Note:

CHAPTER 1: INTRO

Version: 0.4.9.0 February 13, 2012

This chapter is part of the textbook:

"Fundamentals of Compressible Flow"

You can download the whole book if you like from: *www.potto.org.*

This chapter is under GDL with a minor modifications. Potto License is no longer applied.

Please be aware that this book is updated frequently — every three weeks or so.

GENICK BAR-MEIR, PH.D.
CHICAGO, ILLINOIS
FEBRUARY 13, 2012

THE LIST OF THE AVAILABLE BOOKS IN POTTO PROJECT

Project Name	**Progress**	**Remarks**	**Version**	**Availability for Public Download**
Compressible Flow	beta		0.4.8.6	✔
Gas Dynamics Tables	final	World biggest	1.2	✔
Die Casting	alpha		0.1.2	✔
Dynamics	NSY		0.0.0	✖
Fluid Mechanics	beta		0.2.9	✔
Heat Transfer	NSY	Based on Eckert	0.0.0	✖
Mechanics	NSY		0.0.0	✖
Open Channel Flow	NSY		0.0.0	✖
Statics	early alpha	first chapter	0.0.1	✖
Strength of Material	NSY		0.0.0	✖
Thermodynamics	early alpha		0.0.01	✖
Two/Multi phases flow	NSY	Tel-Aviv's notes	0.0.0	✖

NSY = Not Started Yet

Fundamentals of Compressible Fluid Mechanics

Genick Bar–Meir, Ph. D.

7449 North Washtenaw Ave
Chicago, IL 60645
email: "barmeir@gmail.com"

Version (0.4.9.0 February 13, 2012)

‘We are like dwarfs sitting on the shoulders of giants”

from The Metalogicon by John in 1159

CONTENTS

LIST OF FIGURES

LIST OF TABLES

NOMENCLATURE

$\bar{R}$	Universal gas constant, see equation (2.26), page 29
$\boldsymbol{\tau}$	The shear stress Tenser, see equation (3.33), page 51
ℓ	Units length., see equation (2.1), page 25
$\mathfrak{M}$	Angular Momentum, see equation (3.43), page 52
$\boldsymbol{F}_{ext}$	External forces by non–fluids means, see equation (3.36), page 51
ρ	Density of the fluid, see equation (4.1), page 68
B	bulk modulus, see equation (4.38), page 76
B_f	Body force, see equation (2.9), page 27
c	Speed of sound, see equation (4.1), page 68
C_p	Specific pressure heat, see equation (2.23), page 29
C_v	Specific volume heat, see equation (2.22), page 29
E	Young's modulus, see equation (4.40), page 78
E_U	Internal energy, see equation (2.3), page 26
E_u	Internal Energy per unit mass, see equation (2.6), page 26
E_i	System energy at state i, see equation (2.2), page 26
H	Enthalpy, see equation (2.18), page 28
h	Specific enthalpy, see equation (2.18), page 28

k	the ratio of the specific heats, see equation (2.24), page 29
k_T	Fluid thermal conductivity, see equation (3.47), page 54
M	Mach number, see equation (5.8), page 84
n	The polytropic coefficient, see equation (4.35), page 74
P	Pressure, see equation (4.3), page 68
q	Energy per unit mass, see equation (2.6), page 26
Q_{12}	The energy transferred to the system between state 1 and state 2, see equation (2.2), page 26
R	Specific gas constant, see equation (2.27), page 30
R_{mix}	The universal gas constant for mixture, see equation (4.51), page 80
S	Entropy of the system, see equation (2.13), page 28
t	Time, see equation (4.18), page 71
U	velocity , see equation (2.4), page 26
w	Work per unit mass, see equation (2.6), page 26
W_{12}	The work done by the system between state 1 and state 2, see equation (2.2), page 26
z	The compressibility factor, see equation (4.22), page 72

The Book Change Log

Version 0.4.9

On 13rd Feb 2012 (3.6M pp. 432)

- Significant Enhancment the shock tube section.
- Update the book to compile with the current potto.sty.
- insert the introduction to fluid mechanics.
- English and typo corrections.

Version 0.4.8.8

On 29th Dec 2011 (3.6M pp. 386)

- Add two figures explaing the maximum Mach number limits in the shock tube.
- English and typo corrections.

Version 0.4.8.7

On 29th Dec 2011 (3.6M pp. 386)

- Significaly impoved the shock tube section.
- Improvments of the structure to meed to the standard.
- English and typo corrections.

Version 0.4.8.6

On 23rd Oct 2009 (3.6M pp. 384)

- Add the section about Theodor Meyer's biography
- Addition of Temperature Velocity diagram. (The addition to the other chapters was not added yet).

Version 0.4.8.5b

On 07th Sep 2009 (3.5M pp. 376)

- Corrections in the Fanno chapter in Trends section.
- English corrections.

Version 0.4.8.5a

On 04th July 2009 (3.5M pp. 376)

- Corrections in the thermodynamics chapter to the gases properties table.
- English corrections.
- Improve the multilayer sound traveling example (Heru's suggestion)

Version 0.4.8.5a

On 04th July 2009 (3.3M pp. 380)

- Correction to the gases properties table (Michael Madden and Heru Reksoprodjo)
- English corrections.
- Improving the multilayer sound wave traveling

Version 0.4.8.5

On 14th January 2009 (3.3M pp. 380)

- Improve images macro (two captions issue).
- English corrections.

Version 0.4.8.5rc

On 31st December 2008 (3.3M pp. 380)

- Add Gary Settles's color image in wedge shock and an example.
- Improve the wrap figure issue to oblique shock.
- Add Moody diagram to Fanno flow.
- English corrections to the oblique shock chapter.

Version 0.4.8.4

On 7th October 2008 (3.2M pp. 376)

- More work on the nomenclature issue.
- Important equations and useful equations issues inserted.
- Expand the discussion on the friction factor in isothermal and fanno flow.

Version 0.4.8.3

On 17th September 2008 (3.1M pp. 369)

- Started the nomenclature issue so far only the thermodynamics chapter.
- Started the important equations and useful equations issue.
- Add the introduction to thermodynamics chapter.
- Add the discussion on the friction factor in isothermal and fanno flow.

Version 0.4.8.2

On 25th January 2008 (3.1M pp. 353)

- Add several additions to the isentropic flow, normal shock,
- Rayleigh Flow.
- Improve some examples.
- More changes to the script to generate separate chapters sections.
- Add new macros to work better so that php and pdf version will be similar.
- More English revisions.

Version 0.4.8

November-05-2007

- Add the new unchoked subsonic Fanno Flow section which include the "unknown" diameter question.
- Shock (Wave) drag explanation with example.
- Some examples were add and fixing other examples (small perturbations of oblique shock).
- Minor English revisions.

Version 0.4.4.3pr1

July-10-2007

- Improvement of the pdf version provide links.

Version 0.4.4.2a

July-4-2007 version

- Major English revisions in Rayleigh Flow Chapter.
- Continue the improvement of the HTML version (imageonly issues).
- Minor content changes and addition of an example.

Version 0.4.4.2

May-22-2007 version

- Major English revisions.
- Continue the improvement of the HTML version.
- Minor content change and addition of an example.

Version 0.4.4.1

Feb-21-2007 version

- Include the indexes subjects and authors.
- Continue the improve the HTML version.
- solve problems with some of the figures location (float problems)

- Improve some spelling and grammar.
- Minor content change and addition of an example.
- The main change is the inclusion of the indexes (subject and authors). There were some additions to the content which include an example. The "naughty professor's questions" section isn't completed and is waiting for interface of Potto-GDC to be finished (engine is finished, hopefully next two weeks). Some grammar and misspelling corrections were added.

  Now include a script that append a title page to every pdf fraction of the book (it was fun to solve this one). Continue to insert the changes (log) to every source file (latex) of the book when applicable. This change allows to follow the progression of the book. Most the tables now have the double formatting one for the html and one for the hard copies.

Version 0.4.4pr1

Jan-16-2007 version

- Major modifications of the source to improve the HTML version.
- Add the naughty professor's questions in the isentropic chapter.
- Some grammar and miss spelling corrections.

Version 0.4.3.2rc1

Dec-04-2006 version

- Add new algorithm for Fanno Flow calculation of the shock location in the supersonic flow for given fld (exceeding Max) and M1 (see the example).
- Minor addition in the Sound and History chapters.
- Add analytical expression for Mach number results of piston movement.

Version 0.4.3.1rc4 aka 0.4.3.1

Nov-10-2006 aka Roy Tate's version

For this release (the vast majority) of the grammatical corrections are due to Roy Tate

- Grammatical corrections through the history chapter and part of the sound chapter.
- Very minor addition in the Isothermal chapter about supersonic branch.

Version 0.4.3.1rc3

Oct-30-2006

- Add the solutions to last three examples in Chapter Normal Shock in variable area.
- Improve the discussion about partial open and close moving shock dynamics i.e. high speed running into slower velocity
- Clean other tables and figure and layout.

Version 0.4.3rc2

Oct-20-2006

- Clean up of the isentropic and sound chapters
- Add discussion about partial open and close moving shock dynamics i.e. high speed running into slower velocity.
- Add the partial moving shock figures (never published before)

Version 0.4.3rc1

Sep-20-2006

- Change the book's format to 6x9 from letter paper
- Clean up of the isentropic chapter.
- Add the shock tube section
- Generalize the discussion of the the moving shock (not including the change in the specific heat (material))
- Add the Impulse Function for Isothermal Nozzle section
- Improve the discussion of the Fliegner's equation
- Add the moving shock table (never published before)

Version 0.4.1.9 (aka 0.4.1.9rc2)

May-22-2006

- Added the Impulse Function
- Add two examples.
- Clean some discussions issues .

Version 0.4.1.9rc1

May-17-2006

- Added mathematical description of Prandtl-Meyer's Function
- Fixed several examples in oblique shock chapter
- Add three examples.
- Clean some discussions issues .

Version 0.4.1.8 aka Version 0.4.1.8rc3

May-03-2006

- Added Chapman's function
- Fixed several examples in oblique shock chapter
- Add two examples.
- Clean some discussions issues .

Version 0.4.1.8rc2

Apr-11-2006

- Added the Maximum Deflection Mach number's equation
- Added several examples to oblique shock

Notice of Copyright For This Book:

This document published Modified FDL. The change of the license is to prevent from situations where the author has to buy his own book. The Potto Project License isn't long apply to this document and associated documents.

GNU Free Documentation License

The modification is that under section 3 “copying in quantity” should be add in the end.

"If you print more than 200 copies, you are required to furnish the author with two (2) copies of the printed book. This part is major part of this license."

Preamble

The purpose of this License is to make a manual, textbook, or other functional and useful document "free" in the sense of freedom: to assure everyone the effective freedom to copy and redistribute it, with or without modifying it, either commercially or noncommercially. Secondarily, this License preserves for the author and publisher a way to get credit for their work, while not being considered responsible for modifications made by others.

This License is a kind of "copyleft", which means that derivative works of the document must themselves be free in the same sense. It complements the GNU General Public License, which is a copyleft license designed for free software.

We have designed this License in order to use it for manuals for free software, because free software needs free documentation: a free program should come with manuals providing the same freedoms that the software does. But this License is not limited to software manuals; it can be used for any textual work, regardless of subject matter or whether it is published as a printed book. We recommend this License principally for works whose purpose is instruction or reference.

1. APPLICABILITY AND DEFINITIONS

This License applies to any manual or other work, in any medium, that contains a notice placed by the copyright holder saying it can be distributed under the terms of this License. Such a notice grants a world-wide, royalty-free license, unlimited in duration, to use that work under the conditions stated herein. The **"Document"**, below, refers to any such manual or work. Any member of the public is a licensee, and is addressed as **"you"**. You accept the license if you copy, modify or distribute the work in a way requiring permission under copyright law.

A **"Modified Version"** of the Document means any work containing the Document or a portion of it, either copied verbatim, or with modifications and/or translated into another language.

A **"Secondary Section"** is a named appendix or a front-matter section of the Document that deals exclusively with the relationship of the publishers or authors of the Document to the Document's overall subject (or to related matters) and contains nothing that could fall directly within that overall subject. (Thus, if the Document is in part a textbook of mathematics, a Secondary Section may not explain any mathematics.) The relationship could be a matter of historical connection with the subject or with related matters, or of legal, commercial, philosophical, ethical or political position regarding them.

The **"Invariant Sections"** are certain Secondary Sections whose titles are designated, as being those of Invariant Sections, in the notice that says that the Document is released under this License. If a section does not fit the above definition of Secondary then it is not allowed to be designated as Invariant. The Document may contain zero Invariant Sections. If the Document does not identify any Invariant Sections then there are none.

The **"Cover Texts"** are certain short passages of text that are listed, as Front-Cover Texts or Back-Cover Texts, in the notice that says that the Document is released under this License. A Front-Cover Text may be at most 5 words, and a Back-Cover Text may be at most 25 words.

A **"Transparent"** copy of the Document means a machine-readable copy, represented in a format whose specification is available to the general public, that is suitable for revising the document straightforwardly with generic text editors or (for images composed of pixels) generic paint programs or (for drawings) some widely available drawing editor, and that is suitable for input to text formatters or for automatic

translation to a variety of formats suitable for input to text formatters. A copy made in an otherwise Transparent file format whose markup, or absence of markup, has been arranged to thwart or discourage subsequent modification by readers is not Transparent. An image format is not Transparent if used for any substantial amount of text. A copy that is not "Transparent" is called **"Opaque"**.

Examples of suitable formats for Transparent copies include plain ASCII without markup, Texinfo input format, LaTeX input format, SGML or XML using a publicly available DTD, and standard-conforming simple HTML, PostScript or PDF designed for human modification. Examples of transparent image formats include PNG, XCF and JPG. Opaque formats include proprietary formats that can be read and edited only by proprietary word processors, SGML or XML for which the DTD and/or processing tools are not generally available, and the machine-generated HTML, PostScript or PDF produced by some word processors for output purposes only.

The **"Title Page"** means, for a printed book, the title page itself, plus such following pages as are needed to hold, legibly, the material this License requires to appear in the title page. For works in formats which do not have any title page as such, "Title Page" means the text near the most prominent appearance of the work's title, preceding the beginning of the body of the text.

A section **"Entitled XYZ"** means a named subunit of the Document whose title either is precisely XYZ or contains XYZ in parentheses following text that translates XYZ in another language. (Here XYZ stands for a specific section name mentioned below, such as **"Acknowledgements"**, **"Dedications"**, **"Endorsements"**, or **"History"**.) To **"Preserve the Title"** of such a section when you modify the Document means that it remains a section "Entitled XYZ" according to this definition.

The Document may include Warranty Disclaimers next to the notice which states that this License applies to the Document. These Warranty Disclaimers are considered to be included by reference in this License, but only as regards disclaiming warranties: any other implication that these Warranty Disclaimers may have is void and has no effect on the meaning of this License.

2. VERBATIM COPYING

You may copy and distribute the Document in any medium, either commercially or noncommercially, provided that this License, the copyright notices, and the license notice saying this License applies to the Document are reproduced in all copies, and that you add no other conditions whatsoever to those of this License. You may not use technical measures to obstruct or control the reading or further copying of the copies you make or distribute. However, you may accept compensation in exchange for copies. If you distribute a large enough number of copies you must also follow the conditions in section 3.

You may also lend copies, under the same conditions stated above, and you may publicly display copies.

3. COPYING IN QUANTITY

If you publish printed copies (or copies in media that commonly have printed covers) of the Document, numbering more than 100, and the Document's license notice requires Cover Texts, you must enclose the copies in covers that carry, clearly and legibly, all these Cover Texts: Front-Cover Texts on the front cover, and Back-Cover Texts on the back cover. Both covers must also clearly and legibly identify you as the publisher of these copies. The front cover must present the full title with all words of the title equally prominent and visible. You may add other material on the covers in addition. Copying with changes limited to the covers, as long as they preserve the title of the Document and satisfy these conditions, can be treated as verbatim copying in other respects.

If the required texts for either cover are too voluminous to fit legibly, you should put the first ones listed (as many as fit reasonably) on the actual cover, and continue the rest onto adjacent pages.

If you publish or distribute Opaque copies of the Document numbering more than 100, you must either include a machine-readable Transparent copy along with each Opaque copy, or state in or with each Opaque copy a computer-network location from which the general network-using public has access to download using public-standard network protocols a complete Transparent copy of the Document, free of added material. If you use the latter option, you must take reasonably prudent steps, when you begin distribution of Opaque copies in quantity, to ensure that this Transparent copy will remain thus accessible at the stated location until at least one year after the last time you distribute an Opaque copy (directly or through your agents or retailers) of that edition to the public.

It is requested, but not required, that you contact the authors of the Document well before redistributing any large number of copies, to give them a chance to provide you with an updated version of the Document.

4. MODIFICATIONS

You may copy and distribute a Modified Version of the Document under the conditions of sections 2 and 3 above, provided that you release the Modified Version under precisely this License, with the Modified Version filling the role of the Document, thus licensing distribution and modification of the Modified Version to whoever possesses a copy of it. In addition, you must do these things in the Modified Version:

A. Use in the Title Page (and on the covers, if any) a title distinct from that of the Document, and from those of previous versions (which should, if there were any, be listed in the History section of the Document). You may use the same title as a previous version if the original publisher of that version gives permission.

B. List on the Title Page, as authors, one or more persons or entities responsible for authorship of the modifications in the Modified Version, together with at least five of the principal authors of the Document (all of its principal authors, if it has fewer than five), unless they release you from this requirement.

C. State on the Title page the name of the publisher of the Modified Version, as the publisher.

D. Preserve all the copyright notices of the Document.

E. Add an appropriate copyright notice for your modifications adjacent to the other copyright notices.

F. Include, immediately after the copyright notices, a license notice giving the public permission to use the Modified Version under the terms of this License, in the form shown in the Addendum below.

G. Preserve in that license notice the full lists of Invariant Sections and required Cover Texts given in the Document's license notice.

H. Include an unaltered copy of this License.

I. Preserve the section Entitled "History", Preserve its Title, and add to it an item stating at least the title, year, new authors, and publisher of the Modified Version as given on the Title Page. If there is no section Entitled "History" in the Document, create one stating the title, year, authors, and publisher of the Document as given on its Title Page, then add an item describing the Modified Version as stated in the previous sentence.

J. Preserve the network location, if any, given in the Document for public access to a Transparent copy of the Document, and likewise the network locations given in the Document for previous versions it was based on. These may be placed in the "History" section. You may omit a network location for a work that was published at least four years before the Document itself, or if the original publisher of the version it refers to gives permission.

K. For any section Entitled "Acknowledgements" or "Dedications", Preserve the Title of the section, and preserve in the section all the substance and tone of each of the contributor acknowledgements and/or dedications given therein.

L. Preserve all the Invariant Sections of the Document, unaltered in their text and in their titles. Section numbers or the equivalent are not considered part of the section titles.

M. Delete any section Entitled "Endorsements". Such a section may not be included in the Modified Version.

N. Do not retitle any existing section to be Entitled "Endorsements" or to conflict in title with any Invariant Section.

O. Preserve any Warranty Disclaimers.

If the Modified Version includes new front-matter sections or appendices that qualify as Secondary Sections and contain no material copied from the Document, you may at your option designate some or all of these sections as invariant. To do this, add their titles to the list of Invariant Sections in the Modified Version's license notice. These titles must be distinct from any other section titles.

You may add a section Entitled "Endorsements", provided it contains nothing but endorsements of your Modified Version by various parties–for example, statements of peer review or that the text has been approved by an organization as the authoritative definition of a standard.

You may add a passage of up to five words as a Front-Cover Text, and a passage of up to 25 words as a Back-Cover Text, to the end of the list of Cover Texts in the Modified Version. Only one passage of Front-Cover Text and one of Back-Cover Text may be added by (or through arrangements made by) any one entity. If the Document already includes a cover text for the same cover, previously added by you or by arrangement made by the same entity you are acting on behalf of, you may not add another; but you may replace the old one, on explicit permission from the previous publisher that added the old one.

The author(s) and publisher(s) of the Document do not by this License give permission to use their names for publicity for or to assert or imply endorsement of any Modified Version.

5. COMBINING DOCUMENTS

You may combine the Document with other documents released under this License, under the terms defined in section 4 above for modified versions, provided that you include in the combination all of the Invariant Sections of all of the original documents, unmodified, and list them all as Invariant Sections of your combined work in its license notice, and that you preserve all their Warranty Disclaimers.

The combined work need only contain one copy of this License, and multiple identical Invariant Sections may be replaced with a single copy. If there are multiple Invariant Sections with the same name but different contents, make the title of each such section unique by adding at the end of it, in parentheses, the name of the original author or publisher of that section if known, or else a unique number. Make the same adjustment to the section titles in the list of Invariant Sections in the license notice of the combined work.

In the combination, you must combine any sections Entitled "History" in the various original documents, forming one section Entitled "History"; likewise combine any sections Entitled "Acknowledgements", and any sections Entitled "Dedications". You must delete all sections Entitled "Endorsements".

6. COLLECTIONS OF DOCUMENTS

You may make a collection consisting of the Document and other documents released under this License, and replace the individual copies of this License in the various documents with a single copy that is included in the collection, provided that you follow the rules of this License for verbatim copying of each of the documents in all other respects.

You may extract a single document from such a collection, and distribute it individually under this License, provided you insert a copy of this License into the extracted document, and follow this License in all other respects regarding verbatim copying of that document.

7. AGGREGATION WITH INDEPENDENT WORKS

A compilation of the Document or its derivatives with other separate and independent documents or works, in or on a volume of a storage or distribution medium, is called an "aggregate" if the copyright resulting from the compilation is not used to limit the legal rights of the compilation's users beyond what the individual works permit. When the Document is included in an aggregate, this License does not apply to the other works in the aggregate which are not themselves derivative works of the Document.

If the Cover Text requirement of section 3 is applicable to these copies of the Document, then if the Document is less than one half of the entire aggregate, the Document's Cover Texts may be placed on covers that bracket the Document within the aggregate, or the electronic equivalent of covers if the Document is in electronic form. Otherwise they must appear on printed covers that bracket the whole aggregate.

8. TRANSLATION

Translation is considered a kind of modification, so you may distribute translations of the Document under the terms of section 4. Replacing Invariant Sections with translations requires special permission from their copyright holders, but you may include translations of some or all Invariant Sections in addition to the original versions of these Invariant Sections. You may include a translation of this License, and all the license notices in the Document, and any Warranty Disclaimers, provided that you also include the original English version of this License and the original versions of those notices and disclaimers. In case of a disagreement between the translation and the original version of this License or a notice or disclaimer, the original version will prevail.

If a section in the Document is Entitled "Acknowledgements", "Dedications", or "History", the requirement (section 4) to Preserve its Title (section 1) will typically require changing the actual title.

9. TERMINATION

You may not copy, modify, sublicense, or distribute the Document except as expressly provided for under this License. Any other attempt to copy, modify, sublicense or distribute the Document is void, and will automatically terminate your rights under this License. However, parties who have received copies, or rights, from you under this License will not have their licenses terminated so long as such parties remain in full compliance.

10. FUTURE REVISIONS OF THIS LICENSE

The Free Software Foundation may publish new, revised versions of the GNU Free Documentation License from time to time. Such new versions will be similar in spirit to the present version, but may differ in detail to address new problems or concerns. See http://www.gnu.org/copyleft/.

Each version of the License is given a distinguishing version number. If the Document specifies that a particular numbered version of this License "or any later

version" applies to it, you have the option of following the terms and conditions either of that specified version or of any later version that has been published (not as a draft) by the Free Software Foundation. If the Document does not specify a version number of this License, you may choose any version ever published (not as a draft) by the Free Software Foundation.

ADDENDUM: How to use this License for your documents

To use this License in a document you have written, include a copy of the License in the document and put the following copyright and license notices just after the title page:

> Copyright ©YEAR YOUR NAME. Permission is granted to copy, distribute and/or modify this document under the terms of the GNU Free Documentation License, Version 1.2 or any later version published by the Free Software Foundation; with no Invariant Sections, no Front-Cover Texts, and no Back-Cover Texts. A copy of the license is included in the section entitled "GNU Free Documentation License".

If you have Invariant Sections, Front-Cover Texts and Back-Cover Texts, replace the "with...Texts." line with this:

> with the Invariant Sections being LIST THEIR TITLES, with the Front-Cover Texts being LIST, and with the Back-Cover Texts being LIST.

If you have Invariant Sections without Cover Texts, or some other combination of the three, merge those two alternatives to suit the situation.

If your document contains nontrivial examples of program code, we recommend releasing these examples in parallel under your choice of free software license, such as the GNU General Public License, to permit their use in free software.

CONTRIBUTOR LIST

How to contribute to this book

As a copylefted work, this book is open to revision and expansion by any interested parties. The only "catch" is that credit must be given where credit is due. This *is* a copyrighted work: it is *not* in the public domain!

If you wish to cite portions of this book in a work of your own, you must follow the same guidelines as for any other GDL copyrighted work.

Credits

All entries arranged in alphabetical order of surname. Major contributions are listed by individual name with some detail on the nature of the contribution(s), date, contact info, etc. Minor contributions (typo corrections, etc.) are listed by name only for reasons of brevity. Please understand that when I classify a contribution as "minor," it is in no way inferior to the effort or value of a "major" contribution, just smaller in the sense of less text changed. Any and all contributions are gratefully accepted. I am indebted to all those who have given freely of their own knowledge, time, and resources to make this a better book!

- **Date(s) of contribution(s):** 2004 to present
- **Nature of contribution:** Original author.
- **Contact at:** `barmeir at gmail.com`

John Martones

- **Date(s) of contribution(s):** June 2005

- **Nature of contribution:** HTML formatting, some error corrections.

Grigory Toker

- **Date(s) of contribution(s):** August 2005
- **Nature of contribution:** Provided pictures of the oblique shock for oblique shock chapter.

Ralph Menikoff

- **Date(s) of contribution(s):** July 2005
- **Nature of contribution:** Some discussions about the solution to oblique shock and about the Maximum Deflection of the oblique shock.

Domitien Rataaforret

- **Date(s) of contribution(s):** Oct 2006
- **Nature of contribution:** Some discussions about the French problem and help with the new wrapImg command.

Gary Settles

- **Date(s) of contribution(s):** Dec 2008, July 2009
- **Nature of contribution:** Four images for oblique shock two dimensional, and cone flow.
- **Nature of contribution:** Information about T. Meyer –2009.

Your name here

- **Date(s) of contribution(s):** Month and year of contribution
- **Nature of contribution:** Insert text here, describing how you contributed to the book.
- **Contact at:** `my_email@provider.net`

Typo corrections and other "minor" contributions

- **H. Gohrah, Ph. D.**, September 2005, some LaTeX issues.
- **Roy Tate** November 2006, Suggestions on improving English and grammar.
- **Nancy Cohen** 2006, Suggestions on improving English and style for various issues.
- **Irene Tan** 2006, proof reading many chapters and for various other issues.
- **Michael Madden** 2009, gas properties table corrections
- **Heru Reksoprodjo** 2009, point to affecting dimensional parameter in multi layer sound travel, and also point to the mistake in the gas properties.

About This Author

Genick Bar-Meir holds a Ph.D. in Mechanical Engineering from University of Minnesota and a Master in Fluid Mechanics from Tel Aviv University. Dr. Bar-Meir was the last student of the late Dr. R.G.E. Eckert. Much of his time has been spend doing research in the field of heat and mass transfer (related to renewal energy issues) and this includes fluid mechanics related to manufacturing processes and design. Currently, he spends time writing books (there are already three very popular books) and softwares for the POTTO project (see Potto Prologue). The author enjoys to encourage his students to understand the material beyond the basic requirements of exams.

In his early part of his professional life, Bar-Meir was mainly interested in elegant models whether they have or not a practical applicability. Now, this author's views had changed and the virtue of the practical part of any model becomes the essential part of his ideas, books and software.

He developed models for Mass Transfer in high concentration that became a building blocks for many other models. These models are based on analytical solution to a family of equations[1]. As the change in the view occurred, Bar-Meir developed models that explained several manufacturing processes such the rapid evacuation of gas from containers, the critical piston velocity in a partially filled chamber (related to hydraulic jump), application of supply and demand to rapid change power system and etc. All the models have practical applicability. These models have been extended by several research groups (needless to say with large research grants). For example, the Spanish Comision Interministerial provides grants TAP97-0489 and PB98-0007, and the CICYT and the European Commission provides 1FD97-2333 grants for minor aspects of that models. Moreover, the author's models were used in numerical works, in GM, British industry, Spain, and Canada.

In the area of compressible flow, it was commonly believed and taught that there is only weak and strong shock and it is continue by Prandtl–Meyer function. Bar–

[1]Where the mathematicians were able only to prove that the solution exists.

Meir discovered the analytical solution for oblique shock and showed that there is a quiet buffer between the oblique shock and Prandtl–Meyer. He also build analytical solution to several moving shock cases. He described and categorized the filling and evacuating of chamber by compressible fluid in which he also found analytical solutions to cases where the working fluid was ideal gas. The common explanation to Prandtl–Meyer function shows that flow can turn in a sharp corner. Engineers have constructed design that based on this conclusion. Bar-Meir demonstrated that common Prandtl–Meyer explanation violates the conservation of mass and therefor the turn must be around a finite radius. The author's explanations on missing diameter and other issues in fanno flow and "naughty professor's question" are used in the industry.

In his book "Basics of Fluid Mechanics", Bar-Meir demonstrated several things which include Pushka equation, dealing with the pressure accounted the slight compressibility (a finite Bulk Modulus effect), speed of sound in slightly compressible liquid. He showed the relationship between the wavy surface and the multi–phases flow.

The author lives with his wife and three children. A past project of his was building a four stories house, practically from scratch. While he writes his programs and does other computer chores, he often feels clueless about computers and programing. While he is known to look like he knows a lot a lot about many things, the author just know to learn quickly. The author spent years working on the sea (ships) as a engine sea officer but now the author prefers to remain on a solid ground.

Prologue For The POTTO Project

This books series was born out of frustrations in two respects. The first issue is the enormous price of college textbooks. It is unacceptable that the price of the college books will be over $150 per book (over 10 hours of work for an average student in The United States).

The second issue that prompted the writing of this book is the fact that we as the public have to deal with a corrupted judicial system. As individuals we have to obey the law, particularly the copyright law with the "infinite[2]" time with the copyright holders. However, when applied to "small" individuals who are not able to hire a large legal firm, judges simply manufacture facts to make the little guy lose and pay for the defense of his work. On one hand, the corrupted court system defends the "big" guys and on the other hand, punishes the small "entrepreneur" who tries to defend his or her work. It has become very clear to the author and founder of the POTTO Project that this situation must be stopped. Hence, the creation of the POTTO Project. As R. Kook, one of this author's sages, said instead of whining about arrogance and incorrectness, one should increase wisdom. This project is to increase wisdom and humility.

The POTTO Project has far greater goals than simply correcting an abusive Judicial system or simply exposing abusive judges. It is apparent that writing textbooks especially for college students as a cooperation, like an open source, is a new idea[3]. Writing a book in the technical field is not the same as writing a novel. The writing of a technical book is really a collection of information and practice. There is always someone who can add to the book. The study of technical material isn't only done by having to memorize the material, but also by coming to understand and be able to solve

[2]After the last decision of the Supreme Court in the case of Eldred v. Ashcroff (see `http://cyber.law.harvard.edu/openlaw/eldredvashcroft` for more information) copyrights practically remain indefinitely with the holder (not the creator).

[3]In some sense one can view the encyclopedia Wikipedia as an open content project (see `http://en.wikipedia.org/wiki/Main_Page`). The wikipedia is an excellent collection of articles which are written by various individuals.

related problems. The author has not found any technique that is more useful for this purpose than practicing the solving of problems and exercises. One can be successful when one solves as many problems as possible. To reach this possibility the collective book idea was created/adapted. While one can be as creative as possible, there are always others who can see new aspects of or add to the material. The collective material is much richer than any single person can create by himself.

The following example explains this point: The army ant is a kind of carnivorous ant that lives and hunts in the tropics, hunting animals that are even up to a hundred kilograms in weight. The secret of the ants' power lies in their collective intelligence. While a single ant is not intelligent enough to attack and hunt large prey, the collective power of their networking creates an extremely powerful intelligence to carry out this attack[4]. When an insect which is blind can be so powerful by networking, So can we in creating textbooks by this powerful tool.

Why would someone volunteer to be an author or organizer of such a book? This is the first question the undersigned was asked. The answer varies from individual to individual. It is hoped that because of the open nature of these books, they will become the most popular books and the most read books in their respected field. For example, the books on compressible flow and die casting became the most popular books in their respective area. In a way, the popularity of the books should be one of the incentives for potential contributors. The desire to be an author of a well–known book (at least in his/her profession) will convince some to put forth the effort. For some authors, the reason is the pure fun of writing and organizing educational material. Experience has shown that in explaining to others any given subject, one also begins to better understand the material. Thus, contributing to these books will help one to understand the material better. For others, the writing of or contributing to this kind of books will serve as a social function. The social function can have at least two components. One component is to come to know and socialize with many in the profession. For others the social part is as simple as a desire to reduce the price of college textbooks, especially for family members or relatives and those students lacking funds. For some contributors/authors, in the course of their teaching they have found that the textbook they were using contains sections that can be improved or that are not as good as their own notes. In these cases, they now have an opportunity to put their notes to use for others. Whatever the reasons, the undersigned believes that personal intentions are appropriate and are the author's/organizer's private affair.

If a contributor of a section in such a book can be easily identified, then that contributor will be the copyright holder of that specific section (even within question/answer sections). The book's contributor's names could be written by their sections. It is not just for experts to contribute, but also students who happened to be doing their homework. The student's contributions can be done by adding a question and perhaps the solution. Thus, this method is expected to accelerate the creation of these high quality books.

These books are written in a similar manner to the open source software

[4]see also in Franks, Nigel R.; "Army Ants: A Collective Intelligence," American Scientist, 77:139, 1989 (see for information `http://www.ex.ac.uk/bugclub/raiders.html`)

process. Someone has to write the skeleton and hopefully others will add "flesh and skin." In this process, chapters or sections can be added after the skeleton has been written. It is also hoped that others will contribute to the question and answer sections in the book. But more than that, other books contain data[5] which can be typeset in LaTeX. These data (tables, graphs and etc.) can be redone by anyone who has the time to do it. Thus, the contributions to books can be done by many who are not experts. Additionally, contributions can be made from any part of the world by those who wish to translate the book.

It is hoped that the books will be error-free. Nevertheless, some errors are possible and expected. Even if not complete, better discussions or better explanations are all welcome to these books. These books are intended to be "continuous" in the sense that there will be someone who will maintain and improve the books with time (the organizer(s)).

These books should be considered more as a project than to fit the traditional definition of "plain" books. Thus, the traditional role of author will be replaced by an organizer who will be the one to compile the book. The organizer of the book in some instances will be the main author of the work, while in other cases only the gate keeper. This may merely be the person who decides what will go into the book and what will not (gate keeper). Unlike a regular book, these works will have a version number because they are alive and continuously evolving.

The undersigned of this document intends to be the organizer–author–coordinator of the projects in the following areas:

Table -1. Books under development in Potto project.

Project Name	Progress	Remarks	Version	Availability for Public Download	Number DownLoads
Compressible Flow	beta		0.4.8.4	✔	120,000
Die Casting	alpha		0.1	✔	60,000
Dynamics	NSY		0.0.0	✖	-
Fluid Mechanics	alpha		0.1.8	✔	15,000
Heat Transfer	NSY	Based on Eckert	0.0.0	✖	-
Mechanics	NSY		0.0.0	✖	-
Open Channel Flow	NSY		0.0.0	✖	-
Statics	early alpha	first chapter	0.0.1	✖	-
Strength of Material	NSY		0.0.0	✖	-

[5] Data are not copyrighted.

Table -1. Books under development in Potto project. (continue)

Project Name	Progress	Remarks	Version	Availability for Public Download	Number DownLoads
Thermodynamics	early alpha		0.0.01	✖	-
Two/Multi phases flow	NSY	Tel-Aviv'notes	0.0.0	✖	-

NSY = Not Started Yet

The meaning of the progress is as:

- The Alpha Stage is when some of the chapters are already in a rough draft;
- in Beta Stage is when all or almost all of the chapters have been written and are at least in a draft stage;
- in Gamma Stage is when all the chapters are written and some of the chapters are in a mature form; and
- the Advanced Stage is when all of the basic material is written and all that is left are aspects that are active, advanced topics, and special cases.

The mature stage of a chapter is when all or nearly all the sections are in a mature stage and have a mature bibliography as well as numerous examples for every section. The mature stage of a section is when all of the topics in the section are written, and all of the examples and data (tables, figures, etc.) are already presented. While some terms are defined in a relatively clear fashion, other definitions give merely a hint on the status. But such a thing is hard to define and should be enough for this stage.

The idea that a book can be created as a project has mushroomed from the open source software concept, but it has roots in the way science progresses. However, traditionally books have been improved by the same author(s), a process in which books have a new version every a few years. There are book(s) that have continued after their author passed away, i.e., the *Boundary Layer Theory* originated[6] by Hermann Schlichting but continues to this day. However, projects such as the Linux Documentation project demonstrated that books can be written as the cooperative effort of many individuals, many of whom volunteered to help.

Writing a textbook is comprised of many aspects, which include the actual writing of the text, writing examples, creating diagrams and figures, and writing the

[6]Originally authored by Dr. Schlichting, who passed way some years ago. A new version is created every several years.

LaTeX macros[7] which will put the text into an attractive format. These chores can be done independently from each other and by more than one individual. Again, because of the open nature of this project, pieces of material and data can be used by different books.

[7] One can only expect that open source and readable format will be used for this project. But more than that, only LaTeX, and perhaps troff, have the ability to produce the quality that one expects for these writings. The text processes, especially LaTeX, are the only ones which have a cross platform ability to produce macros and a uniform feel and quality. Word processors, such as OpenOffice, Abiword, and Microsoft Word software, are not appropriate for these projects. Further, any text that is produced by Microsoft and kept in "Microsoft" format are against the spirit of this project In that they force spending money on Microsoft software.

Prologue For This Book

Version 0.4.9 pp. ? Feb ?, 2012

over 400,000 downloads

In the last three years the focus was on building the fluid mechanics book. In the construction of the fluid book the potto style file significantly changed to the the point that render the old files of book as un–compilable. This work was to bring these file up to date. Several chapters from that the fluid book were summarized into single introduction chapter on Fluid Mechanics. There are several additions which include better description of the shock tube, and sound in variable liquid density etc.

Version 0.4.8.5a . July 21, 2009

over 150,000 downloads

The spread of the book was the biggest change that can be observed during the last year (more than a year). Number of download reached to over 160,000 copies. The book became the main textbook in many universities. This time, the main work focused on corrections and minor additions. The fluid mechanics book is under construction and reached to 0.17x version. Hopefully when finished, with good help in the coming months will be used in this book to make better introduction. Other material in this book like the gas dynamics table and equation found their life and very popular today. This additions also include GDC which become the standard calculator for the gas dynamics class.

Version 0.4.8 Jan. 23, 2008

It is more than a year ago, when the previous this section was modified. Many things have changed, and more people got involved. It nice to know that over 70,000 copies have been download from over 130 countries. It is more pleasant to find that this book is used in many universities around the world, also in many institutes like NASA (a tip from Dr. Farassat, NASA "to educate their "young scientist, and engineers") and others. Looking back, it must be realized that while, this book is the best in many areas, like oblique shock, moving shock, fanno flow, etc there are missing some sections, like methods of characteristics, and the introductory sections (fluid mechanics, and thermodynamics). Potto–GDC is much more mature and it is changing from "advance look up" to a real gas dynamics calculator (for example, calculation of unchoked Fanno Flow). Today Potto–GDC has the only capability to produce the oblique shock figure. Potto-GDC is becoming the major educational educational tool in gas dynamics. To kill two birds in one stone, one, continuous requests from many and, two, fill the introductory section on fluid mechanics in this book this area is major efforts in the next few months for creating the version 0.2 of the "Basic of Fluid Mechanics" are underway.

Version 0.4.3 Sep. 15, 2006

The title of this section is change to reflect that it moved to beginning of the book. While it moves earlier but the name was not changed. Dr. Menikoff pointed to this inconsistency, and the author is apologizing for this omission.

Several sections were add to this book with many new ideas for example on the moving shock tables. However, this author cannot add all the things that he was asked and want to the book in instant fashion. For example, one of the reader ask why not one of the example of oblique shock was not turn into the explanation of von Neumann paradox. The author was asked by a former client why he didn't insert his improved tank filling and evacuating models (the addition of the energy equation instead of isentropic model). While all these requests are important, the time is limited and they will be inserted as time permitted.

The moving shock issues are not completed and more work is needed also in the shock tube. Nevertheless, the ideas of moving shock will reduced the work for many student of compressible flow. For example solving homework problem from other text books became either just two mouse clicks away or just looking at that the tables in this book. I also got request from a India to write the interface for Microsoft. I am sorry will not be entertaining work for non Linux/Unix systems, especially for Microsoft. If one want to use the software engine it is okay and permitted by the license of this work.

The download to this mount is over 25,000.

Version 0.4.2

It was surprising to find that over 14,000 downloaded and is encouraging to receive over 200 thank you eMail (only one from U.S.A./Arizona) and some other reactions. This textbook has sections which are cutting edge research[8].

The additions of this version focus mainly on the oblique shock and related issues as results of questions and reactions on this topic. However, most readers reached to www.potto.org by searching for either terms "Rayleigh flow" (107) and "Fanno flow" ((93). If the total combined variation search of terms "Fanno" and "Rayleigh" (mostly through google) is accounted, it reaches to about 30% (2011). This indicates that these topics are highly is demanded and not many concerned with the shock phenomena as this author believed and expected. Thus, most additions of the next version will be concentrated on Fanno flow and Rayleigh flow. The only exception is the addition to Taylor–Maccoll flow (axisymmetricale conical flow) in Prandtl–Meyer function (currently in a note form).

Furthermore, the questions that appear on the net will guide this author on what is really need to be in a compressible flow book. At this time, several questions were about compressibility factor and two phase flow in Fanno flow and other kind of flow models. The other questions that appeared related two phase and connecting several chambers to each other. Also, an individual asked whether this author intended to write about the unsteady section, and hopefully it will be near future.

Version 0.4

Since the last version (0.3) several individuals sent me remarks and suggestions. In the introductory chapter, extensive description of the compressible flow history was written. In the chapter on speed of sound, the two phase aspects were added. The isothermal nozzle was combined with the isentropic chapter. Some examples were added to the normal shock chapter. The fifth chapter deals now with normal shock in variable area ducts. The sixth chapter deals with external forces fields. The chapter about oblique shock was added and it contains the analytical solution. At this stage, the connection between Prandtl–Meyer flow and oblique is an note form. The a brief chapter on Prandtl–Meyer flow was added.

Version 0.3

In the traditional class of compressible flow it is assumed that the students will be aerospace engineers or dealing mostly with construction of airplanes and turbomachinery. This premise should not be assumed. This assumption drives students from other fields away from this knowledge. This knowledge should be spread to other fields because it needed there as well. This "rejection" is especially true when students feel that they have to go through a "shock wave" in their understanding.

[8] A reader asked this author to examine a paper on Triple Shock Entropy Theorem and Its Consequences by Le Roy F. Henderson and Ralph Menikoff. This led to comparison between maximum to ideal gas model to more general model.

This book is the second book in the series of POTTO project books. POTTO project books are open content textbooks. The reason the topic of Compressible Flow was chosen, while relatively simple topics like fundamentals of strength of material were delayed, is because of the realization that manufacture engineering simply lacks fundamental knowledge in this area and thus produces faulty designs and understanding of major processes. Unfortunately, the undersigned observed that many researchers who are dealing with manufacturing processes are lack of understanding about fluid mechanics in general but particularly in relationship to compressible flow. In fact one of the reasons that many manufacturing jobs are moving to other countries is because of the lack of understanding of fluid mechanics in general and compressible in particular. For example, the lack of competitive advantage moves many of the die casting operations to off shore[9]. It is clear that an understanding of Compressible Flow is very important for areas that traditionally have ignored the knowledge of this topic[10].

As many instructors can recall from their time as undergraduates, there were classes during which most students had a period of confusion, and then later, when the dust settled, almost suddenly things became clear. This situation is typical also for Compressible Flow classes, especially for external compressible flow (e.g. flow around a wing, etc.). This book offers a more balanced emphasis which focuses more on internal compressible flow than the traditional classes. The internal flow topics seem to be common for the "traditional" students and students from other fields, e.g., manufacturing engineering.

This book is written in the spirit of my adviser and mentor E.R.G. Eckert. Who, aside from his research activity, wrote the book that brought a revolution in the heat transfer field of education. Up to Eckert's book, the study of heat transfer was without any dimensional analysis. He wrote his book because he realized that the dimensional analysis utilized by him and his adviser (for the post doc), Ernst Schmidt, and their colleagues, must be taught in engineering classes. His book met strong criticism in which some called to burn his book. Today, however, there is no known place in world that does not teach according to Eckert's doctrine. It is assumed that the same kind of individuals who criticized Eckert's work will criticize this work. This criticism will not change the future or the success of the ideas in this work. As a wise person says "don't tell me that it is wrong, show me what is wrong"; this is the only reply. With all the above, it must be emphasized that this book will not revolutionize the field even though considerable new materials that have never been published are included. Instead, it will provide a new emphasis and new angle to Gas Dynamics.

Compressible flow is essentially different from incompressible flow in mainly two respects: discontinuity (shock wave) and choked flow. The other issues, while important, are not that crucial to the understanding of the unique phenomena of compressible flow. These unique issues of compressible flow are to be emphasized and

[9] Please read the undersigned's book "Fundamentals of Die Casting Design," which demonstrates how ridiculous design and research can be.

[10] The fundamental misunderstanding of choking results in poor models (research) in the area of die casting, which in turn results in many bankrupt companies and the movement of the die casting industry to offshore.

shown. Their applicability to real world processes is to be demonstrated[11].

The book is organized into several chapters which, as a traditional textbook, deals with a basic introduction of thermodynamics concepts (under construction). The second chapter deals with speed of sound. The third chapter provides the first example of choked flow (isentropic flow in a variable area). The fourth chapter deals with a simple case of discontinuity (a simple shock wave in a nozzle). The next chapter is dealing with isothermal flow with and without external forces (the moving of the choking point), again under construction. The next three chapters are dealing with three models of choked flow: Isothermal flow[12], Fanno flow and Rayleigh flow. First, the Isothermal flow is introduced because of the relative ease of the analytical treatment. Isothermal flow provides useful tools for the pipe systems design. These chapters are presented almost independently. Every chapter can be "ripped" out and printed independently. The topics of filling and evacuating of gaseous chambers are presented, normally missed from traditional textbooks. There are two advanced topics which included here: oblique shock wave, and properties change effects (ideal gases and real gases) (under construction). In the oblique shock, for the first time analytical solution is presented, which is excellent tool to explain the strong, weak and unrealistic shocks. The chapter on one-dimensional unsteady state, is currently under construction.

The last chapter deals with the computer program, Gas Dynamics Calculator (CDC-POTTO). The program design and how to use the program are described (briefly).

Discussions on the flow around bodies (wing, etc), and Prandtl–Meyer expansion will be included only after the gamma version unless someone will provide discussion(s) (a skeleton) on these topics.

It is hoped that this book will serve the purposes that was envisioned for the book. It is further hoped that others will contribute to this book and find additional use for this book and enclosed software.

[11] If you have better and different examples or presentations you are welcome to submit them.

[12] It is suggested to referred to this model as Shapiro flow

How This Book Was Written

This book started because I needed an explanation for manufacturing engineers. Apparently many manufacturing engineers and even some researchers in manufacturing engineering were lack of understanding about fluid mechanics in particularly about compressible flow. Therefore, I wrote to myself some notes and I converted one of the note to a chapter in my first book, "Fundamentals Of Die Casting Design." Later, I realized that people need down to earth book about compressible flow and this book was born. Later I need a chapter on fluid mechamics introduction so I wrote about fluid mechacnics and several of the chapter from that book were summirized to be included in this book.

The free/open content of the book was created because the realization that open content accelerated the creation of books and reaction to the corruption of the court implementing the copyright law by manufacturing facts and laws. It was farther extended by the allegation of free market and yet the academic education cost is sky rocketing without a real reason and real competition. There is no reason why a textbook which cost at the very most $10 to publish/produce to cost about 150 dollars. If a community will pull together, the best books can be created. Anyone can be part of it. For example, even my 10 years old son, Eliezer made me change the chapter on isothermal flow. He made me realized that the common approach to supersonic branch of isothermal as non–existent is the wrong approach. It should be included because this section provides the explanation and direction on what Fanno flow model will approach if heat transfer is taken into account[13].

I realized that books in compressible flow are written in a form that is hard for non fluid mechanic engineer to understand. Therefore, this book is designed to be in such form that is easy to understand. I wrote notes and asked myself what materials should be included in such a book so when I provide consultation to a company, I do not need to explain the fundamentals. Therefore, there are some chapters in this book

[13]Still in untyped note form.

which are original materials never published before. The presentation of some of the chapters is different from other books. The book does not provide the old style graphical solution methods yet provide the graphical explanation of things.

Of course, this book was written on Linux (MicrosoftLess book). This book was written using the vim editor for editing (sorry never was able to be comfortable with emacs). The graphics were done by TGIF, the best graphic program that this author experienced so far. The old figures were done by grap (part the old Troff). Unfortunately, I did not have any access to grap and switched to Grace. Grace is a problematic program. Finally, the gle is replacing the old grace. So far, it seems much better choice and from version 0.4.8 all will be done using GLE. The spell checking was done by gaspell, a program that cannot be used on a new system and I had to keep my old Linux to make it work[14]. I hope someone will write a new spell check so I can switch to a new system.

The figure in the cover page was created by Michael Petschauer, graphic designer, and is open/free content copyrighted by him (happy_circle@yahoo.com).

[14] If you would like to to help me to write a new spell check user interface, please contact me.

About Gas Dynamics Calculator

Gas Dynamic Calculator, (Potto–GDC) was created to generate various tables for the book either at end the chapters or for the exercises. This calculator was given to several individuals and they found Potto–GDC to be very useful. So, I decided to include Potto–GDC to the book.

Initially, the Potto-GDC was many small programs for specific tasks. For example, the stagnation table was one such program. Later, the code became a new program to find the root of something between the values of the tables e.g. finding parameters for a given $\frac{4fL}{D}$. At that stage, the program changed to contain a primitive interface to provide parameters to carry out the proper calculations. Yet, then, every flow model was a different program.

When it become cumbersome to handle several programs, the author utilized the object oriented feature of C++ and assigned functions to the common tasks to a base class and the specific applications to the derived classes. Later, a need to intermediate stage of tube flow model (the PipeFlow class) was created and new classes were created.

The graphical interface was created only after the engine was written. The graphical interface was written to provide a filter for the unfamiliar user. It also remove the need to recompile the code every time.

Version 0.5

In this version the main point was on the bugs fixing but also add the results can be shown in a HTML code. In fanno flow, many problems of unchoked Fanno flow now possible to solve (by one click).

Version 0.4.3

This version add several features among them is the shock dynamics calculations with the iteration info. The last feature is good for homework either for the students or the instructors.

Version 0.4.1.7

Version 4.1.7 had several bug fixes and add two angle calculations to the oblique shock. Change the logtable to tabular environment for short tables.

Preface

"In the beginning, the POTTO project was without form, and void; and emptiness was upon the face of the bits and files. And the fingers of the Author moved upon the face of the keyboard. And the Author said, Let there be words, and there were words."[15].

This book, Fundamentals of Compressible Flow, describes the fundamentals of compressible flow phenomena for engineers and others. This book is designed to replace the book(s) or instructor's notes for the compressible flow in (mostly) undergraduate classes for engineering/science students. It is hoped that the book could be used as a reference book for people who have at least some knowledge of the basics of fundamental fluid mechanics, and basic science such as calculus, physics, etc. It is hoped that the computer program enclosed in the book will take on a life of its own and develop into an open content or source project.

The structure of this book is such that many of the chapters could be usable independently. For example, if you need information about, say, Fanno flow, you can read just chapter 10. I hope this makes the book easier to use as a reference manual. However, this manuscript is first and foremost a textbook, and secondly a reference manual only as a lucky coincidence.

I have tried to describe why the theories are the way they are, rather than just listing "seven easy steps" for each task. This means that a lot of information is presented which is not necessary for everyone. These explanations have been marked as such and can be skipped.[16] Reading everything will, naturally, increase your understanding of the fundamentals of compressible fluid flow.

This book is written and maintained on a volunteer basis. Like all volunteer work, there is a limit on how much effort I was able to put into the book and its

[15] To the power and glory of the mighty God. This book is only to explain his power.

[16] At the present, the book is not well organized. You have to remember that this book is a work in progress.

organization. Moreover, due to the fact that English is my third language and time limitations, the explanations are not as good as if I had a few years to perfect them. Nevertheless, I believe professionals working in many engineering fields will benefit from this information. This book contains many original models, and explanations never published before.

I have left some issues which have unsatisfactory explanations in the book, marked with a Mata mark. I hope to improve or to add to these areas in the near future. Furthermore, I hope that many others will participate of this project and will contribute to this book (even small contributions such as providing examples or editing mistakes are needed).

I have tried to make this text of the highest quality possible and am interested in your comments and ideas on how to make it better. Incorrect language, errors, ideas for new areas to cover, rewritten sections, more fundamental material, more mathematics (or less mathematics); I am interested in it all. If you want to be involved in the editing, graphic design, or proofreading, please drop me a line. You may contact me via Email at "barmeir@gmail.com".

Naturally, this book contains material that never was published before. This material never went through a peer review. While peer review and publication in a professional publication is excellent idea in theory. In practice, this process leaves a large room to blockage of novel ideas and plagiarism. If you would like be "peer reviews" or critic to my new ideas please send me your idea(s). Even reaction/comments from individuals like David Marshall[17]

Several people have helped me with this book, directly or indirectly. I would like to especially thank to my adviser, Dr. E. R. G. Eckert, whose work was the inspiration for this book. I also would like to thank Amy Ross for her advice ideas, and assistance. Our new volunteer, Irene Tan had done wonderful job.

The symbol META was added to provide typographical conventions to blurb as needed. This is mostly for the author's purposes and also for your amusement. There are also notes in the margin, but those are solely for the author's purposes, ignore them please. They will be removed gradually as the version number advances.

I encourage anyone with a penchant for writing, editing, graphic ability, LaTeX knowledge, and material knowledge and a desire to provide open content textbooks and to improve them to join me in this project. If you have Internet e-mail access, you can contact me at "barmeir@gmail.com".

[17]Dr. Marshall wrote to this author that the author should review other people work before he write any thing new (well, literature review is always good?). Over ten individuals wrote me about this letter. I am asking from everyone to assume that his reaction was innocent one. While his comment looks like unpleasant reaction, it brought or cause the expansion the oblique shock chapter. However, other email that imply that someone will take care of this author aren't appreciated.

To Do List and Road Map

This book is not complete and probably never will be completed. There will always new problems to add or to polish the explanations or include more new materials. Also issues that associated with the book like the software has to be improved. It is hoped the changes in TEX and LATEX related to this book in future will be minimal and minor. It is hoped that the style file will be converged to the final form rapidly. Nevertheless, there are specific issues which are on the "table" and they are described herein.

At this stage, several chapters are missing. The effects of the deviations from the ideal gas model on the properties should be included. Further topics related to non-ideal gas such as steam and various freons are in the process of being added to this book especially in relationship to Fanno flow.

One of the virtue of this book lay in the fact that it contains a software that is extensible. For example, the Fanno module can be extended to include effects of real gases. This part will be incorporated in the future hopefully with the help of others.

Specific missing parts from every chapters are discussed below. These omissions, mistakes, approach problems are sometime appears in the book under the Meta simple like this

Meta

sample this part.

Meta End

Questions/problems appear as a marginal note. On occasions a footnote was used to point out for a need of improvement. You are always welcome to add a new material: problem, question, illustration or photo of experiment. Material can be further illuminate. Additional material can be provided to give a different angle on the issue at hand.

Speed of Sound [beta]

- Discussion about the movement in medium with variation in speed of sound. This concept in relation of the wind tunnel
- Problems with atmosphere with varied density and temperature. Mixed gases and liquids. (some what done)
- More problems in relationship to two phase. Speed of sound in wet steam.

Stagnation effects [advance]

- Extend the applicability with examples.
- C_p as a function of temperature (deviation from ideal gas model) "real gas"' like water vapor
- History – on the teaching part (for example when the concept of stagnation was first taught).

Nozzle [advance]

- The effect of external forces (add problems).
- Real gases effects (mere temperature effects)
- Flow with "tabulated gases" calculations
- Phase change and two phase flow (multi choking points) effects (after 1.0 version).
- The dimensional analysis of the flow when the flow can be considered as isothermal.
- The combined effects of isentropic nozzle with heat transfer (especially with relationship to the program.).

Normal Shock [advance]

- Extend the partially (open/close) moving shock theory. [done]
- Provide more examples on the previous topic.
- Shock in real gases like water vapor.
- Shock in (partially) two phase gases like air with dust particles.
- Extend the shock tube [almost done]
- Shocks in two and three dimensions.

Minor Loss [NSV]

- Abrupt expansion
- Flow in Bend

Isothermal Flow [advance]

- Classification of Problems
- Comparison of results with Fanno flow
- Pipes Network calculations.

Fanno Flow [advance]

- More examples: various categories
- Some improvement on the software (clean up)
- Real gas effects (compressible factor)
- Tabulated gas

Rayleigh Flow [beta]

- To mature the chapter: discussion on the "dark" corners of this model.
- Provide discussion on variations of the effecting parameters.
- Examples: provide categorization

Add mass [NSY]

- Simple add mass in a continuous form

Evacuation and filling semi rigid Chambers [alpha]

- To construct the Rayleigh flow in the tube (thermal chocking)
- Energy equation (non isentropic process)
- Examples classifications
- Software (converting the FORTRAN program to c++)

Evacuating and filling chambers under external forces [alpha]

- Comparison with chemical reaction case
- Energy equation (non isentropic process)
- Examples
- Software transformation from FORTRAN to c++. The FORTRAN version will not be included.

Oblique Shock [advance]

- Add application to design problems
- Real Gas effects

Prandtl–Meyer

- The limitations (Prandtl-Meyer) (done).
- Application
- Cylindrical coordinate
- Marcell–Taylor (from the notes)
- Examples

Transient problem [NYP]

- Method of Characteristic

General 1-D flow [NYP]