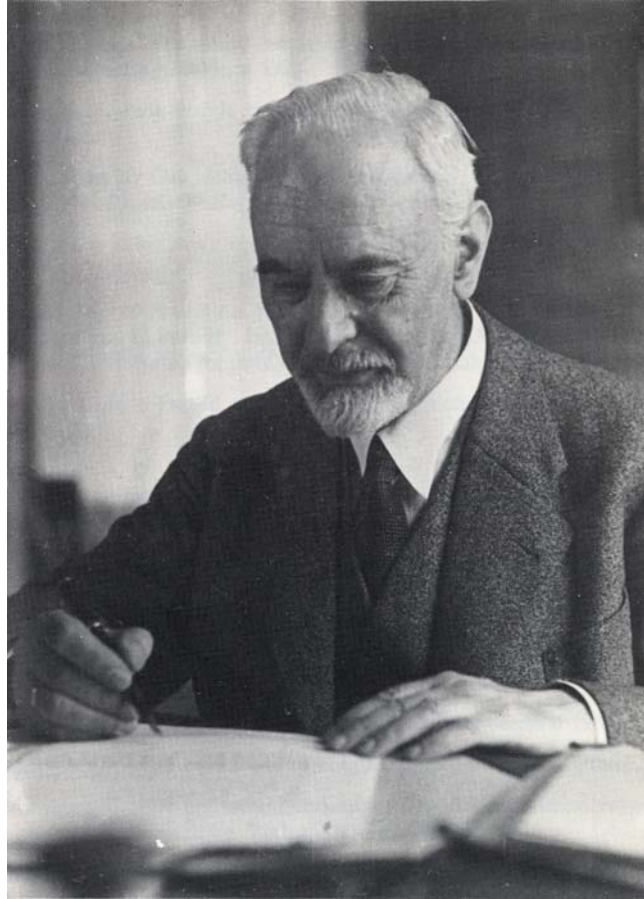
4. Choosing a successor to the world-renowned Munich theoretician Sommerfeld--to whom, besides many other things, one owes a clear ordering of the laws of spectral lines - is something special. This successor, Wilhelm Müller, was earlier an *Assistent*, and later became a professor of technical mechanics, first in Hannover, later in Prague and Aachen. Until now he has worked primarily on fluid flows and flight mechanics, and has also written text books on areas of these subjects. He possesses no qualifications in theoretical physics, absolutely none. Instead of giving lectures on subjects needed in the education of physicists, viz. electrodynamics, electron theory, optics and radiation, thermodynamics, mathematical statistics and partial differential equations of physics, he lectures, according to his own statements, on flight mechanics and other branches of engineering mechanics. It cannot be denied that it is useful, even for those attending a university, to get to know something of these subjects. But, if, on this account, they are left unexposed to an essential part of physics, it generates a state that can only be described as a sabotage of essential teaching. Herr Müller has expressed himself extensively on his programme in the journal "*Zeitschrift für die gesamte Naturwissenschaft*" (November-December 1940, pp. 281-298). In this article bearing the title "The State of Theoretical Physics in the Universities ("*Die Lage der theoretischen Physik an den Universitäten*")", he has not failed to pass adverse comments concerning the German representatives of theoretical physics. As far as the rest are concerned, the Lenard Group is profuse in its profession of a faith in physics: the article suggests that, among the theoreticians, there is a "secret group of authorities" forcing people... "almost by magic, to subscribe to a certain program" that "threatens everyone who ventures to express an opinion of his own independent of the Guild". (I wish to note here that the "secret authorities" are none other than the experimentally observed facts, and the threats to those thinking otherwise are nothing but the justified rebuttal of those who do not want to see the facts.) Incidentally, the publisher *Helingsche Verlagsanstalt* in Leipzig has announced the publication of a brochure under the title "Jewish and German Physics" (*Jüdische und deutsche Physik*) authored by Herr Stark and Herr

¹⁵ See different, partly malicious articles by Kubach, Thüring, Dingler and others in the journal "*Zeitschrift für die gesamte Naturwissenschaft*", a journal that proclaims itself in its sub-title as "The voice of the *Reichsfachgruppe Naturwissenschaft der Reichsstudentenführung*". (There is a list of editors on the inside of the cover page.)

Müller, which promises a fierce campaign "against a dogmatism that still clings on to the Jewish spirit, that does not serve truth and knowledge, but pursues the goal of assaulting nature and degrading it to be a mere servant of formulas". The brochure is supposed to explain, through examples , "the basic difference between this Jewish or Jewish-influenced theoretical arbitrariness and the German pragmatic theory", noting that the latter "does not aim at establishing that everything observable can be traced back to a given order that is easy to visualize and understand through a system of laws of causality."

I believe that these sample extracts from their texts suffice to characterize the attitude of the Lenard group adequately.

L. Prandtl



At his working desk

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Glossary

During translation, it became clear, as might have been expected, that the meaning of the original, as intended by the author, is better preserved by taking over the German word into English instead of another choice, say according to a dictionary. The main guideline adopted for translation has been conveying the meaning intended by the author, and in this spirit, German words have been taken over wherever this is, in the opinion of the translator, more appropriate. When this has been done, the German word has been set in italics. Its meaning, although often self-explanatory, is given in brackets to facilitate understanding. The following Glossary lists a selection of these words that occur more often, together with a brief note on its meaning in the context of its use.

Aktuar civil servant in the Department of Justice

Amtsrichter district court judge

Arisch one finds this word often translated as 'aryan'. The roots of this word, as a reference to a standard dictionary, e.g.. Oxford Illustrated (1984), Webster's New Dictionary (1995), or Chambers's Twentieth Century (1964), would show, can be traced back to Sanskrit. Its meaning, in the dictionary, is 'noble', and it is in this meaning that the word 'aryan' has been used in the abundant literature in Sanskrit and other Indian languages, both old and recent, as well as in literature on Indian languages and culture in English, German and other European languages . However, the meaning this term has acquired after its use by the *NAZIs* to designate the 'aryan' race, mostly in the context of standing out against the 'Jewish', has been exactly the opposite. A discussion on the meaning of the word 'aryan' as such does not fall within the scope of the present translation, but, in order to convey the meaning of the term as used in the context more properly, the translator has opted to take over the word 'arisch' unchanged.

Assistent an assistant attached to an *Ordinariat*. An *Assistent* was entrusted with carrying out duties at a higher level, both of scientific and organisational nature, than those done commonly to an assistant in English or American universities, or other universities following this tradition

Auskippen deflect away, lateral deflection

ausserordentlicher Professor professor without a chair, in the days of Prandtl without voting rights in the *Fakultät*

AVA abbreviation for *Aerodynamische Versuchsanstalt*, Laboratory for aerodynamic testing

Baurat building councillor, designation of a civil servant in the public works department

Diplom-Ingenieur title awarded on graduation in engineering at a technical university (*Technische Hochschule*)

Dozent a person entitled or commissioned to teach at a *Hochschule*, as an *Ordinarius*, *ausserordentlicher Professor*, or a *Privat-Dozent*

Extraordinariat position of an *ausserordentlicher Professor*

Fakultät an autonomously governing unit in academic matters in German universities

Gau the word is an old German word for an area surrounded by water (not necessarily an island) or, later, a settlement. There are many old towns and areas in the German speaking parts of Europe whose names end with *gau* and their meaning is easily understandable in this context. The word was also used to designate an area under the jurisdiction of a court. and/or an administrative district. It is no longer employed in this meaning after 1945

Gauleiter official (mostly of the Party *NSDAP*) entrusted in charge of the *Gau*, in a powerful position

GAMM- Gesellschaft für Angewandte Mathematik und Mechanik (German Society of Applied Mathematics and Mechanics, founded by L. Prandtl and R. Von Mises)

Geheimrat title awarded by the King or the Kaiser (until 1918) , roughly equivalent to Privy Councillor

Habilitation the process of earning a *Venia legendi* at a university

Hilfsassistent an auxiliary assistant, a helper assistant

Hilfskraft, Hilfskräfte (plural) helping hands

Hochschule an institution of higher education, can refer to both, a college or a university

Institut a research unit within the *Fakultät*, generally headed by an *Ordinarius*

Ith the *Ith* is the crest of a hill along the river *Weser* near the town of Hameln, known to many from the 'Pied Piper's' story

Keplerbund club of scientists that had given itself the name of the great astronomer

Kreis an administrative unit smaller than the *Gau*

Kurator Trustee

KWG abbreviation for *Kaiser-Wilhelm-Gesellschaft*, forerunner of the present *Max-Planck-Gesellschaft* (*MPG*)

Luftwirbel vortices in air. There is a pun in the use of this word in the present context (Chapter 3) which would amount to the same as 'making a lot of (empty) noise'

Ministerialrat designation of a senior civil servant in the ministry

Mitarbeiter literally, a co-worker. The word is often used to designate one in a subordinate position, not in a supervisory or managerial position

Modellversuchsanstalt Laboratory for Model Testing

Motorluftschiff-Studiengesellschaft Society for the study of Powered Airships

MPG abbreviation for *Max-Planck-Gesellschaft*. *MPG*

NSDAP abbreviation for *Nationalsozialistische Deutsche Arbeiterpartei*, the Party of the *NAZIs*

Oberamtsrichter Chief District Judge

Ordinariat chair of an *Ordinarius*. An *Ordinariat* was equipped budgetarily, with a certain number of *Assistents*, secretarial staff, *Mitarbeiter* and (technical) personnel, as needed, often negotiated as terms of appointment

Ordinarius a full professor, with a chair, at a university. Generally, the head of an *Institut*

Privat-Dozent a person entitled to teach at a university, one having a *Venia legendi*. For an explanation from a humorous angle the reader may wish to see reference [15], p. 45

Promotion the process of earning a doctor's degree at a university through writing a Dissertation

SS-Hauptmann holder of the rank of a Captain in the *SS*

Steuerliquidator civil servant in the Ministry of Finance

Verein Deutscher Ingenieure (VDI) German Society of Engineers

Venia legendi the right to teach at a universty. It is granted by the *Fakultät*, it is to be earned by presentation of a thesis

Weltanschauung view of life, used with a philosophical touch

Zeitschrift des Vereins Deutscher Ingenieure (Fachgruppe Luftfahrt) Journal of *VDI* (aeronautics division)