Why and how to draw a bold typeface to accompany a regular

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Abstract

This paper defines a method for analysing bold letters and provides advice for designers on how to draw a bold weight typeface to accompany a regular weight. In order to define the importance of bold in typesetting, applicable uses of bold are defined and the context in which bold emerged as a practical typographic tool for printers is explained. These chapters are followed by descriptions of existing theories for designing bold letters and a methodology for analysing bolds from the first era of font families. The methodology for data analysis is derived from existing studies in letterforms. The range of topographical metrics of the letterforms analysed are derived from existing practices and the principle aspects of bold letters. The paper then describes conclusions drawn from the data gathered. A correlation is found between the results of existing theories and the results drawn from this study on how to draw bold letters. This study also goes on to define other rates of gain and changes in letterforms between regular and bold which have previously not been defined in the literature. The outcome is the description and results of a process of analysis which can help type designers draw bold letters.

The formatting of this paper was completed by the author. Images and illustrations are as credited throughout.

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Figure 1
The image shows a regular and bold 24pt Plantin letter s overlayed in order to compare stem weight, contrast increase, x-height *etc*. See Appendix B for a full collection of the regular and bold specimen images used in the study. Images collected by the author.

1. Goals, methods, and structure

The goal of this paper is to provide practical advice for type designers looking to draw a bold; to describe a methodology of letter analysis which can be replicated by other designers; and to demonstrate that in order a draw a competent bold it is important to understand how different topographical aspects of letters change in form as weight is added to them.

The first section of this paper explains the historical conditions in-which bold emerged as a necessary counterpart to regular, and how bold has been used in various aspects of typesetting. The second section of the paper goes on to offer a comparative methodology for analysing regular and bold. Then presented is a demonstration of the application of this methodology by an analysis of a broad selection of typefaces from the first era of type families which included related bolds. The paper concludes with the results of this analysis and provides guidelines for type designers looking to design a bold.

It should be noted that practicing type designers were not interviewed for this paper. This is due to the limited time-scale available to make this study. However, interviewing experienced designers about their methods of drawing accompanying bolds would provide useful insights. Similarly, due to times-cale, this research only focuses on the upper- and lowercase Latin alphabet. The research and methods in this study are applicable to other writing systems. However, the study presented here is by no means definitive. Further practical research and comparison of regular and bold would only benefit a type designer interested in the subject.

I.
Background of bold

[Bold offers] greatly increased advantages of attraction to vision, and consequent impression on memory
– Bell, J. 1842

2. Where is bold used and why?

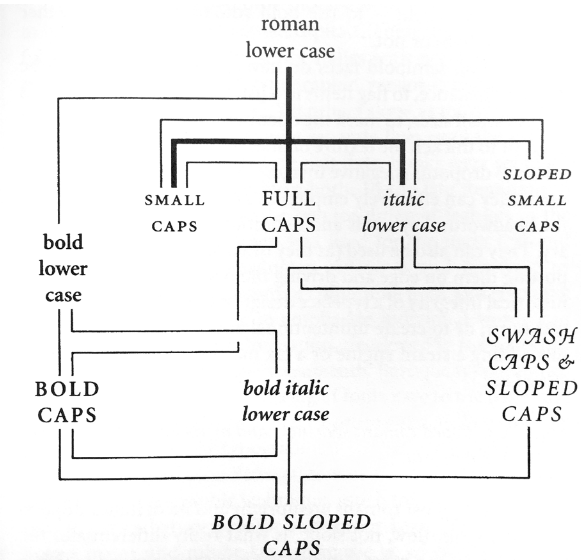
2.1 Bold in lines and paragraphs of text

'Bold' is a term that defines the characteristics of a letter in relation to a 'regular' weighted counterpart. This distinction is not merely practical but also semantic. Bold by definition stands out. So, the question of *why use bold?* is the same as *why use contrast?* Bold letters have thicker stems[1] and are by definition darker and boost overall colour contrast on a page. The higher contrast of bold letters is more memorable and draws the attention of a viewer[2]. In this chapter, the terms *hierarchy, emphasis* and *distinction* describe the tools by which the attention of the reader is gotten. In the context of the situations described below maintaining the readers attention is the aim of the writer, designer, editor or printer.

As shall be discussed in chapter 3, the utility of a heavy weighted letter set alongside a regular weight (of a different design) in order to add emphasis has long been known. The use of heavy blackletter type was described by John Smith in *Printer's Grammar,* 1755 to be useful for *"matter which the Author would particularly enforce to the reader."* [3]. In this chapter it will be shown that the sparing use of emphasis and distinction on a page in order to devise hierarchies of text has always been of practical-use to editors, printers, readers and designers when setting documents.

The recommended practice of using bold in books, documents, labelling and reference is well covered in style guides and manuals (for example, The Chicago Manual of Style[4], the Oxford Guide to Style[5], Robert Bringhurst's Elements of Typographic Style[6], *et al*) aimed at a range of different users. While it is generally stressed that bold be used sparingly in order to most efficiently draw a readers attention, differences in the practice of using bold do exist between different design needs. As shall be shown in this chapter, directions for use of bold in the historically formal environment of literary book design differs from the legally enforced guidelines of food packaging. Similarly, the use of bold in highly complicated sets of text in scientific reference books differs from how bold has been suggested to be used on government issued forms and even in the referencing of naval vessels. This chapter will cover a variety of ways printers, editors and designers have been directed to use bold.

Figure 1
Hierarchy of text. Bringhurst, R. (2001) E*lements of Typographic Style,* pp.55



2.2 Bold in a hierarchy of text

A hierarchy of text is described by Robert Bringhurst in *Elements of Typographic Style,* 1992 in diagrams as a branching tree of ever-less used yet ever-more attention grabbing settings of type[7] (see Figure 1). From the most often used lowercase regular; to italic for emphasis in a paragraph, or bold in a list; to the less-used uppercase roman for headings; then to the sparingly used uppercase bold for large titles. Bringhurst suggests that however rare on a page bolds should be by comparison to regular, they are best used,

to flag items in a list; to set titles and subheads u&lc in small sizes; to

1 Font Forge (n.d), *Stylistic Transformations on Fonts* Online at https://fontforge.github.io/en-US/documentation/interface/Styles/ Accessed 20 August 2019
2 *"[Bold offers] greatly increased advantages of attraction to vision, and consequent impression on memory"* Bell, J. (1842) *A View of Universal History,* London, pp.9 First seen by the author in Twyman, M. (1993) *The Bold Idea,* Journal of the Printing Historical Society 22 pp.124
3 Smith, J. (1755) *Printers Grammar,* London, pp.18
4 Chicago Manual of Style, (1993) *Design and Typography: Alphabets,* Chicago, Sec 18.12 pp.768
5 Ritter, R. *Oxford Guide to Style,* (2002) Oxford Sec 13.3.3 pp.426
6 Bringhurst, R. (2001) *Elements of Typographic Style,* Hartley & Marks, pp.53
7 Ibid, pp.52

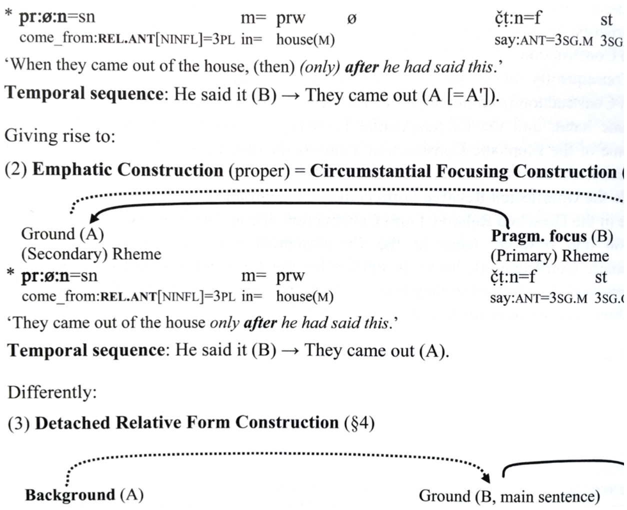
mark the opening of the text on a complex page; ... Sparingly used they can effectively emphasise numbers or words, such as the headwords, keywords and definition numbers in a dictionary[8].

Sparing use of bold is a common theme in many typographic guides. The *Oxford Guide to Style,* 2002 edition, recommends that writers, editors and designers avoid using bold whenever possible[9]. If bold is to be used it should only appear,

in complex analysis where other typographical distinctions (*italic, small capitals, underlines*) *have already been used.*[10]

Sparing use primarily in indexing is also the recommendation of the The *Chicago Manual of Style*[11], which suggests that bold has a function in the setting of the numerals used for cross-referencing and indexing. Similarly, Jost Hochuli in *Detail in Typography*, 2008 translation[12], explains that dictionaries and reference work are not read linearly, and that bold as a form of emphasis is necessary in reference works and schoolbooks. Bold emphasis (along with italic, small caps etc) is useful in non-linear reading[13] in-order to draw the eye to key information (see Figure 2). The same suggestion is made by Mitchel & Wightman in *Typographic Style Handbook,* 2017,

Figure 2
Bold emphasis useful in non linear reading. Grossman, E., Polis, A., Stauder, A., Winand, J., (2014) *On Forms and Functions: Studies in Ancient Egyptian Grammar,* Hamburg: Widmaier Verlag



Bold and semibold are not to be used in text. Bold and semibold are used to highlight words numbers in informational publications.[14]

The *Chicago Manual of Style*[15] also suggests using bold in complex indexing as a means of differentiating illustrative materials by their medium. For example, where photographic page references require more emphasis. The *Oxford Guide to Style,* 2002 edition explains that:

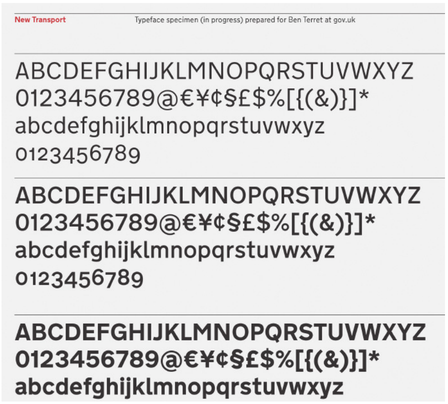
Bold is often used for headwords in dictionaries; bibliographies and reference lists; indexing and cross-referencing generally, to distinguish between types of reference or their degree of importance; and titles and headings in tables.[16]

Complex hierarchies of text like dictionaries, encyclopaedias, reference books and even train timetables require speedy and efficient use. Using emphasis on a complex page of information is a common strategy and has been used for a long time by printers, editors and designers as shall be shown in chapter 3.

However, as will be discussed in chapter 3, bold is a relatively new invention in typography. Robert Bringhurst in *Elements of Typographic Style* notes that generations of typographers have faired well without using bold[17]. But, despite the aid of contemporary digital technology and the ease of switching to using bolds, manuals of style in various fields have continually stressed that bold should be used only in a limited fashion as part of a larger hierarchy of text styles. Their sparing use allows for bolds to emphasise key information.

8 Ibid
9 Ritter, R. *Oxford Guide to Style,* (2002) Oxford Sec 13.3.3 pp.426
10 Ibid
11 Chicago Manual of Style, (1993) *Design and Typography: Alphabets,* Chicago, Sec 18.12 pp.768
12 Hochuli, J. (1987) *Detail in Typography* Hyphen Press pp.46
13 Hochuli also suggests that repetitive use of bold can hinder linear reading, pp.44
14 Mitchel, M., Wightman, S. (2017) *Typographic Style Handbook,* MacLehose Press Sec 2.2.1 pp.51
15 Chicago Press, *Chicago Manual of Style,* (1993) Sec 17.142 pp.755
16 Ritter, R. *Oxford Guide to Style,* (2002), Oxford, Sec 6.8.1 pp.163
17 Bringhurst, R. (2001) *Elements of Typographic Style,* Hartley & Marks, pp.52

FIGURE 3
GDS Transport. Online at https://designnotes.blog.gov.uk/2015/03/11/can-i-use-the-gov-uk-fonts/accessed 17 July 2019



2.3 Bold as emphasis in text

Bold can be used to emphasise key information in non-linear text. One area where this done is in government issued documents. Government issued forms are required to convey easily interpretable and consistent information[18]. Using aspects of layout and emphasis in a form or website helps readers understand information being relayed. As well as giving a sense of familiarity to readers[19]. In order to do this, the UK government issued a style guide for web developers which suggests the use of bold to *emphasise particular words in a transaction*[20]. As well as to *high-light critical information*[21] like reference numbers of personal email addresses that users *need to refer to.* Again, the UK government suggests using bold sparingly as,

overuse will make it difficult for users to know which parts of your content they need to pay the most attention to.[22]

The same suggestion appears in the 1983 University of Reading *Forms Information Centre* guidelines, which explains that,

Bolds are extremely useful for emphasising headings or important words or phrases within text. As with any form of emphasis, bold should be used sparingly if it is to have maximum impact.[23]

Notably, the custom font GDS Transport[24] used by the UK government contains no italic (see Figure 3). So bold is the primary tool for emphasis in hierarchies of texts on UK governmental websites, along with underlining and colour[25].

The 1983 Department of Health and Social Security *Good Forms Guide* suggested avoiding confusing a reader with a multitude of hierarchies of text[26]. Different methods of emphasis risk diluting a message or misleading a reader. The *Good Forms Guide* recommends using one form of emphasis such as *size, slant, bold, underline, capitals, use of colour, text set apart from main text.* Emphasising critical information for readers is an important aspect of form design.

Bold can be used as an authoritative and clear means of emphasis in official communication. In some government cases its use is also tightly dictated. For example, *US Government Printing Office Style Manual,* 1973 has a several well defined uses for bold in officially printed documents. In long and complex tables of information, bold should be used for emphasis in numerals and additionally bold caps used for the term 'continued'[27] when a table runs over several pages. However, use of emphasis is not only restricted to tables and page navigation. According to the *US Government Printing Office Style Manual,* 1973, names of sea vessels can also be printed in bold[28].

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18 *"We should use the same language and the same design patterns wherever possible. This helps people get familiar with our services, but when this isn't possible we should make sure our approach is consistent."* Online at https://www.gov.uk/guidance/government-design-principles#be-consistent-not-uniform Accessed 31 May 2019
19 Ibid
20 UK Government (n.d.) *Styles: Typography* Online at https://design-system.service.gov.uk/styles/typography/ Accessed 31 May 2019
21 Ibid
22 Ibid
23 University of Reading (1983) *Forms Design Centre, Topic Sheet 1, Legibility* Forms Information Centre: Reading, Sec 5
24 UK Government (n.d.) *Styles: Typography* Online at https://design-system.service.gov.uk/styles/typography/#font Accessed 31 May 2019
25 UK Government (n.d.) *Styles: Colour* Online at https://design-system.service.gov.uk/styles/colour/ Accessed 31 May 2019
26 Department of Health and Social Security (1983) *Good Forms Guide: Worksheet 5, Emphasis,* The DHSS Forms Unit
27 US Government (1973) *Printing Office Style Manual: Tabular work, Continued heads,* Sec 13.53 pp.196
28 Ibid, *Italic* Sec 11.7 pp.175

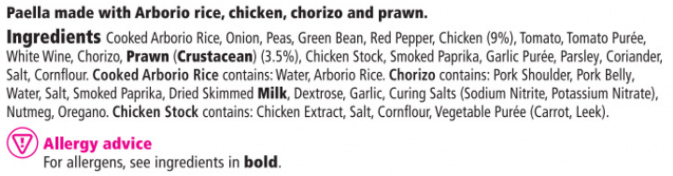


FIGURE 4
EU Food packaging. Allergens are listed in bold so as to be emphasised. Dakota Intergrated Solutions (2014) *Currently printing barcode labels for food products? Are you compliant with the EU Food Allergen Labeling Regulation?* Online at https://dakotais.co.uk/pages/currently-printing-barcode-labels-for-food-products-are-you-compliant-wiht-the-eu-food-allergen-labelling-regulation- Accessed 18 July 2019

2.4 Bold as distinction in text

Where as bold helps emphasise text within a non-linear textual hierarchy, bold can also be used as a means of distinction within in running text. Drawing a readers attention to the names of things can be important in a variety of situations. One vital aspect of this need for distinction is in food labelling and highlighting of allergens amongst other ingredients. The EU instructs food producers (and label designers) that ingredients which cause allergies and dietary intolerances need to be distinguished[29] (see Figure 4). Article 21 / 1b states:

the name of the substance or product as listed in Annex II shall be emphasised through a typeset that clearly distinguishes it from the rest of the list of ingredients, for example by means of the font, style or background colour.

For example, in the EU a product containing wheat will need to make clear this fact in its ingredients listing. A simple and effective way in which to distinguish text in the formal environment of nutrition label on the reverse side of packaging is by use of bold.

In scientific writing bold is used in a variety of ways to distinguish components of names and formulae. In the editorial guide *Scientific Style and Format,* 1994, it is suggested that the key letters in spelt-out acronyms are set in bold[30]. For example,

AIDS = ***a***cquired ***i***mmuno***d***eficiency ***s***yndrome.

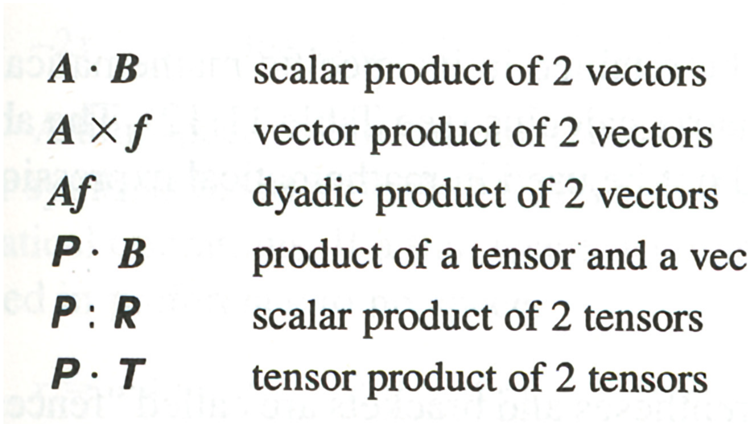


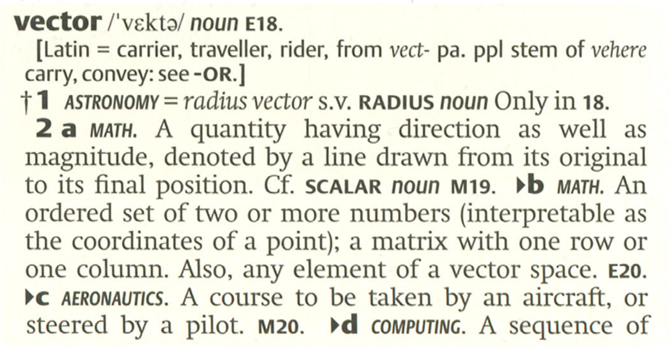
FIGURE 5
Council of Biology Editors (1994) *Scientific Style and Format,* Sec 11.18 pp.211

In reading environments rich in acronymised terminology, bold is a clear means of drawing attention to the important beats within long scientific descriptions.

Similarly, *Scientific Style and Format,* 1994, suggests that tensors are set in bold italic[31] so as to be visually distinct from mathematically similar scalars[32]. The complexity required for long mathematical and scientific expressions often pushes the limitations of digital typesetting[33]. What can be easily written by hand is a lot more complicated in a digital setting. For example, vectors in mathematical expressions when written by hand would have an arrow above them. This could be achieved in a font with contextual alternates, but would require the end-user to turn them on and off – combined with thousands of other typographic demands in scientific and mathematical formulae writing, using a .calt feature could also be inefficient. Mathematical expressions are so numerous that they are written in Latin, Greek, German Fraktur and Hebrew as a means of shorthand. The solution given in *Scientific Style and Format,* 1994, is that vectors should be written in bold italic[34] (see Figure 5), instead of with an arrow above. The heavier letter makes a distinction from what surrounds and the italic indicates the motion of the arrow.

29 Official Journal of the European Union (2011) *Annex II to Regulation (EU) No 1169/2011 of the European Parliament and of the Council on the provision of food information.* Online at https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2011:304:0018:0063:EN:PDF Accessed 31 May 2019
30 Council of Biology Editors (1994) *Scientific Style and Format,* Sec 9.4 pp.171
31 Ibid, Sec 11.15 pp.208-209
32 A tensor is a geometric mathematical object which describes a space. A scalar is a simplified tensor. They are both common in physics and engineering.
33 John Hudson (2012) *Scholarly Types: Cambria Math* Online at https://youtu.be/DT5Qn_Dhiqk?t=1668 Accessed 31 May 2019
34 Council of Biology Editors (1994) *Scientific Style and Format,*Sec 9.4 pp.171

Figure 6
Shorter Oxford English dictionary, 5th edition, 2002. Luna, P. (2017) *Information Design: Choosing type for information design,* Routledge pp.484


vector /ˈvɛktə/ *noun* **E18.**
[Latin = carrier, traveller, rider, from *vect-* pa. ppl stem of *vehere* carry, convey: see **-OR.**]
†**1** *ASTRONOMY* = *radius vector* s.v. **RADIUS** *noun* Only in **18.**
2 a *MATH.* A quantity having direction as well as magnitude, denoted by a line drawn from its original to its final position. Cf. **SCALAR** *noun* **M19.** ▸**b** *MATH.* An ordered set of two or more numbers (interpretable as the coordinates of a point); a matrix with one row or one column. Also, any element of a vector space. **E20.** ▸**c** *AERONAUTICS.* A course to be taken by an aircraft, or steered by a pilot. **M20.** ▸**d** *COMPUTING.* A sequence of

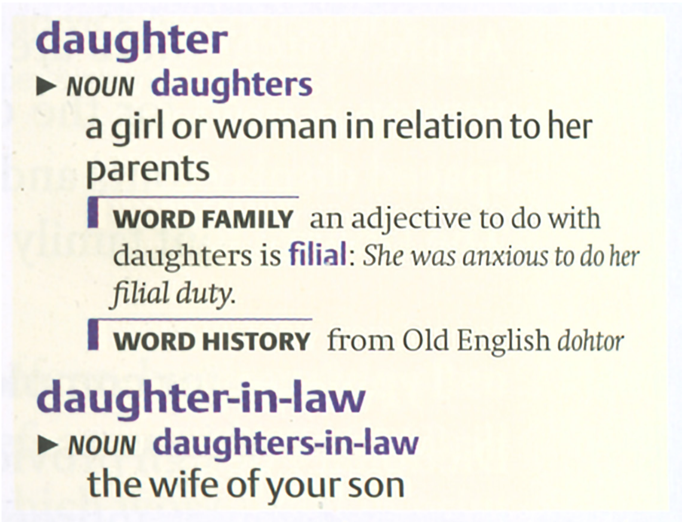

daughter
▶ *NOUN* **daughters**
a girl or woman in relation to her parents
WORD FAMILY an adjective to do with daughters is **filial**: *She was anxious to do her filial duty.*
WORD HISTORY from Old English *dohtor*
daughter-in-law
▶ *NOUN* **daughters-in-law**
the wife of your son

Figure 7
Proposal for a school dictionary. Luna, P. (2017) *Information Design: Choosing type for information design,* Routledge pp.484

However, due to expediency and technology (or the lack of) bolds as a means of distinction in complicated texts have not always served the variety of functions described in previous sections. For example, bold in a printed dictionary in the 1990s would serve a variety of functions as both headword and any derivative or subsidiary headword[35] (see Figure 6). With the onset of digital typesetting the textual hierarchy in dictionaries could become more complicated. Bolds could still be used for distinguishing keywords but additional styles and weights could also map typography to semantic elements within the text[36] (see Figure 7).

Bold is a tool to be used for emphasis and distinction within a formal hierarchy of text. As has been shown it should be used sparingly and consistently. Expediency and technical availability have effected the popularity of the use of bold, but not its core function of adding emphasis and distinction in order to draw a readers attention to headlines and key words within paragraphs and lines of text. The historical origins and uses of bold in all these areas will be discussed in chapter 3.

35 Luna, P. (2017) *Information Design: Choosing type for information design,* Routledge pp.484
36 Ibid

3. Background and origin of the bold

3.1 Origins of emphasis and distinction

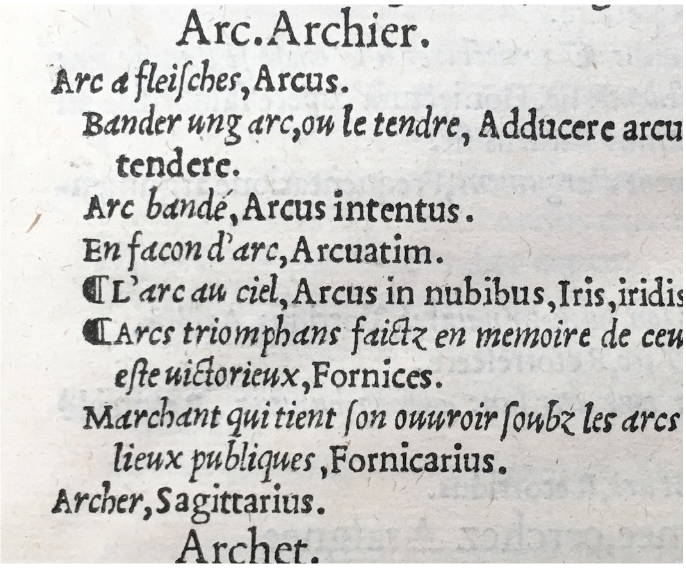
This chapter will present a short narrative on the history and evolution of bold type. The previous chapter described how bold is used for typographic hierarchy, textual emphasis and distinction in document design. It will be shown in this chapter that the historical development of bold for these uses was a matter of utility and technical expediency.

Prior to the invention of printing, emphasis and distinction in written documents was achieved primarily by the use of colour. Archaeological evidence from Ancient Egypt show that scribes would make use of a palette which held two pots for both red and black ink[1]. Important parts of texts would be highlighted with bands to red in order to draw the readers attention to key information. Later in Europe ecclesiastical paintings of the Middle Ages depicting the Evangelists writing the gospels with double-potted ink wells[2]. The practice of emphasising and making distinct key passages within blocks of text was clearly considered worthwhile. However it was not until 19th century that using bold for emphasis became an established practice which continues to this day[3]. Even the term ‘bold’ took time to become established, with printers referring to heavier types as ‘black’, ‘fat’, ‘heavy’ or even ‘Clarendon’[4]. The development of bold (and the type family Clarendon) in the mid 19th century will be discussed later in this chapter.

With the invention of printing, emphasis and distinction within text changed with the visual revolution in the design of the page. Books became largely monochromatic[5] however it was known for a second impression of red ink to be used in early printing[6]. The Gutenberg Bibles also contained limited amounts of colour on some pages[7].

In the early 16th century the advent of italic offered new options for emphasis to printers. In 1501, Francesco Griffo cut the first printing italic for Aldus Manutius[8]. The italic design was a humanistic script which was cut to imitate the hand-written cursive chancery letter[9]. Later, in Paris in 1539, with a movable type italic available, Robert Estienne printed the Dictionnaire Francois-Latin which made great use of both a regular and italic (see Figure 1). In his dictionary references to common vernacular and expressions were all set in an italic. Suggesting the italic is a more informal, spoken-word when set in contrast to the formal and rigid regular. Emphasis and contrast had been achieved by combining to different but complementary styles of letter. The outcome being a page of text which combined two styles that could be read by the reader as a distinct vernacular paired with a formal Latin[10,11].

Figure 1
Estienne, *R.* (1539) *Dictionnaire Francois-Latin contenant les motz & manieres de parler francois, tournez en latin*. Paris. Image taken by the author.


Arc.Archier.
Arc a fleiſches, Arcus.
Bander ung arc, ou le tendre, Adducere arcu
tendere.
Arc bandé, Arcus intentus.
En facon d'arc, Arcuatim.
L'arc au ciel, Arcus in nubibus, Iris, iridis
Arcs triomphans faictz en memoire de ceu
eſte uictorieux, Fornices.
Marchant qui tient ſon ouuroir ſoubz les arcs
lieux publiques, Fornicarius.
Archer, Sagittarius.
Archer.

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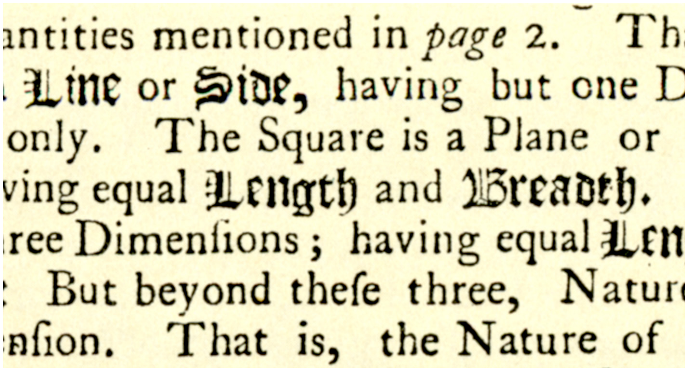
1 Twyman, M. (1993) *The Bold Idea,* Journal of the Printing Historical Society 22 pp.107
2 Ibid
3 Lawson, A. (1990) *Anatomy of Typeface,* Boston pp.315
4 Twyman, M. (1993) *The Bold Idea,* Journal of the Printing Historical Society 22 pp.142
5 Ibid pp.107
6 Duggan, M. (1993) *The Design of the Early Printed Missal,* Journal of the Printing Historical Society 22 pp.54
7 Twyman, M. (1993) *The Bold Idea,* Journal of the Printing Historical Society 22 pp.107
8 Fischer, S.R. (2003) *A History of Writing,* Reaktion London pp.273
9 Wardrop, J. (1963) *The Script of Humanism,* Oxford pp.35
10 Twyman, M. (1993) *The Bold Idea,* Journal of the Printing Historical Society 22 pp.108
11 NB This paper uses a similar format by combining regular running text with italicised quotations.

In addition to italic, printers especially in Britain made use of combinations of regular and black-letter types as a means of adding emphasis to a page. In Printers Grammar, 1755, John Smith wrote about the use of black-letter in combination with a regular. *“Because its Face, taking a larger compass than Roman or Italic of the same Body, the full and spreading strokes thereof appear more black upon the paper, than common.”* Smith later suggests that black-letter was effective at enforcing an idea to a reader.[12]

FIGURE 2
Twyman, (1993) *The Bold Idea,* Journal of the Printing Historical Society 22 pp.111



Using black-letter to give emphasis in book printing however had its issues. A lasting problem was the matter of irregular x-heights and the combination of regular and blackletter looking ‘inelegant’ across a line of text[13] (see Figure 2).

In the late eighteenth and nineteenth century, to meet the demands of a new generation of entrepreneurs and industrialists, printers began to modify late eighteenth century Continental types by thickening their stems and shortening the serifs[14]. Thus developing the ‘fat face’ (see Figure 3). Within twenty years, square seriffed ‘Egyptian’ types joined heavy attention grabbing fat faces[15] followed by bracketed serif types like Clarendon, which will be discussed in the following section.

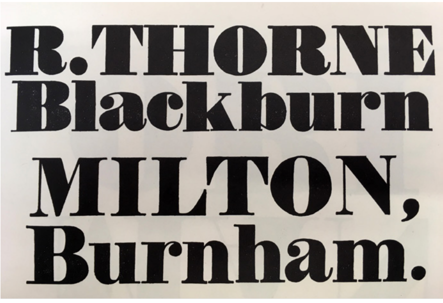


FIGURE 3
Top: Thorowgood, Five-line pica No.5, 1821. Gray N. (1938), *Nineteenth Century Ornamented Types and Title Pages*, London, pp.185. Image taken by the author. Bottom: Figgins, *Six-line pica No.1,* 1821.Gray N. (1938), *Nineteenth Century Ornamented Types and Title Pages*, London, pp.185. Image taken by the author.

Regardless, giving impact and emphasis became hugely important in early 19th century. With the demands of an expanding commercial market in printed ephemera[16] attention grabbing bold types became important design tools for printers in what became known as jobbing printing[17].

4.2 ‘Variegated type’ and the Clarendon family

In 1842 printer James Bell referred to the utility of bold type in his own practice as, *“affording greatly increased advantages of attraction to vision, and consequent impression on memory*[18]*.”* Bell was especially adept at combining regular with heavy Egyptian slab and sans serifs in his printed work (see Figure 4). This style of design proved impactful and useful for conveying important information to the reader. Bell described his bold and his use of various styles and sizes of letter as ‘variegated type’. This term refers to the distinction between regular and bold on the page. Using bold allowed the typesetter/editor/printer to decisively emphasise key information to a reader.[19]

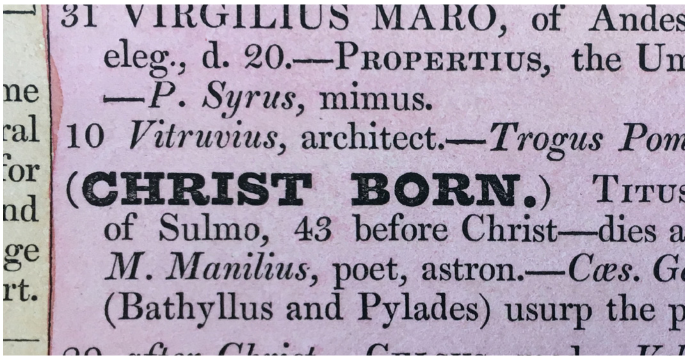


FIGURE 4
Bell, J. (1833) C*ompendious view of universal history and literature, in a series of twenty tables, arranged in collateral columns of nations, and progressively divided into grand compartments of historical and literary time,* London. Image taken by the author.

Robin Kinross notes in *Modern Typography,* 1992 that in commercial, ephemeral and information printing of the 19th century *“the need to articulate over-rode considerations of good taste and the conventions of book printing*[20]*.”*

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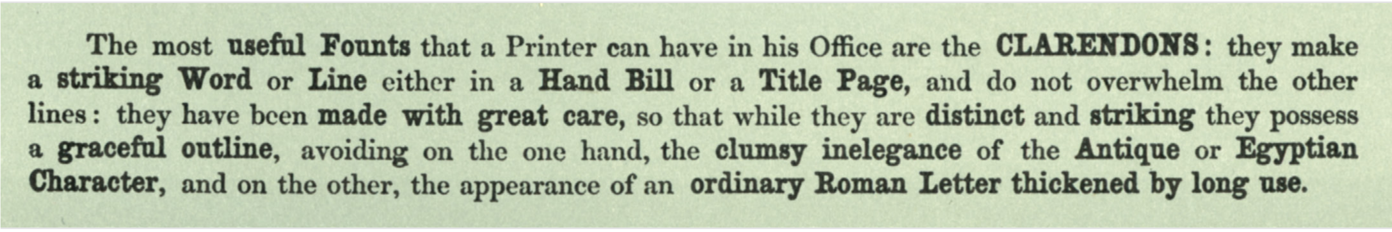
12 Smith, J. (1755) *Printers Grammar,* London, pp.18 NB. In Twyman, M. (1993) *The Bold Idea* pp.10, Twyman thanks James Mosley for bringing his attention to this line in Smith’s *Printers Grammar* which is where the author was also made aware of the quote.
13 Mosley, J. (1958) *Putting a boldface on it,* Linotype Matrix 30, pp.5
14 Lawson, A. (1990) *Anatomy of Typeface,* Boston pp.308
15 Ibid
16 Ibid pp.312
17 Ibid
18 Bell, J. (1842) *A View of Universal History,* London, pp.9 First seen by the author in Twyman, M. (1993) *The Bold Idea,* Journal of the Printing Historical Society 22 pp.124
19 Twyman, M. (1993) *The Bold Idea,* Journal of the Printing Historical Society 22 pp.124
20 Kinross, R. (1992) *Modern Typography* Hyphen Press pp.29

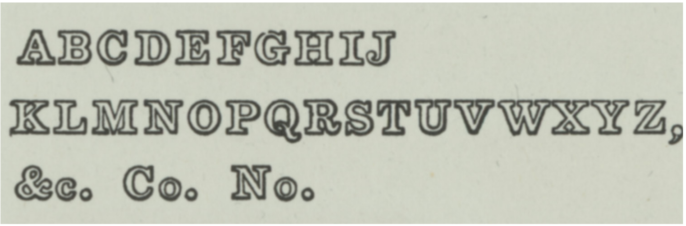
Figure 5
Besleys original Clarendon, 1850. Mosley, J. (1960) *An essentially English type,* Monotype Newsletter 60 pp.6

An issue of style for the printer using variegated type in the early 19th century was that of wide, uneven and unbalanced lines, and inconsistent x-heights[21]. The bold Egyptian slabs used by James Bell were significantly wider than the regular type they were set to counterpose. Heavy condensed sans serifs intermingled with


The most **useful Founts** that a Printer can have in his Office are the **CLARENDONS:** they make a **striking Word** or **Line** either in a **Hand Bill** or a **Title Page,** and do not overwhelm the other lines: they have been **made with great care,** so that while they are **distinct** and **striking** they possess a **graceful outline,** avoiding on the one hand, the **clumsy inelegance** of the **Antique** or **Egyptian Character,** and on the other, the appearance of an **ordinary Roman Letter thickened by long use.**

the regular created an optically uneven effect on the leading. These typographic problems led Robert Besley and the punch-cutter Benjamin Fox at the Fann Street Foundry to devise a solution which would improve the style of English printing[22]. Clarendon was the first type family with what became to be known as a 'related bold'[23] (see Figure 5). Clarendon was a conservative design[24], sharing similarities with existing Egyptian slab faces like Stephenson & Blake's 1833 Pearl Outline[25] and Caslon's 1844 Ionic[26] (see Figures 6 & 7). As with other Egyptian slabs, the shape and form of Clarendon was derived from the modern-face roman letter yet was more condensed[27].

Figure 6
Two Lines Pearl Outline, Stephenson & Blake, 1833. Mosley, J. (1960) *An essentially English type,,* Monotype Newsletter 60 pp.6



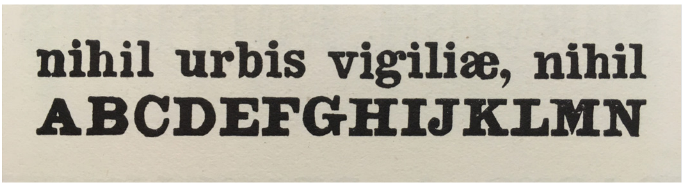


Figure 7
Doudble Pica Ionic, Caslon, 1844. Gray N. (1938)*, Nineteenth Century Ornamented Types and Title Pages*, London, pp.185. Image taken by the author.

The horizontal emphasis of Clarendon's bracketed serifs unites each word it is set in and its large x-height means that it is still readable at a small size[28]. These characteristics meant that enough space is retained around the letter that when it is compared to its heavier bold counterpart, both letters seem optically similar in width.

Clarendon was registered under the Designs Copyright Amendment Act of 1845. This meant that the design was legally protected from being copied for three years. In order to copyright Clarendon, Besley was asked to explain its unique qualities.

The distinctive difference is as follows: First, the Egyptian character or Antique (meaning competitor designs) is a square spreading character and where suryphs join the mainstrokes are cut out in sharp angles—the distinctive character of the Clarendon is that these junctions are formed in a graceful curve and the shape of the letters generally partake of the oval rather than the round. Second, its utility consists in its preserving an equal degree of boldness with the Egyptian or Antique (competitor designs), while its oval character enables the printer to compress a much greater number of words in the same space.[29]

Curiously, Besley does not mention the accompanying bold in the copyright application. Once the three years had passed, Clarendon was free to be copied by other foundries.

21 Mosley, J. (1958) Putting a boldface on it, Linotype Matrix 30, pp.5
22 Mosley, J. (1960) *An essentially English type,* Monotype Newsletter 60 pp.6
23 Ibid
24 Mosley, J. (1960) *An essentially English type,* Monotype Newsletter 60 pp.7
25 Ibid pp.6
26 Gray, N. (1938) *Nineteenth Century Ornamented Types and Title Pages*, London, pp.185
27 Mosley, J. (1960) *An essentially English type,* Monotype Newsletter 60 pp.6
28 Ibid pp.7
29 Mosley, J. (1958) *Plagiarism and protection: Some notes on copyright of type-design,* Linotype Matrix 29, pp7

Figure 8 & 9
Clarendon Series 617 & Series 618, Monotype (1960) *Desk Catalogue of 'Monotype' Faces,* The Monotype Corporation Limited. Image collected by the author.

No sooner was the time of copyright allowed by the Act expired, than the trade was inundated with all sorts of Piracies and Imitations[30]

Later, imitations of the expanded version of Clarendon (see Figure 8 & 9) became popular all across Britain, as well as in the US published by the Bruce and Cincinnati foundries, in Germany by the Bauer foundry and also in France where it was sold as 'Egyptiennes Anglaises'[31]. Once available, Besley's Clarendon proved to be immediately popular[32].

Providing a bold which would sit in harmony with a counterpart regular was a change that made the slab-serif bold types of previous decades, with wider proportions and varying x-heights, look clumsy by comparison[33]. The design of Clarendon was aided in no small part by the inclusion of well cut accompanying bold. With the name Clarendon itself becoming synonymous with any thickened type used for emphasis[34].

However, with a few exceptions, the practice of producing a bold to accompany a regular in a seriffed type family was not typical until the 1930s[35]. Walter Tracy in *Letters of Credit,* 1986 explains that 'related bolds' are a relatively new phenomenon (20th century) because,

Monotype's own Series 53, a bold roman in the old face mode had for many years served as an excellent companion to such plan text types as Caslon, Imprint, Old Style 2, and even Modern 7.[36]

Figure 10
Futura by the Bauer foundry. Ulrich, F. (2014) *A short history of the geometric sans* Online at https://www.fontshop.com/content/short-intro-to-geometric-sans Accessed 18 July 2019

For Monotype in the UK bolds were largely unnecessary because darker heavier typefaces were available. However, in regards sans serifs, the German type foundry Bauer designed Futura (1927) with 5 weights (see Figure 10), and American Linotype's version of Futura, called Spartan (1939) had 7 weights[37]. Later, with the advent of phototype and Ikarus, multiple weights could be added to serif faces and by the mid 1980s even Garamond had four weights.[38]

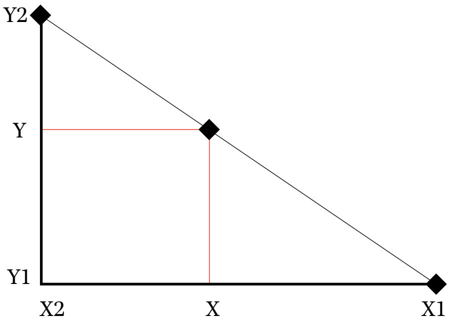
The next chapter will jump forward to the digital era and show how designs of bold within font families have been theorised by practicing designers. Then part two of this paper will examine the design of bolds from 20th century font families.

30 Gray, N. (1938) *Nineteenth Century Ornamented Types and Title Pages*, London, pp.51
31 Mosley, J. (1960) *An essentially English type,* Monotype Newsletter 60 pp.7
32 Gray, N. (1976) *Nineteenth Century Ornamented Typefaces*, London, pp.66
33 Twyman, M. (1993) *The Bold Idea,* Journal of the Printing Historical Society 22 pp.124
34 Kinross, R. (1992) *Modern Typography* Hyphen Press pp.29
35 Tracy, W. (1986) *Letters of Credit,* Boston pp.66
36 Ibid
37 Ibid
38 Ibid

4. Methods and theories for designing bolds

4. Methods and theories for designing bolds

As outlined in chapter 2, 'bold' is a term that defines the characteristics of a letter in relation to a 'regular' weighted counterpart. This chapter will jump forward to the digital era and explain how some designers have attempted to devise systems for applying weight to regular letters in order to create bolds. Part two of this paper will return to the early 20th century and begin to analyse bold type from the 1930s onwards.



$$Y = Y1 + (X - X1) \frac{(Y2 - Y1)}{(X2 - X1)}$$

Figure 1
Calculating linear interpolation along an axis between Y2 and X1. Sourced and re-drawn from Peltier, J. (2011) *Excel Interpolation Formulas* Online at https://peltiertech.com/excel-interpolation-formulas/Accessed 17 July 2019

To help understand the relationship between regular and bold in metric terms, the two weights can be interpolated along an axis[1] (see Figure 1). In mathematics interpolation means the computation of points or values between ones that are known[2]. Interpolation results in intermediate weights (medium, semibold, demi-bold *etc*) between the regular and bold. The relationship between regular and bold is the focus of this study and is also the basis of several theories regarding adding weight to letters in digital type design. These theories are discussed below.

4.1 Ratios as methods for adding weight to letters

Ratios have been used by several practitioners to describe the relationship between regular and bold. This section will show how they have been used and note some of their limitations.

Microsoft uses designations of weight in its CSS font-weight property. In CSS coding, a font weighted at 400 is designated as 'normal', while 700 is bold[3]. This 700/400 suggests the stem width of a bold font should 1.75 that of the regular. Donald Knuth in *Computers & Typesetting,* 1986, suggests that the stem width of a bold font should be 1.6 times that of the stem width of the regular[4]. It is therefore suggested that a ratio between regular and bold stems of 1.6 - 1.75 is acceptable. That is a regular stem is 1 and the equivalent bold stem is 1.6. - 1.75.

In designing the font family Lucida, Chuck Biglow and Kris Holmes matched the numerical categories in the CSS font-weight property with the stem and x-height ratio of the font. So that the UltraThin weight (CSS 100) has a stem ratio of 1:22 and the Thin weight (CSS 200) has a stem to x-height ratio of 1:11, and so on. However, Bigelow and Holmes, did not correspond the Normal weight (CSS 400) to the Bold weight (CSS 600), instead using the Black weight at the 800 designation[5]. Showing that Microsoft's regular to bold relationship in CSS is not steadfast.

Bigelow and Holmes noted that:

Measured by ratio of stem thickness to x-height, the minimum step for a noticeably bold weight is a factor around 1.5 times the normal stem/x-height. That is, if the normal weight stem is a unit of 1.0, then the bold is around 1.5 units[6].

1 Microsoft (2018) *Registered design-variation axis tag: 'wght'* Online at https://docs.microsoft.com/en-us/typography/opentype/spec/dvaraxistag_wght Accessed 20 June 2019
2 Wolfram (n.d.) *Interpolation* Online at http://mathworld.wolfram.com/Interpolation.html Accessed 20 August 2019
3 Microsoft (n.d.) *font-weight property* Online at https://msdn.microsoft.com/en-us/ie/ms530762(v=vs.94) Accessed 20 June 2019
4 Font Forge (n.d), *Stylistic Transformations on Fonts* Online at https://fontforge.github.io/en-US/documentation/interface/Styles/ Accessed 20 August 2019
5 Microsoft (n.d.) *font-weight property* Online at https://msdn.microsoft.com/en-us/ie/ms530762(v=vs.94) Accessed 20 June 2019
6 Bigelow & Holmes (2015) *On font weight.* Online at https://bigelowandholmes.typepad.com/bigelow-holmes/2015/07/on-font-weight.html Accessed 20 June 2019

Figure 2
Ratio increases of stem weight in six fonts. Bigelow & Holmes (2015) *On font weight.* Online at https://bigelowandholmes.typepad.com/bigelow-holmes/2015/07/on-font-weight.html Accessed 20 June 2019

Font	Ratio >
Lucida Grande	1.5
Palatino	1.54
Times Roman	1.7
Baskerville (*depending on which version*)	1.8
Verdana	1.9

Figure 3
Letter expansion. Font Forge, (n.d.) *Stylistic Transformations on Fonts.* Online at https://fontforge.github.io/Styles.html Accessed 20 June 2019

Font	Ratio >
Computer Modern Roman	1.15

Figure 4
Serif height. Font Forge, (n.d.) *Stylistic Transformations on Fonts.* Online at https://fontforge.github.io/Styles.html Accessed 20 June 2019

Font	Ratio >
Times New Roman	1
Adobe Times	1.1
Garamond Antiqua	1.05

Figure 5
Serif width. Font Forge, (n.d.) *Stylistic Transformations on Fonts.* Online at https://fontforge.github.io/Styles.html Accessed 20 June 2019

Font	Ratio >
Times New Roman	0.98
Adobe Times	0.97
Garamond Antiqua	0.9

Expanding on the idea of stem to x-height ratio, Bigelow and Holmes analysed the ratios of other digital fonts (see Figure 2).

Bigelow and Holmes also noted that,

Microsoft's ClearType fonts, designed for improved screen display technology, tend to have bold weights between 1.5 to 1.7 times the respective normal weights[7].

Donald Knuth and Microsoft's suggestion of a ratio of 1.6-1.75 between the regular and bold stems is a useful guide, while Bigelow and Holmes expanded on this methodology of the ratio by considering the x-height of the letter. Thereby taking into consideration the variation in x-height between regular and bold letters. Further layers of detail, like that provided in the online instructions for the software FontForge, on the relationship between regular and bold serifs and letter expansion (width) is also available (see Figures 3, 4, 5)[8]

However useful, these details are scant and only hint at a methodology for understanding the relationship between regular and bold.

4.2 Graphs as methods for adding weight to letters
Lucas de Groot's mathematically derived Interpolation Theory describes the increasing ratio by which to add weight to stem and cross-bars, best visualised as a concave curve along a graph. In other words, de Groot's theory states that the ideal means of adding weight to a letter from regular to bold does not follow a linear line (see Figure 6). He explains that,

if the verticals of the Regular weight have a value of 40 units and those of the Bold weight 70, then the SemiBold verticals should not be 55 units wide but slightly less, in order to give the optical impression of being exactly "in the middle".[9]

De Groot expanded upon this method with his Anisotropic Topology-dependent Interpolation Theory (see Figure 7). This simply means that the theory extends to different types of stroke on an x-y axis within single letters. For example, vertical strokes within a letter are able to expand endlessly wide (for example the stem of an L), where as horizontal strokes are limited by the height of the letter (the foot of the L can only grow in height so far). Similarly, within a related character like an E, while the vertical can expand endlessly, the ratio by which horizontal strokes can expand is more limited than the L because of the need to include three of them (see Figure 7). Hence the rates of increased contrast between strokes varies from to letter to letter, as a font becomes heavier and different letter topologies need their own interpolation curve.[10]

Pablo Impallari saw a flaw in de Groot's Interpolation Theory. At the extremes of a sequence of interpolations the steps between each become too large. In other words, at the bold end of the concave curve, the appearance of an even progression of weights degrades. For example from the semibold, the next interpolated step jumps to what can be perceived as a heavy[11].

7 Ibid
8 Font Forge, (n.d.) *Stylistic Transformations on Fonts.* Online at https://fontforge.github.io/Styles.html Accessed 20 June 2019
9 de Groot, L. (n.d.) *Interpolation theory* Online at https://www.lucasfonts.com/about/interpolation-theory/ Accessed 20 June 2019
10 Ibid
11 Scheichelbauer, R.E. (2013) *Multiple Masters, Part 3: Setting up Instances* https://glyphsapp.com/tutorials/multiple-masters-part-3-setting-up-instances Accessed 20 June 2019

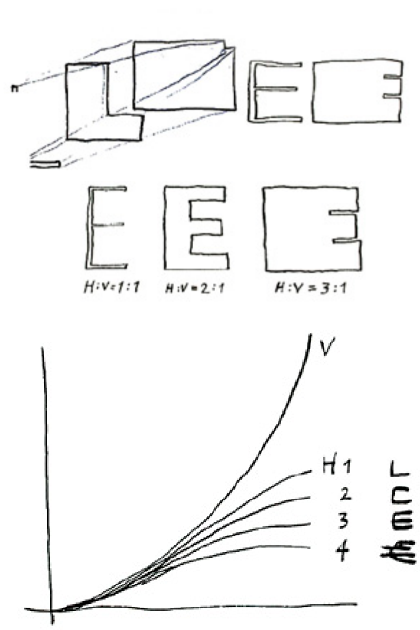


Figure 7
Lucas de Groot's Anisotropic Topology-dependent Interpolation Theory. de Groot, L. (n.d.) *Interpolation theory.* Online at https://www.lucas-fonts.com/about/interpolation-theory/ Accessed 20 June 2019

So, to interpolate a more incremental set of heavier weights, Impallari devised a system whereby the distribution begins to level out at the extremes of the curve. Where as the de Groot distribution continues to climb up the graph, Impallari's graph is no longer concave, but levels out to form a more gradual wave (see Figure 8). Impallari refined de Groots theory for adding weight to letters using the methodology of the graph.

In chapter 7 the conclusions from the results of the research are backed-up with a graphical analysis of the transition between regular and extra bold.

4.3 Percentages as methods for adding weight to letters
Bigelow and Holmes in their work on the Lucida font family also describe their method of ink/pixel percentage coverage across a weight axis. The advantage of measuring percentage coverage over x-height to stem ratio is that percentage takes into account other aspects of the glyph space, such as the space left for the above the x-height and below the baseline, plus overall letter width and the space inside and surrounding the letters[12]. Percentage coverage also accounts for the overall increased width of bold weight letters which can reduce the emboldening effect of increased stem thicknesses[13]. Bigelow and Holmes note that,

A more accurate way to indicate visual weight is to measure actual ink coverage of each weight, or, for modern digital devices, the percentage of black pixels in the total area of the typeface body when the font is set solid, that is, with no extra leading or inter-line spacing.

In Bigelow and Holmes' Lucida, percentage coverage does not correspond to the ratio expansion described in the previous two sections (see Figure 9). The bold is 28% darker than the normal weight, not the 50% which could be assumed by following the x-height to stem ratio method. Similarly, the black weight is only 37% darker than the normal, not 100%[14]. Percentage coverage as a measurement for determing how much bolder a bold is by comparison to a regular was used in this study – see chapter 5 for how this was done and chapter 6 for conclusions drawn from the results of the study.

4.4 Conclusion
While Lucas de Groot's theory (and Impallari's development of it) deals with the topography of individual letters, using the x-height to stem ratio as a means of devising a bold is limited. It does not take into account the texture of word patterns across lines and paragraphs. For example, ascenders, descenders, the space above and below the x-height and baseline, details of terminals and serifs, width of letters and counter space will all vary as weight is added to a letter. Bigelow and Holmes percentage coverage theory suggests a methodology which not only accounts for stem thickness (as with de Groots theory), but for other factors which affect the colour of a paragraph of text.

Part two of this paper will present a study using in-part some of the methods explained in this chapter and focus on details and aspects of adding weight to letters which have not so far been addressed in the previously discussed theories for designing bolds.

12 Bigelow & Holmes (2015) *On font weight.* Online at https://bigelowandholmes.typepad.com/bigelow-holmes/2015/07/on-font-weight.html Accessed 20 June 2019
13 Ibid
14 Ibid

Figure 8
Comparative graph showing the Lucas, Impallari and linear curves. Sourced and re-drawn from forum post by Lee, A. (February 2017) *Proper weight instance progression for a multiple master* Online at https://typedrawers.com/discussion/1991/proper-weight-instance-progression-for-a-multiple-master

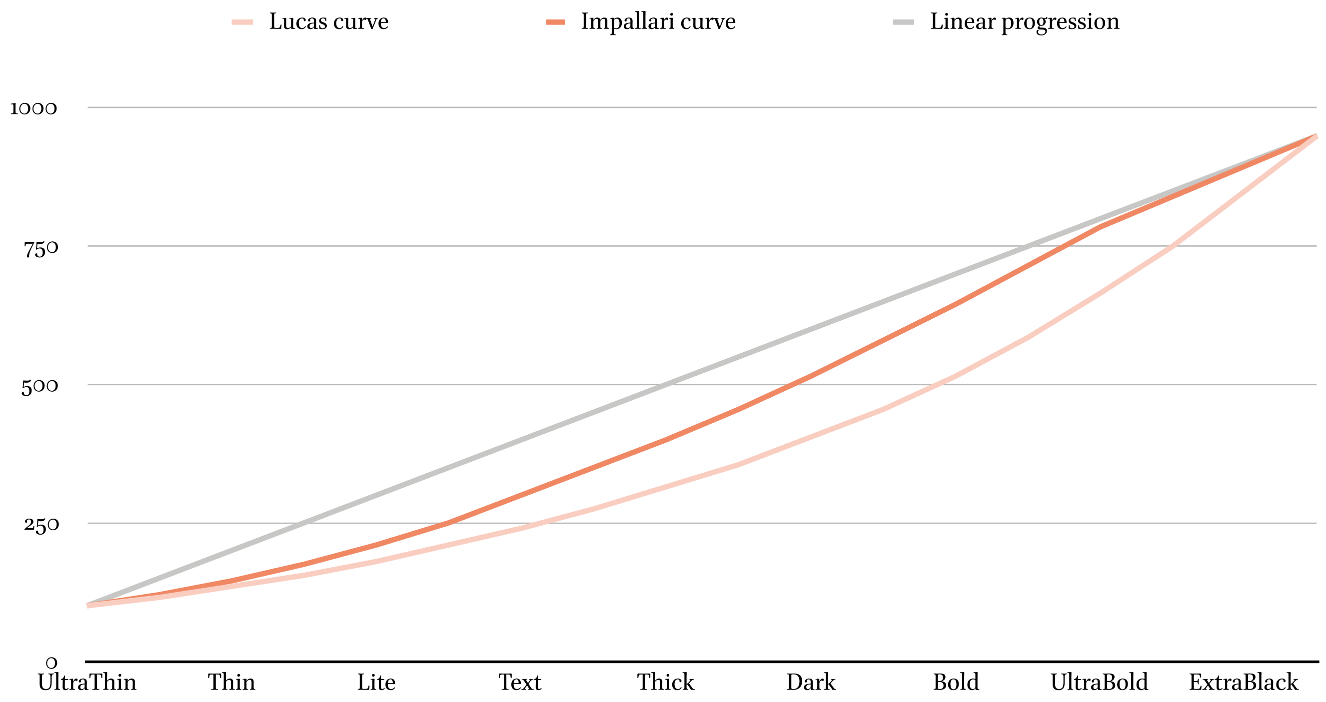
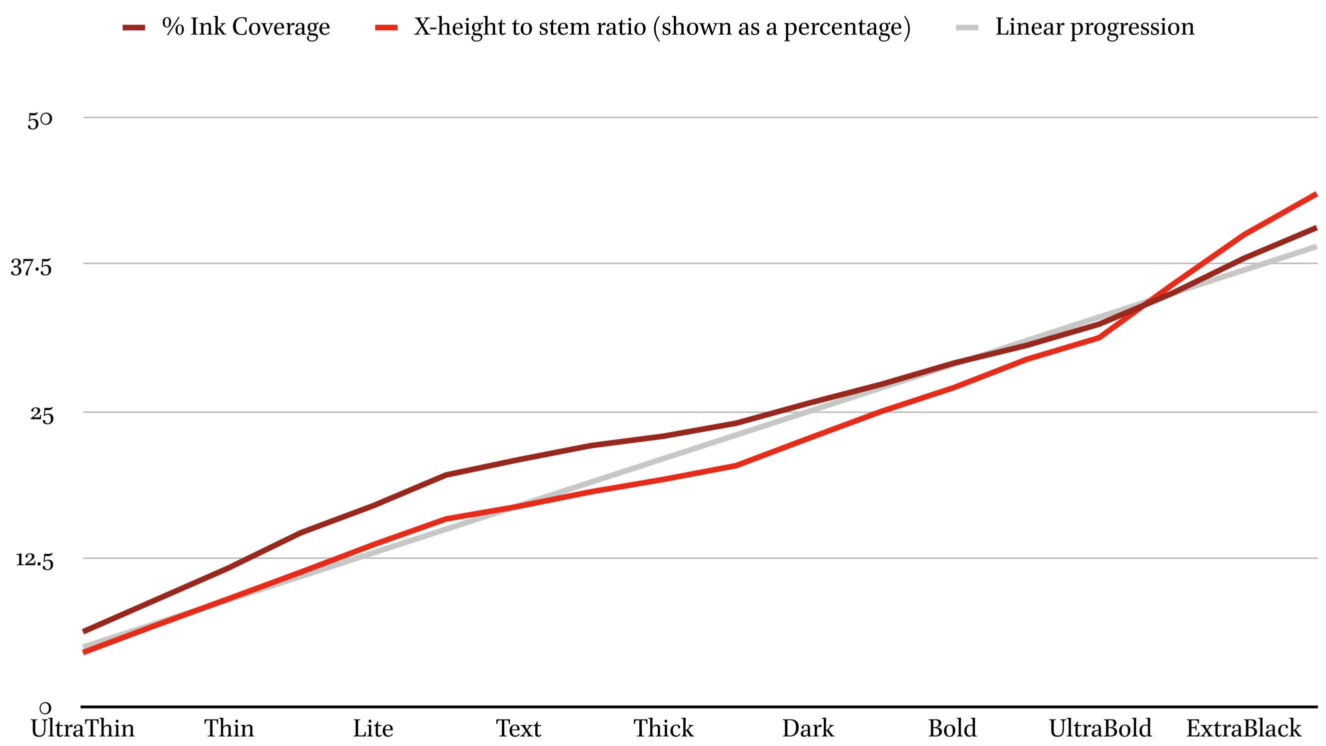


Figure 9
Comparative graph showing the percentage ink coverage, x-height to stem ratio and linear curves. Sourced and re-drawn from Bigelow & Holmes (2015) *On font weight.* Online at https://bigelowandholmes.typepad.com/bigelow-holmes/2015/07/on-font-weight.html Accessed 20 June 2019

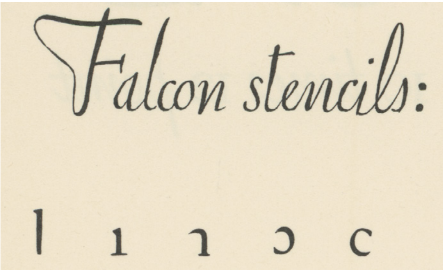


II.
Designing a bold

Weight numbers definitely help, and they are getting better the more we study them, but so far, they remain at best, signs on the road to understanding, not our destination.
– Bigelow & Holmes, 2015

5. An approach to analysis

Figure 1
Detail of Dwiggins Falcon stencils and the key components of letters from which an alphabet can be drawn. Dwiggns, WA (1940) *WAD to RR a letter about designing type* Harvard College Library Department of Printing and Graphic Arts.



5. An approach to analysis
This paper began by noting the development of bold for typographic hierarchy, textual emphasis and distinction in document design (see chapter 2). In order to be a useful tool for designers and printers, and carry out these functional jobs, bold has relied on its development as a suitable accompaniment to a regular weighted letter (see chapter 3). The theoretical development of which has been explored by some previous designers (see chapter 4). The aim of this paper was to expand on this theoretical development with a study of existing bolds and to provide applicable advice for future type designers (see chapter 6).

To gather data for this study, specific definable (therefore repeatable) components and characteristics between regular and bold letters of the Latin alphabet were compared. Repeating components such as serifs, stems, bowls, joints (also demonstrated by W.A. Dwiggins approach to component letterforms in this *Falcon stencils*[1] – see Figure 1) and characteristics like x-height, weight[2] etc were analysed.

This study focused primarily on metal type. Metal type was cut in ranges of optical sizes (see Figure 2) and by analysing two optical sizes (rather than one optical size available in digital type, for example) the scope of the study could be more expansive. More details about the type of specimens used in the study can be found in Appendix B.

Figure 2
Optical sizes in metal type. Plantin Light 6-8-10-12pt scaled to the same height. Image collected by the author.

In metal type, optical sizes were common[3]. So, in this study a consistent approach to analysing metal cut letters was needed so create comparable data sets. The study focuses on two sizes – 12/13pt and 24pt. If these sizes were not available in a type specimen nearest possible sizes were analysed. For example, if a 12/13pt regular was not available, 13pt regular was compared with 13pt bold.

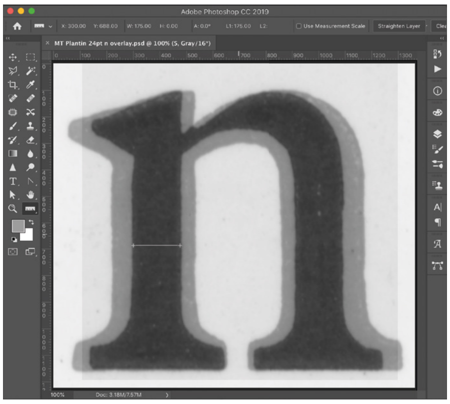
It is acknolwedged that in this study there was a margin of error in the results. Ink spread and differences in paper and printing conditions mean that the boundary of each printed letter can move. In order to account for this, conclusions of results were drawn from averages across each measured metric which showed trends and similarities of bold across a range of types – see chapter 6 for conclusions drawn from the results.

Similarly, technological limitations on the width of characters within a bold typeface have been a factor on their design. For example, the overly condensed feeling[4] of the bold in the original Times New Roman was, according John Dreyfus in Penrose Annual 66, due to The Times newspaper using line-composing machines which required regular and bold letters to be combined in a single matrix, and therefore needed to be the same width[5] (see Figure 3). However it should be noted that Walter Tracy disputes this reason for Times Bold being so narrow and believes the reason was on over-zealous adherence by Victor Lardent to keeping the bold economical in a line of text[6]. Affects on the results of the analysis are noted in chapter 6.

Figure 3
Comparison of Times New Roman and Times Bold. Dreyfus, J. (1973) *Evolution of Times New Roman,* Penrose Annual 66, pp169

1 Dwiggns, WA (1940) *WAD to RR a letter about designing type* Harvard College Library Department of Printing and Graphic Arts.
2 Garnham, P. (2016) *The A–Z of typographic terms.* Online at https://www.fontsmith.com/blog/2016/06/29/the-a-z-of-typographic-terms accessed 2 July 2019.
3 Font Forge (n.d), *Stylistic Transformations on Fonts* Online at https://fontforge.github.io/en-US/documentation/interface/Styles/ Accessed 20 August 2019
4 Tracy, W. (1986) *Letters of Credit* Gordon Fraser: London pp.205
5 Dreyfus, J. (1973) *Evolution of Times New Roman*, Penrose Annual 66, pp171
6 Tracy, W. (1986) *Letters of Credit* Gordon Fraser: London pp.206

FIGURE 4
Screenshot shows a measurement in Adobe Photoshop of an overlayed regular and bold Plantin 24pt n. Note the pixel width of the image in the ruler (1364px), and the recorded measurement tool (175px). Image by the author.



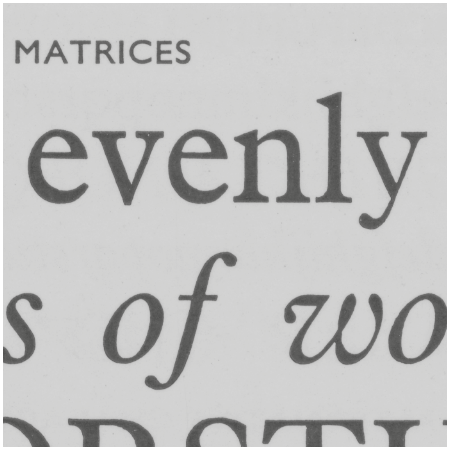
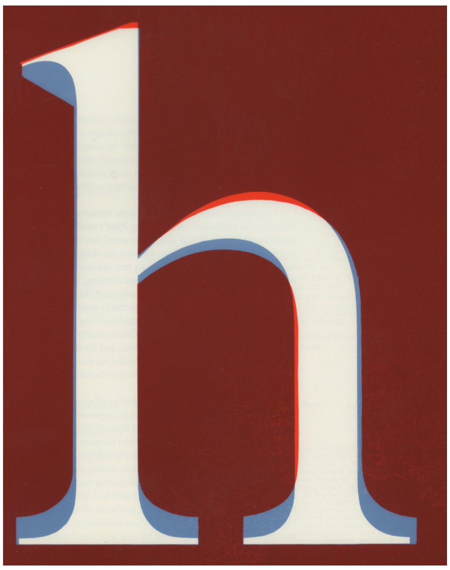


FIGURE 5
A not-to-scale 6400x6400px square inch of a scanned specimen. At 100% resolution the stem of the letter n in the word evenly is 175px wide. Image collected by the author.

FIGURE 6
Comparison of Times New Roman and Times Bold. Dreyfus, J. (1973) *Evolution of Times New Roman,* Penrose Annual 66, pp168



5.1 Process of letter and line analysis

The process of analysis was done using Adobe Photoshop (see Figure 4). Specimens of fonts were scanned at 6400ppi (pixels per inch) and individual letters were measured at that resolution. For example, this meant that the stem width of n in 24pt Plantin regular was 175px (pixels).

Data points were recorded as percentage rates of increase *à la* Bigelow and Holmes[7] (with the exception of degrees° for measuring angles). Percentage results were calculated with a simple formula:

Bold value – Regular value = n, *then*
(n/Regular value) × 100 = % increase.

For example, the stem width of 24pt Plantin regular scanned at 6400ppi is 175px – see Figure 5. Similarly, bold stem width is 293px. So,

293 – 175 = 118
118 / 175 =0.674
0.67 × 100 = 67.4% stem width increase for Plantin 24pt.

The comparison of letterforms was done by overlaying the same regular and bold letters in Photoshop with a transparency filter (see Figure 4). This method is similar to the one shown in John Dreyfus' Penrose Annual article on Times New Roman[8] (see Figure 6).

As mentioned in chapter 4, Bigelow and Holmes suggested tracking increases in pixel/ink coverage as a method for measuring bold. In this study the measurement of the coverage increase was done by comparing two equivalent lines of text in regular and bold. To do this, scans of lines of text were converted into 32 Bits/Channel in order to generate an easier to calculate end result[9]. The respective results were recorded with the Measurement Log tool[10]. This tool measures lightness, so the recorded result (the mean grey value) notes a decrease in light between the regular to bold. This was accounted for in calculating the final ink/pixel increase. The percentage increase in coverage was calculated with the same formula as shown above. See Appendix A for further explanations of methodological approaches to data recording, and Appendix C for the full spreadsheet of results. For conclusions drawn from the data, see chapter 6.

5.2 ExtraBold weight as a proof of concept

The focus of this study was the transition from regular to bold. However, in order to demonstrate that the addition of weight beyond (when plotted in a graph as shown in chapter 4) bold follows a comparable pattern, further extremes on the interpolation curve were measured. Rockwell ExtraBold in comparison to the Regular was also recorded. This aspect was presented as a comparable percentage increase which was mapped onto the regular to bold percentage increase, which demonstrated a consistent rate of increase from regular to bold to ultra. Analysis of ExtraBold is described in chapter 9.

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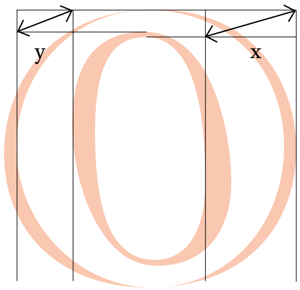
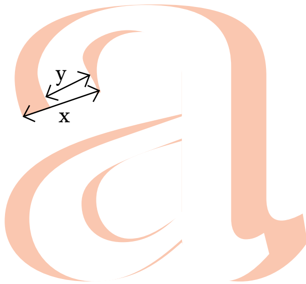
7 Bigelow & Holmes (2015) *On font weight.* Online at https://bigelowandholmes.typepad.com/bigelow-holmes/2015/07/on-font-weight.html Accessed 20 June 2019
8 Dreyfus, J. (1973) *Evolution of Times New Roman*, Penrose Annual 66, pp165
9 *Gray Value: This is a measurement of brightness, either from 0 to 255 (for 8-bit images), 0 to 32,768 (for 16-bit images), or 0.0 to 10 (for 32-bit images).* Adobe, (2019) *About measurement* Online at https://helpx.adobe.com/uk/photoshop/using/measurement.html Accessed 17 July 2019
10 Ibid

FIGURE 7
The font used in the illustrations is MT Plantin which is available via Typekit. Some edits to letterforms were made for emphasis. Plantin (n.d.) *Monotype Typekit Plantin,* Online at https://fonts.adobe.com/fonts/plantin Accessed 17 July 2019

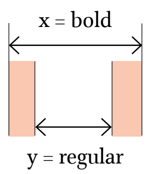
Contrast increase
H, O, o



Terminal serifs
a, c, s

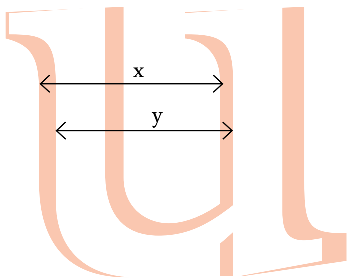


[ASPECT MEASURED]
[Letters measured]

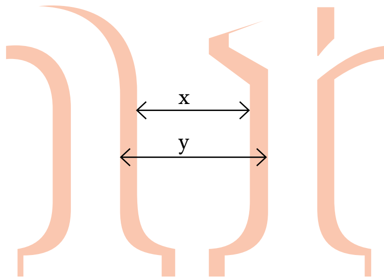


With the exception of angles of degree°, all calculations are formed with Bold value (x) - Regular value (y) = n, *then* (n/y) x 100 = % increase.

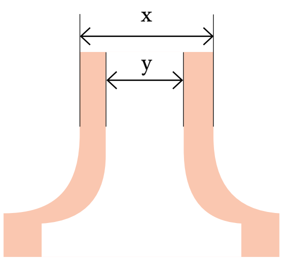
Character proportional width
H, O, A, n, o, d, v



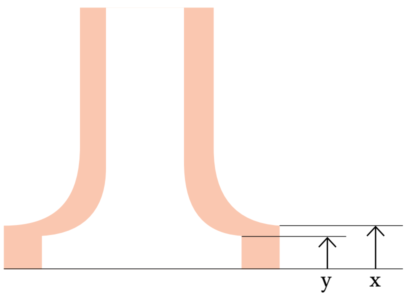
Change in spacing
H, n



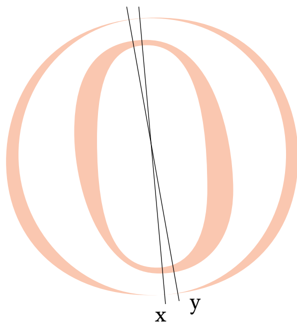
VERTICAL STEM EXPANSION
H, O, A, n, o, v



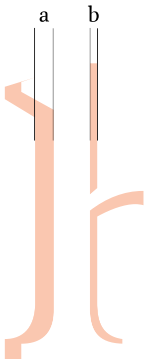
Serif height
H, l, n



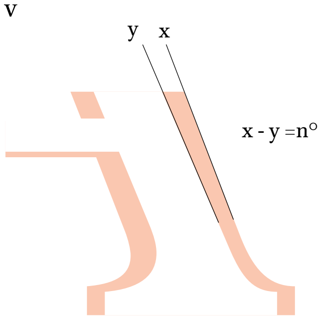
Stress axis in curves
O, o



Vertical stem external expansion : internal expansion
H, O, n, o. *See Appendix A for more on methods of measuring this factor.*



Angle of thick stroke
A, v

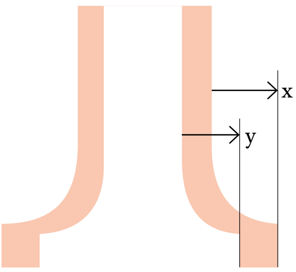


5.3 Components and characteristics analysed
This study analysed letters like H, O, A, n, o, v. These are letters which contain repeatable topographical aspects from typeface to typeface, like straight, curved and angled strokes, angles of stress, serifs, counters and that are key to spacing lines of text. These metrics of which can be used to draw and space other letters in the Latin alphabet.

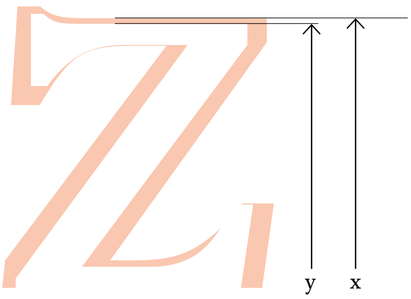
On these pages are a list of the topographical aspects of the key letterforms which were measured. Results were derived from a comparison between regular and bold. Illustrations are by the author using MT Plantin (see Figure 7).

5.4 The study
The fonts used in the study were Plantin, Times New Roman, Garamond, Baskerville, Bodoni, Univers, MT Grotesque, Gill Sans, Rockwell and New Clarendon (see Figure 8). With further time for analysis and research more fonts could be included in a similar study. However, these fonts were chosen because they are commercially successful examples of font families which include regular and bold weights. For examople, Bodoni (American Type Foundry, 1911) was an early example of a font family that contained regular, bold and ultra weights. Univers (Deberny & Peignot, 1957) was similarly a large type family.

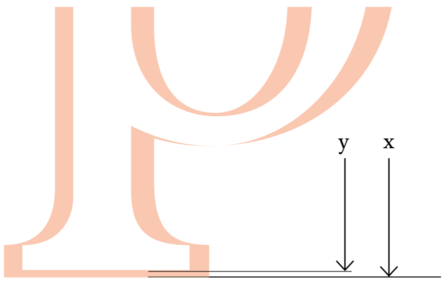
Serif width
H, l, n



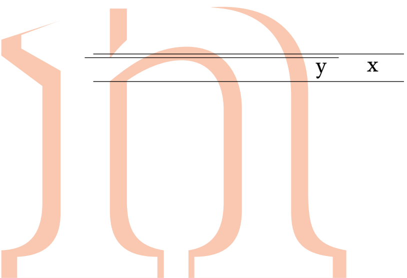
X-height change
z



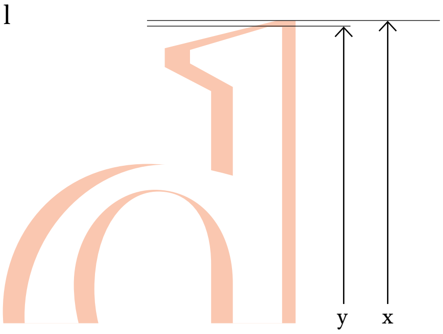
Descender line change
p



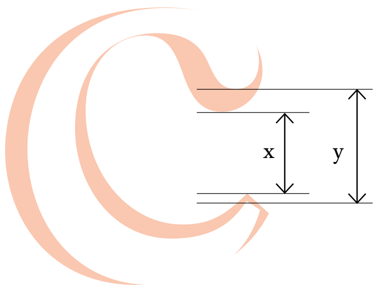
Joint (curve meets stem)



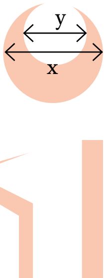
Ascender height change
l



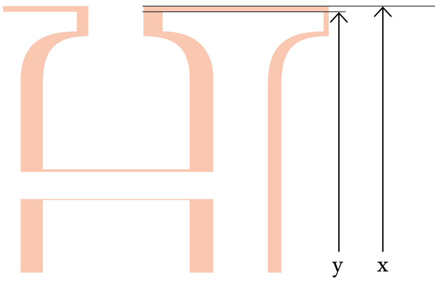
Aperture changes
C, c



Tittle expansion
i



Caps height change
H



Overall density increase
Various. *See Appendix A for more on methods of measuring this factor.*

The study looked at a combination of sans, serifs and slab style fonts. So, not all topographical aspects of letterforms are comparable – for example Univers has no serifs, where as Plantin does. Incompatible characteristics are noted in chapter 6 where particular reference is made to high-contrast (Clarendon, Plantin, Times, Garamond, Baskerville, Bodoni) and low-contrast (Univers, MT Grotesque, Gills Sans, Rockwell) fonts.

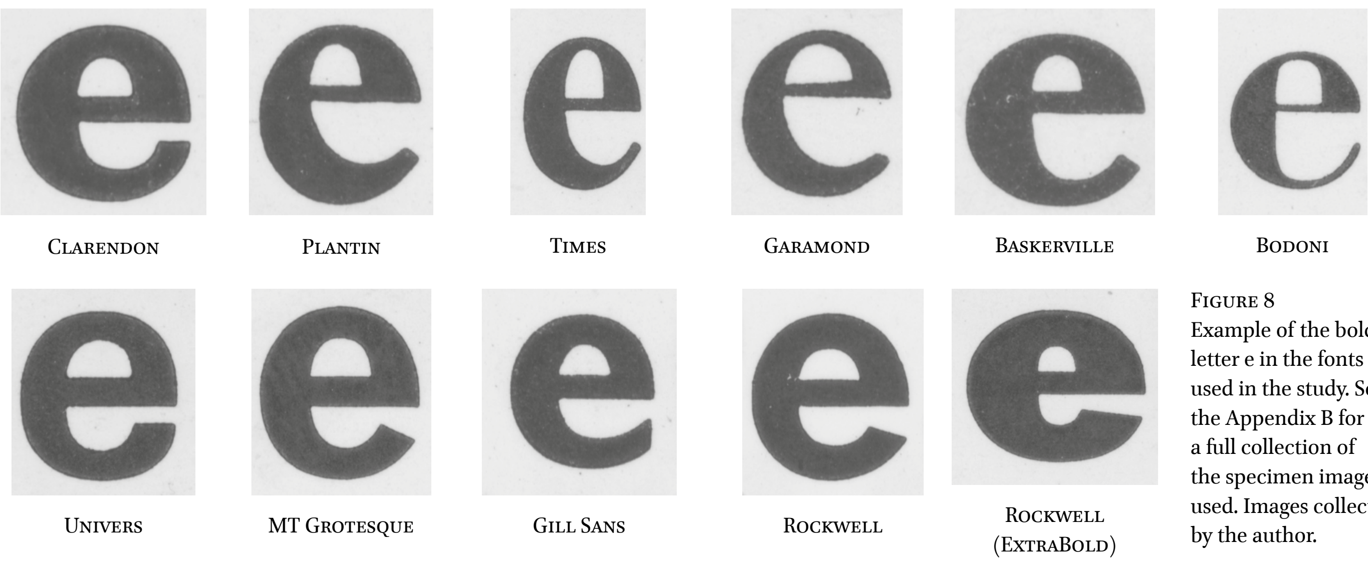


Figure 8
Example of the bold letter e in the fonts used in the study. See the Appendix B for a full collection of the specimen images used. Images collected by the author.

It should be noted that not all regular and bolds were cut at the same time, (as shown with Times Bold earlier in this chapter) and designs for accompanying bolds have been compromised by technological limitations. However, with fonts such as Plantin, Times and Baskerville, the regular and bolds are connected by sharing the same designers (Frank Hinman Pierpont[11] and Stanley Morison[12] respectively) or being produced by the same foundries (Monotype for Plantin and Times, Linotype for Baskerville). For more details on the choice of font specimens used see Appendix B.

The results in Appendix C categorise the fonts and topographical aspects of letterforms analysed in this study and contains all the data gathered. The results show that there are definable (and repeating) characteristics between different fonts in a multitude of aspects of individual letterforms when weight is added to a regular to make a bold. The next chapter will parse the results in the table into usable advice for type designers.

5.5 What was not analysed in this study

There are aspects of letter shape, style and effect of added weight which for reasons of limited time and cross-font compatability were not analysed in this study. In Robert Besley's submission to the Design Copyright Act, 1845 (as discussed in chapter 3) Besley was required to explain the unique characteristics of his new type Clarendon. He explained that,

"where suryphs (in other types) *join the main stroke are cut out in sharp angles – the distinctive character of Clarendon is that these junctions* (between the stem and serif) *are formed in a graceful curve"*[13].

The bracketed serif (as opposed to the 'cut out sharp angle') is a key design aspect of Clarendon. This characteristic is not consistent across other types. For example, in the slab font Rockwell, the darkening effect of this design feature was not recorded. However, a measure of the overall comparative density of a line of text in regular and bold was recorded (a bracketed serif would presumably create a different density effect to a sharp angle serif). See Appendix A for more information on measuring comparative density.

Additionally, no measurement of tapering curves in letters like c and e was recorded. However, the increase (or decrease) in contrast in bold letters, like c, e, o *etc* was recorded.

This study did not analyse any letters in the bold italic style. Including bold italic would increase the scope of this limited study beyond what is manageable in the time available. For the same reason, no non-Latin scripts were analysed.

Due to time limits – and the overall aim of devising general guides for repeating aspects of letterform topography – 'unique' characters like a, g, s, were not anaylsed individually. However, understanding general increases in contrast, letter expansion, stem weight and serif expansion would help a designer draw these letters.

11 Devroye, L. (n.d.) *Frank Hinman Pierpont* Online at http://luc.devroye.org/fonts-33031.html Accessed 25 July 2019
12 Devroye, L. (n.d.) *Stanley Morison* Online at http://luc.devroye.org/fonts-61223.html Accessed 25 July 2019
13 Mosley, J. (1958) *Plagiarism and protection: Some notes on copyright of type-design,* Linotype Matrix 29, pp7

6. Parsed results drawn from the study

This chapter will focus on the conclusions that can be drawn from the results with regards specific repeatable topographical aspects of letterforms. For the full table of results see Appendix C. The aim of this chapter is to provide advice based on specific metric data. Tables of averages results of data and illustrations are used where necessary to illustrate key results. It should be noted that this study did not aim to describe definitive rules for drawing bold. As Bigelow and Holmes concluded in their analysis of Lucida and weight gain,

Weight numbers definitely help, and they are getting better the more we study them, but so far, they remain at best, signs on the road to understanding, not our destination.[1]

That is to say, the judgement of the designer should be aided not overruled by the data gathered in this study.

Figure 1
Averages across all fonts analysed.

Stem weight gain	12/13pt Avg. %>	24pt Avg. %>
Uppercase H	67.8	61.9
Uppercase O	65.4	63.3
Uppercase A	68.3	63.2
Lowercase n	69.6	69.3
Lowercase o	63.5	65
Lowercase v	64.3	64

6.1 Stroke weight gain

Straight vertical strokes

The fundamental characteristic of a bold letter is that it has a thicker vertical stroke than its regular counterpart. As noted in chapter 4, conventional theories show the vertical stroke weight gain ratio for a bold is between 1:1.6-1:1.75. In the terms of this study, this ratio equates to 60-75% stroke weight gain.

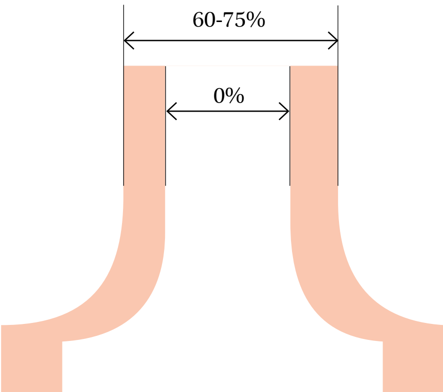


Figure 2
Straight strokes should have a stem weight gain of 60-75%. Illustration by the author.

An increase in vertical stroke weight of between 60-75% was typical of the typefaces measured in this study for an uppercase bold character (see Figure 1 and Figure 2). The results of this study correlate with the conventional theories noted in chapter 4. A notable exception is Times Bold. Although, as described in chapter 5, technical limitations to the width of characters in printing of the bold can account for less than typical stroke weight increase.

For the lowercase vertical stroke, this study showed 60-75% stroke weight gain. However, notable differences in stroke weight gain can be found in some styles of letter. Both Baskerville and Garamond had substantially larger rates of gain in bold lowercase strokes – see Appendix C for the results table. This showed the judgement of the designer in some cases should outweigh any particularly rigid guidelines. There was a negligible difference in the average rate of stroke weight gain between 12-24pt sizes. Similarly, there was a negligible difference (about 4%) in result when low-contrast fonts[2] were removed from the average stroke weight gain of the lowercase n and uppercase H stems – 74.1% and 64.8% respectively.

Curved vertical strokes

The vertical weight of curved strokes in the lowercase followed a relatively consistent pattern across all fonts in relation to straight vertical strokes. For example, on average the vertical stroke of the letter o expanded at a lesser rate than the straight vertical stroke of the n, being overall 5% thinner. So this study showed vertical curved strokes should have a weight gain of 55%-70% (see Figure 3).

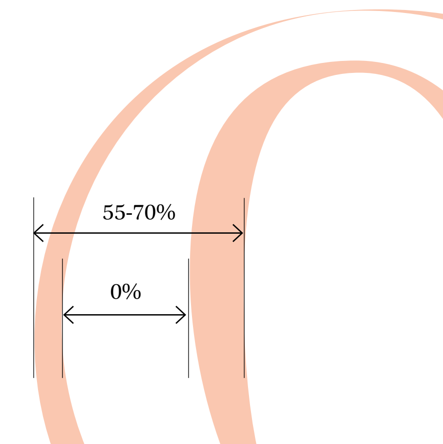


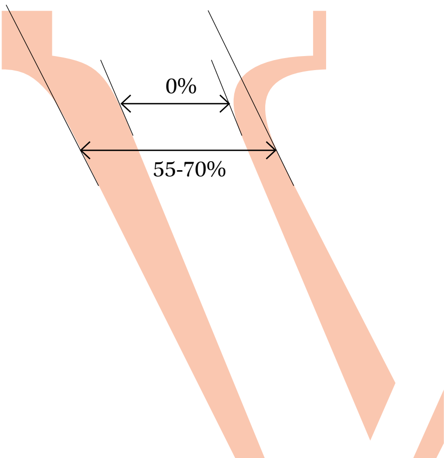
Figure 3
Bold curved vertical strokes should have weight gain of 55-70%. Illustration by the author.

The vertical curved strokes of the uppercase O approximated the rate of gain seen in the straight vertical strokes (60-75%). This result was an average across

1 Bigelow & Holmes (2015) *On font weight.* Online at https://bigelowandholmes.typepad.com/bigelow-holmes/2015/07/on-font-weight.html Accessed 23 July 2019
2 NB. In the following analysis, references to high-contrast fonts in the study refer to Clarendon, Plantin, Times, Garamond, Baskerville and Bodoni. While low-contrast fonts in the study refer to Univers, MT Grotesque, Gill Sans and Rockwell.

the fonts analysed. At 12/13pt the rate of gain was slightly less (2.4%), and at 24pt it was slightly more (1.4%). That is to say, each font analysed varied slightly in how the vertical curve related to the vertical stroke in terms of weight gain. Fundamentally, the rate of gain in the uppercase curve was *about* the same as the uppercase vertical stroke, but minor differences should be a consideration of the designer.

FIGURE 4
Angled stroke weight gain of 55-70% is suitable for a bold. Illustration by the author.



Angled strokes
In this study the rate of weight gain on angled strokes (the letters A and v) was measured on a horizontal plane (see chapter 5 for an explanatory visual guide on measuring). There were some correlations seen in the uppercase angled stroke and straight vertical strokes. With the exception of Times and Gill Sans, the rate of gain was equivalent or more than the rate of gain in the straight vertical stroke, and the overall average weight gain was a 1-2% percent more than appears on the vertical stroke (see Figure 1). This study showed that the uppercase weight gain of an angled stroke could be equal to or 1-2% more than the vertical stem weight gain.

In the lowercase, the rate of gain for an angled stroke was about 5% less than the vertical stroke of the n. The average result was closer to the rate of increase in the curved stroke with a weight gain of 55-70% for the angled strokes (see Figure 4).

FIGURE 5
Averages across all fonts analysed.

Tittle weight gain	12/13PT AVG. %>	24PT AVG. %>
Lowercase i	53.5	54.2

The tittle
The tittle is the dot above the i & j. Its average gain is 16% less than the average vertical stroke weight gain of the lowercase (see Figure 5). The different design of the tittle and stroke from font to font at regular sizes, compared to at bold sizes could account for the less weight gained.

A small note on optical sizing and vertical stem thickness
The vertical stroke weight gain of straight and curved lowercase letters in MT Grotesque (12/13pt) and Gill Sans (12/13pt and 24pt) were noticeably greater than other results (see Appendix C for data table). Univers, the first cohesively designed sans-serif family[3] had a typical rate of increase comparable with serifs and slabs at either size. On average, most of the fonts sampled have thicker bold strokes at 12/13pt than at 24pt, which correlates with Tim Ahrens research[4].

FIGURE 6
Averages across all fonts analysed.

Stem weight gain: external expansion vs internal expansion	12/13PT AVG. %>	24PT AVG. %>
Uppercase H	39.6 – 28.2	42.4 – 19.5
Uppercase O	25.7 – 39.5	28.3 – 35
Lowercase n	40.7 – 28.8	41.7 – 27.6
Lowercase o	19.4 – 44.1	23.2 – 41.8

6.2 Stroke weight gain: external expansion vs internal expansion
The external vs internal expansion (see Figure 6) was always measured on the left-most stroke of the letter (see chapter 5 for an explanatory visual guide on measuring, and Appendix A for how this measurement was calculated). This metric generated some quite varied results from font to font (see Appendix C).

Straight vertical strokes
At 12/13pt, the uppercase rate of external vs internal expansion showed an expansion outwards. That is to say, the uppercase stroke gained 10% more total weight on the outside than the inside of the letter. As a proportion of the stroke weight gain, the study showed 35-45% external increase vs 25-35% internal increase for the stroke of uppercase character H (see Figure 7).

However, at 24pt the uppercase stroke's rate of external vs internal expansion was more pronounced with 20% more total weight on the outside than the inside. It

3 Biemann, E.O. (1961) *Univers: A New Concept in European Type Design.* Print magazine, pp.36. Online at https://www.printmag.com/design-inspiration/subtleties-of-the-univers/ Accessed 26 July 2019
4 Ahrens, T. (2007) *Size-specific adjustments to type designs: An investigation into the principles guiding the design of optical sizes* University of Reading

Figure 7
35-45% external increase vs 25-35% internal increase is appropriate for the stroke of upper-case character H. Illustration by the author.

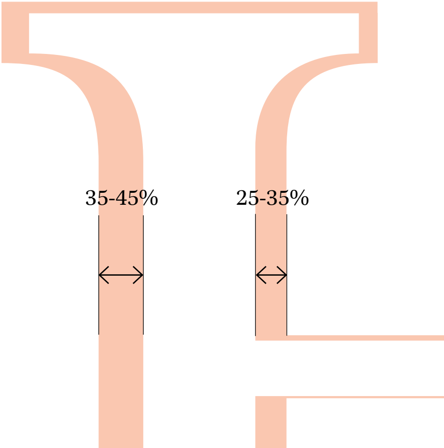


Figure 8
35-45% external increase vs 25-35% internal increase is appropriate for the stroke of the lowercase n. Illustration by the author.

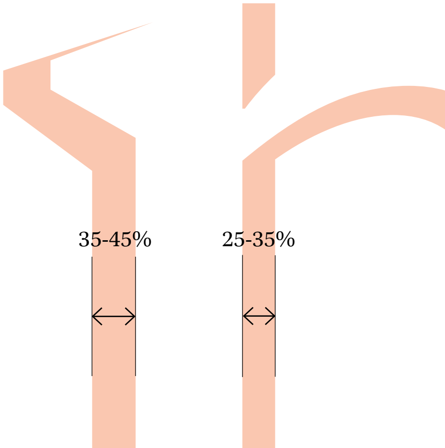


Figure 9
15-25% external gain vs 40-50% internal gain is appropriate for a lowercase o. Illustration by the author.

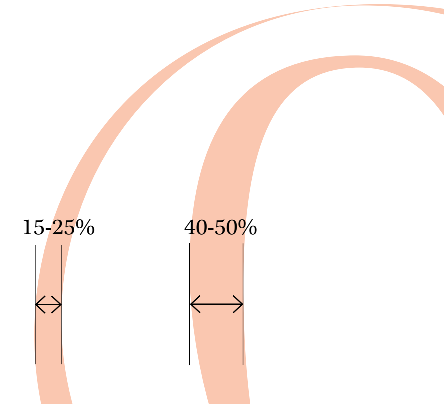
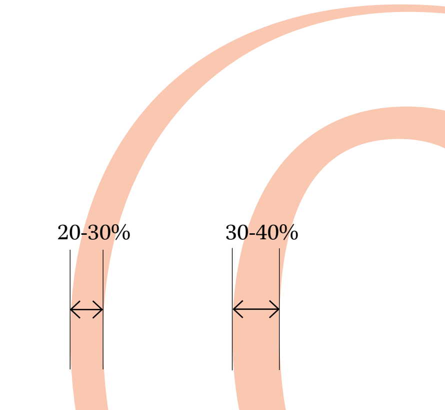


Figure 10
20-30% external gain vs 30-40% internal gain is appropriate for a low-contrast lowercase o. Illustration by the author.



should be noted that the average stem weight gain for the uppercase stroke at 24pt is less than at 12/13pt (see Figure 1). As a proportion of the stroke weight gain, this study shows that 35-45% external vs 15-25% internal increase for larger sizes.

As with the uppercase, at 12/13pt, the average lowercase rate of external vs internal expansion in the straight vertical stroke across all fonts analysed showed 10% more weight on the outside rather the inside. The study suggested a 35-45% external increase compared to 25-35% internal increase for the stroke of the lowercase n (see Figure 8). The 24pt size n produced similar averages (see Figure 6).

Curved vertical strokes
At 12/13pt on average the curved vertical stroke of the uppercase O followed an inverse pattern of expansion in relation to the straight vertical stroke. That is to say, the rate of gain on the inside of the uppercase O was 10% greater than the outside. This study showed a 20-30% external gain vs 35-45% internal gain for the uppercase O (see Figure 6). At 24pt, a similar rate of internal vs external gain was measured.

The lowercase o at 12/13pt and 24pt followed an similar pattern to one another. As with the uppercase O, the rate of gain inside the character was greater than outside. This study showed an 15-25% external gain vs 40-50% internal gain for a lowercase o (see Figure 9).

However, if high-contrast fonts are removed from the average, the results were slightly more balanced. In the lowercase, low-contrast fonts produced a result of 20-30% external gain vs 30-40% internal gain (see Figure 10). Further study of the difference between low-contrast and high-contrast fonts would be needed to draw conclusions from this result.

Inconsistencies in external expansion vs internal expansion
As described above, there are consistent averages between external vs internal weight gain in straight upper and lowercase vertical strokes as well as in curved upper and lowercase strokes. The analysis showed a pattern for adding weight to these parts of letters. However, some fonts analysed produced unexpected results. For example, at 12/13pt size the lowercase Garamond O and the uppercase Baskerville o both had 0% external expansion. All of the weight gained on these characters was internal.

Figure 11
Times New Roman regular weight o is wider than Times Bold o. Note that light shadow on the edges of the overlay - this is the regular weight. See Appendix B for full set of anaylsed images.

Even more extreme were the results for the lowercase Times o which had a negative external gain. That is to say, the regular weight o is wider than the o in Times Bold (see Figure 11). As mentioned in chapter 5, this is likely due to the limitations Stanley Morison and Victor Lardent had while designing Times Bold.

Figure 12
Averages across high-contrast fonts

Contrast increase	12/13pt Avg. %>	24pt Avg. %>
Uppercase H	67.1	62.5
Uppercase O	65.4	57.6
Lowercase t	67.2	77.1
Lowercase o	61.3	61.4

6.3 Contrast increase

The conclusions drawn from the results of this study were not based on a comparison between high- and low-contrast fonts with low-contrast fonts. The two styles of letterform were considered separately (see Figures 12 & 14).

Straight strokes

In high-contrast fonts the uppercase H contrast increase was equivalent to, or slightly more than, the respective stroke weight gain in each font analysed (*see Figure 12*). At 12/13pt, the average contrast increased in the uppercase H was 67.1% while the stroke weight gain was 67.8%. Then, when low-contrast fonts were removed from the stroke weight gain, the result was 64.8%, a marginal difference of 3%. At 24pt, in high-contrast fonts, the contrast increase was also equivalent to the (lower) stroke weight gain at that size. This study showed a relationship between stem weight gain and rates of contrast increase in the uppercase (see Figure 13).

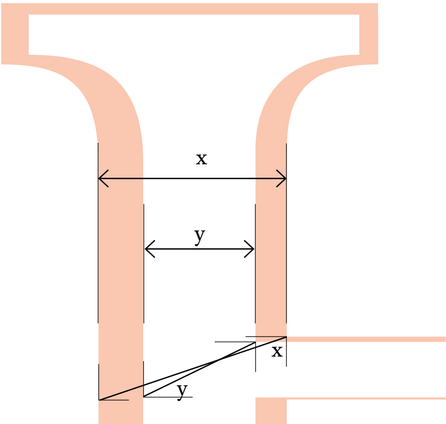


Figure 13
This study shows a relationship between stem weight gain and increase in contrast. Illustration by the author.

Similarly, on average in the lowercase 12/13pt, the contrast of the stroke and crossbar of the t followed a similar pattern to the rate of stem weight gain increase (67.2% contrast, 69.6% stem weight gain). More individual variation between styles of font was found, but on average the stem weight gain of the lowercase n was equivalent to the contrast increase of the t in high-contrast fonts.

Curved strokes

In high-contrast fonts the uppercase O contrast increase followed the same pattern as the straight stroke H (see Figure 12). The increase was equivalent to or slightly more than the respective fonts stroke weight gain. However, the rate of increase was less overall. At 12/13pt, the contrast of the uppercase O was on average about 2-3% less, and at 24pt it was about 5% less. So, while the curved stroke contrast follows a similar pattern to the straight strokes, the horizontal curved strokes are thicker in bold than horizontal straight bars.

Figure 14
Averages across low-contrast fonts

Contrast increase	12/13pt Avg. %>	24pt Avg. %>
Uppercase H	62.8	58.3
Uppercase O	61.8	60.9
Lowercase t	55.7	49
Lowercase o	44.8	54.6

As with the contrast increase between uppercase H and O (see Figure 12) in high-contrast fonts, the lowercase o rate of contrast increase was equivalent to or 5-15% less than the contrast increase of the t.

Low-contrast font contrast increase

In low-contrast fonts, the rate of contrast increase was equivalent to or less across uppercase and especially in the lowercase (see Figure 14). When compared to the vertical stroke gain of lowercase low-contrast fonts at 12/13pt, on average there was a difference of about 12-13% (57.4% stroke gain and 44.8% contrast increase). That is to say, there was a correlation between vertical stroke gain and contrast increase, but it is much less marked than in high-contrast fonts (see Figure 15). Further study low-contrast fonts would be needed to draw further conclusions from this result.

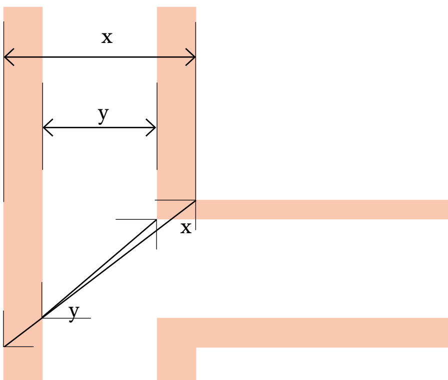


Figure 15
Low-contrast fonts have a less marked relationship between vertical stroke gain and contrast increase. Illustration by the author.

Figure 16
Averages across all fonts

Proportional width	12/13pt Avg. %>	24pt Avg. %>
Uppercase H	2.5	5.7
Uppercase O	-3	0.1
Uppercase A	-5.4	-2.2
Lowercase n	3	3.5
Lowercase o	-5.3	-4.6
Lowercase d	0.7	2
Lowercase v	8.8	10.3

Figure 17
Averages across all *except* Times

Proportional width	12/13pt Avg. %>	24pt Avg. %>
Uppercase H	2.6	6.3
Uppercase O	-3	0
Uppercase A	-4.3	-0.7
Lowercase n	4.4	5.4
Lowercase o	-4	-2.6
Lowercase d	3	4.6
Lowercase v	8.2	10.3

6.4 Proportional width

Proportional width was measured without consideration of serifs and was concerned with the overall horizontal expansion of the letters analysed. On average, the proportional width of the uppercase H at 12/13pt was 2.5% wider and at 24pt it was 5.7% wider (see Figure 16). However, as mentioned in chapter 5, the design of Times Bold was limited in its character width. When Times is removed from the average, proportional width generally increases (see Figure 17). Regardless, the same pattern of increases and decreases in proportional width was found with or without Times included.

High-contrast font proportional width

High-contrast font's patterns of increase and decrease in proportional width had a correlation with external vs internal expansion (see above). That is to say, high-contrast letters with straight vertical strokes expand while letters with curved strokes retract (see Figure 18). Similarly, letters with angled strokes also retracted, but at a more marked rate than curved stroke letters. This study showed an increase of 0-5% in proportional width for high-contrast fonts with straight stems, and a decrease of 0-5% for curved and angled stroke characters.

Low-contrast fonts and optical sizes

However, at 24pt when the proportional width of only low-contrast fonts was averaged, letters with straight vertical strokes expanded less than did high-contrast fonts (see Figure 19).

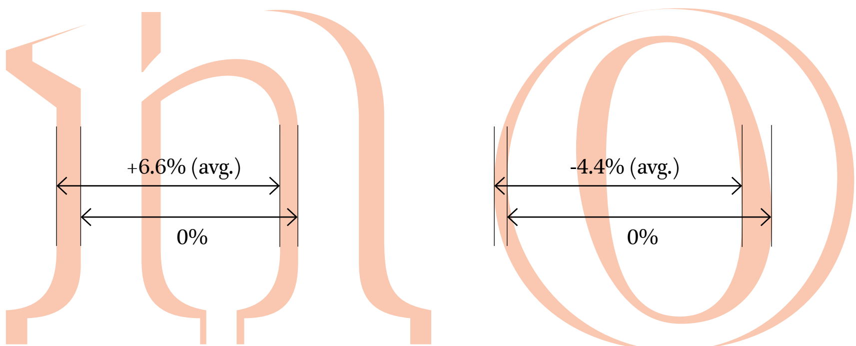


Figure 18
High-contrast letters with straight vertical strokes expand horizontally while letters with curved strokes retract. Illustration by the author.

Figure 19
Averages across low-contrast fonts

Proportional width	12/13pt Avg. %>	24pt Avg. %>
Uppercase H	3.6	2.5
Uppercase O	-1.3	-1
Uppercase A	-5.3	1.6
Lowercase n	6.6	2.3
Lowercase o	-4.4	-7.2
Lowercase d	4.7	-2.2
Lowercase v	10	5.7

Figure 20
Averages across all serif fonts

Serif height	12/13pt Avg. %>	24pt Avg. %>
Uppercase H	58.3	43.6
Lowercase baseline n	58.7	42.7
Lowercase x-height n	49.2	41.8
Lowercase ascender	38.5	38.6

6.5 Serifs & apertures

Serif height

This study covered a range of types of serif – uppercase H, lowercase baseline serif, lowercase x-height serif, lowercase ascender serif. At 12/13pt, the average baseline serif height increase between uppercase (58.3%) and lowercase (58.7%) is very similar (see Figure 20). However, when Baskerville was removed from the average, the lowercase baseline serif increase at 12/13pt was notably smaller (45.7%) than the uppercase (53.6%) (see Figure 21). Baskerville appeared to be an outlier in the serif height results.

At 24pt, the rate of increase in all serif height is markedly less than at 12/13pt. However, regardless of whether Baskerville is included, both uppercase and lowercase baseline serifs had a similar rate of increase (37-44% and 36-42% respectively). It is worth noting that this does not demonstrate that serifs in uppercase and lowercase were the same height when measured. What was shown was that the rate of increase is comparable.

Figure 21
Averages *except* Baskerville

Serif height	12/13pt Avg. %>	24pt Avg. %>
Uppercase H	53.6	36.9
Lowercase baseline n	45.7	36
Lowercase x-height n	40.1	33.7
Lowercase ascender	35.4	31.5

With and without Baskerville included in the average, the lowercase x-height serif rate of increase was less than the baseline serif at at 12/13pt (8.5% less with Baskerville and 5.6% without), but comparable with the baseline serif at 24pt (0.9% with Baskerville and 2.3% without).

This study showed that the increase in serif height at 12/13pt for uppercase was 48-58%, and that for lowercase baseline serifs the increase was 40-50%. Comparatively, the x-height serif was 0-5% less than the baseline serif rate of increase, and the ascender serif 10-15% less than baseline rate of increase (see Figure 22).

Figure 22
Serif height gain for 12/13pt uppercase is 48-58% Illustration by the author.

Serif height gain for 12/13pt lowercase baseline serifs is 40-50%. Illustration by the author.

Serif height gain for 12/13pt lowercase ascender serif is 25-40%. Illustration by the author.

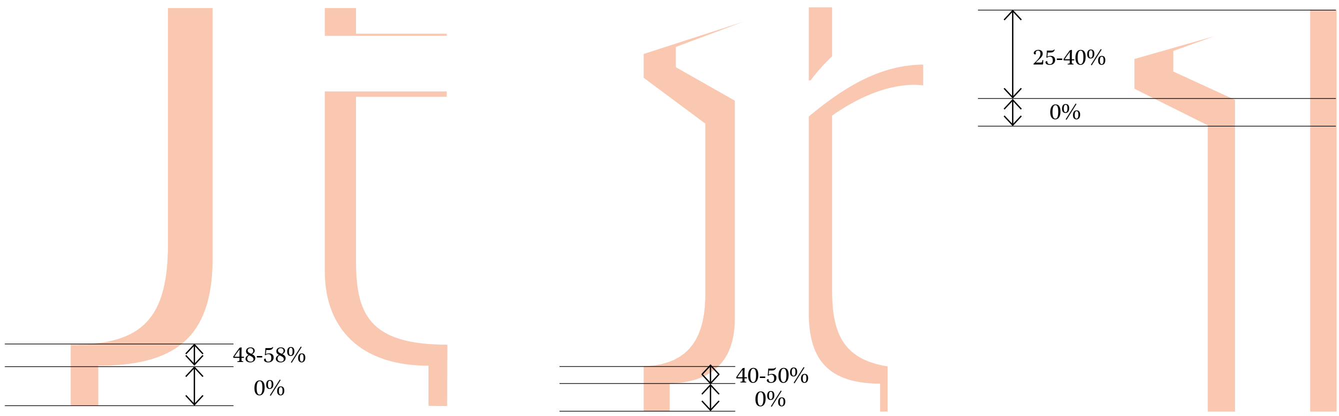


Figure 23
Averages across all serif fonts

Serif width	12/13pt Avg. %>	24pt Avg. %>
Uppercase H	-8.6	-4.3
Lowercase baseline n	-16.7	-4.3
Lowercase x-height n	-9.3	-5.2
Lowercase ascender	-11.5	-3.5

Serif width
The results from this study of measuring the width of serifs showed an almost consistent decrease (see Figure 23). Overall, the lowercase serifs at 12/13pt exhibited decreases in width (between -8.6% to -16.7%), while at 24pt this occurred with less variance (-3.5% to -4.3%). The marked change at 12/13pt may be related to the external expansion vs internal expansion stroke weight gain. This measurement demonstrated that in lowercase letters, straight vertical strokes expanded outwards, with proportionally smaller serifs (see Figure 24). This study showed that for uppercase serifs at 12/13pt there was a decrease of 5-15%. While for baseline serifs at 12/13pt there was a decrease of 10-20%. Similarly, at 12/13pt a the decrease for x-height and ascender serifs was 5-15%.

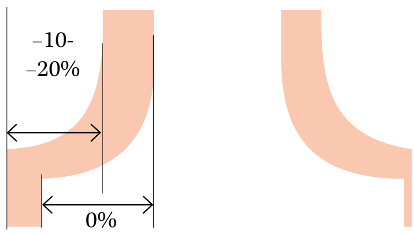


Figure 24
Straight vertical strokes expanded outwards, with proportionally smaller serifs. Illustration by the author.

Serif terminals
Serif terminals showed a gain in weight from regular to bold (see Figure 25). On average this gain was less than the stem weight gain (at 12/13pt, 15.9% less for the serif terminal of the a and and 24.8% less for the serif of the c). However, this was not a consistent pattern across individual fonts. For example Bodoni letter a showed a marked increase in weight gain at the serif terminal compared to its respective stem weight gain (at 12/13pt, 1.5% less for the serif terminal of the a and -8.3% for the serif of the c – see Apendix for full data sheet). This showed the design of the font plays an important factor in how much weight should be added to the serif terminal. On average the weight gain of the serif terminal of the letter a was comparable to the weight gain of the tittle (at 12/13pt, a 0.2% difference in the serif terminal of the a and at 24pt a 1.4% difference – see Figure 5). This study showed a weight gain of 45-55% for the serif terminal of the a and c (see Figure 25).

Figure 25
Averages across all serif fonts

Serif terminals	12/13pt Avg. %>	24pt Avg. %>
Serif a	53.7	52.8
Serif c	44.8	51.8

Figure 26
Averages across all fonts

Aperture change	12/13pt Avg. %>	24pt Avg. %>
Uppercase C	-16.3	-9.1
Lowercase c	-21.3	-14.5

Apertures
The reason this study analysed the apertures of the uppercase C and lowercase c was to find a metric for how an 'open' letter closes up as weight is added. On average the aperture of the lowercase c closed up more than the uppercase C (at 12/13pt an average difference of 5% and at 24pt a difference of 5.4% – see Figure 26). At 12/13pt, both upper and lowercase c's closed up more than at 24pt (-16.3% comnpared to -9.1%, and -21.3% compared to -14.5% respectively). This study showed that overall, the aperture of the lowercase c closed 15-20%, while the uppercase C closed at 10-15%.

Figure 27
The joints of a font with a stem weight gain of 60-75%, increased at a rate of 35-45%. Illustration by the author.

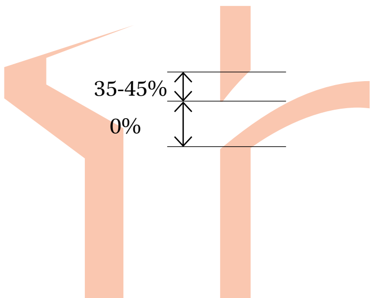


Figure 28
Averages across all fonts

Joint	12/13pt Avg. %>	24pt Avg. %>
Lowercase n	43	40

7.6 Joints (see Figure 27)
The connection between a stem and a curve in Latin is called a joint. This study found that the rate of weight gain in joints across the fonts analysed was substantially less than the corresponding stem weight gain of straight vertical strokes (60-75% stem weight gain compared to 35-45% joint gain). As weight is added to a letter and its contrast increases (see Figure 12), the contrast between stem weight gain (see Figure 1) and the weight of the joint (see Figure 28) increases to lesser degree. Joints therefore look proportionally thinner in bold than in regular. This study showed that joints therefore, with a stem weight gain of 60-75%, increase at a rate of 35-45%.

Figure 29
With a higher x-height bold appears optically the same height as the regular. Illustration by the author.

Figure 30
Averages across all fonts

X-height gain	12/13pt Avg. %>	24pt Avg. %>
Lowercase n	1	1.6

Figure 31
Averages across all fonts

Ascender height gain	12/13pt Avg. %>	24pt Avg. %>
Lowercase l	-0.4	0.3

Figure 32
Averages across all fonts

Descender line gain	12/13pt Avg. %>	24pt Avg. %>
Lowercase p	0.4	0.5

6.7 Vertical proportions
X-height gain
All fonts analysed showed either no gain or marginal gain in x-height (see Figure 29). Measured from the baseline, this growth of x-height averaged 1% at 12/13pt, and 1.6% at 24pt (see Figure 30). This modest gain in height allows for more space insider the letter and makes the bold appear optically the same height as the regular. This study showed a gain in bold x-height of 1-1.6% at 12/13pt and 24pt respectively.

Ascender
Of the fonts analysed, most showed either no gain or a loss of ascender height at 12/13pt. At 24pt the results were more erratic font-to-font, but culminated in an average gain of 0.3% (see Figure 31). The results for both sizes measured were negligibly small (-0.4 to 0.3%) and produced quite different results, this study showed little change in ascender height.

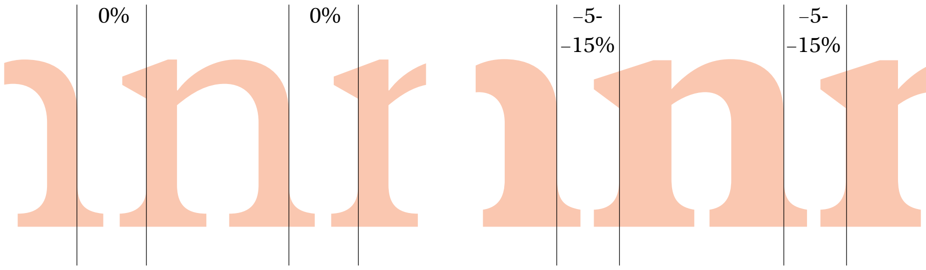
Descender
Similarly, the results of measuring the descender were erratic and varied substantially from font-to-font (see Appendix C for data table). However, the average result for 12/13pt and 24pt was a positive gain in descender length (0.4-0.5% – see Figure 32). This study showed a marginal gain in length from regular to bold in the descender. However, this was not typical in a bold at 12/13pt and 24pt.

Caps height
Most fonts analysed showed either no gain or a marginal gain in caps height (see Appendix C for data table). On average there was a modest gain of 0.6% in caps height at both 12/13pt and 24pt (see Figure 33). However, as with the results from the previous measurements of vertical proportions (x-height, ascender and descender), the average gain was relatively small. This study showed a caps height gain of 0.6% for bold at 12/13pt and 24pt.

Figure 33
Averages across all fonts

Caps height	12/13pt Avg. %>	24pt Avg. %>
Uppercase H	0.6	0.6

Figure 34
Tighter spacing of about –5- –15% for 12/13pt is suitable for a bold. Illustration by the author.



6.8 Spacing
Of all fonts analysed, uppercase at 12/13pt largely showed tighter spacing and on average spacing was 11.4% tighter (see Figure 34). Similarly, the lowercase at 12/13pt also showed tighter spacing to a similar degree of on average 10.2%. On average, 24pt upper and lowercase showed tighter spacing but to a lesser degree, -2.5% and -8.5% respectively. Tighter spacing would be a logical method for designing bold given the counters of bold letters are smaller, therefore to maintain rhythm along a line of text, the space around the letters should be smaller too. This study showed tighter spacing of about -5 to -15% for 12/13pt and 0 to -10% for 24pt (see Figure 35).

Figure 35
Averages across all fonts

Spacing	12/13pt Avg. %>	24pt Avg. %>
Uppercase HHH	–11.4	–2.5
Lowercase nnn	–10.2	–8.5

6.9 Sentence density
As mentioned in chapter 4, Bigelow and Holmes when talking about the sans-serif Lucida, showed that measuring the pixel/ink density of letters would an accurate measurement of bold. They showed that an increase of 10% was adequate for a bold to stand in contrast to a regular. This study focused specifically on density at the text-size of 12/13pt.

At 12/13pt, of the font analysed in this study, the average density increase was found to be 14.6% (see Figure 36). When just high-contrast fonts were averaged, the density increase was found to be 17% (see Figure 37). However, when low-contrast fonts were averaged the density was found to be just 11% (see Figure 38), much closer to Bigelow and Holmes, suggestion of 10%.

Figure 36
Averages across all fonts

Overall density increase	12/13pt Avg. %>
Sentence	14.6

Of all the fonts at 12/13pt analysed, most showed a density increase of between 10-13%. The notable exception (reason the high-contrast average is so high at 17%) was Baskerville. This is accounted for by the design of Baskerville and its above average stem weight gain (see Figure 1). This study supports Bigelow and Holmes' suggestion that an overall pixel/ink density gain of 10% is suitable for a bold. Additionally, this study showed an overall pixel/ink density gain for high-contrast fonts of 10-15%. For further details on how sentence density was measured in this study see Appendix A.

Figure 37
Averages across high-contrast fonts

Overall density increase	12/13pt Avg. %>
Sentence	17

Figure 38
Averages across low-contrast fonts

Overall density increase	12/13pt Avg. %>
Sentence	11

7. Verification of results: A note on ExtraBold and overshoot

This chapter is a stress-test on the conclusions drawn from the results described in chapter 6. In this chapter the conclusions drawn from the results of the stem weight gain analysis will be compared with the stem weight gain of regular to extra bold. With graphical analysis it will be shown that the stem weight gain of regular to bold is comparable to that from regular to extra bold. The second section of this chapter will show how measuring overshoot in curved letters was not successful in this study.

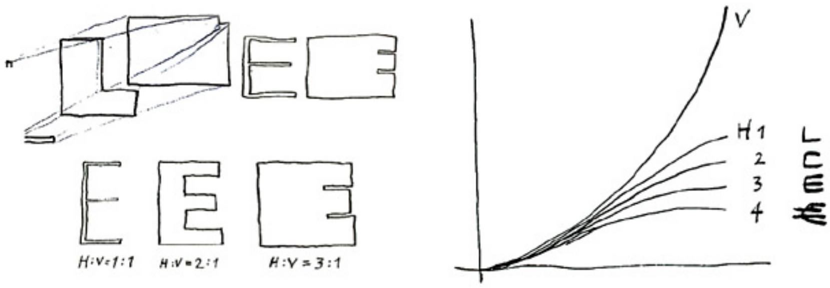


Figure 1
Lucas de Groot's Anisotropic Topology-dependent Interpolation Theory. de Groot, L. (n.d.) *Interpolation theory.* Online at https://www.lucasfonts.com/about/interpolation-theory/ Accessed 20 June 2019

7.1 Rockwell Extrabold

This study analysed a range of regular and bold letters to measure rates of gain in topographical aspects of the letterforms. In order to confirm the validity of the study when compared with previous theories on adding weight to letters (Lucas – see Figure 1, Impallari – see chapter 4), this study also produced a graphical analysis of the comparative rates of gain between a regular and extra bold stem weight gain of the typeface Rockwell 24pt. The full data set gathered for this aspect of the study can be found in the Appendix C results table.

This section will focus on three letters in the study. This section will use graphs to demonstrate a comparable rate of gain between the ideal stem weight proposed in previous theories, the averages derived from this study and the specific data gathered from the analysis of Rockwell extrabold.

As described in chapter 4, stem weight (referred to as vertical stem weight gain in this study) has been a key metric used to measure bold. Figure 2 shows the vertical stem weight gain for the uppercase H at 24pt in this study. The average result from this study follows a similar rate of gain to the previously described theories. Rockwell shows a more comparable rate of gain with the Impallari curve, until it begins to tail off toward the peak of the graph, where it is roughly an average of

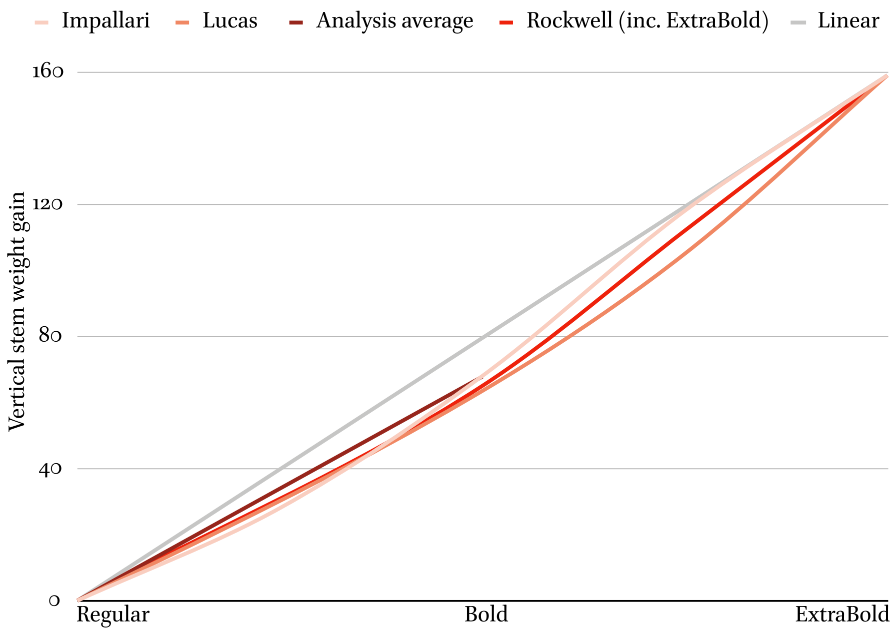
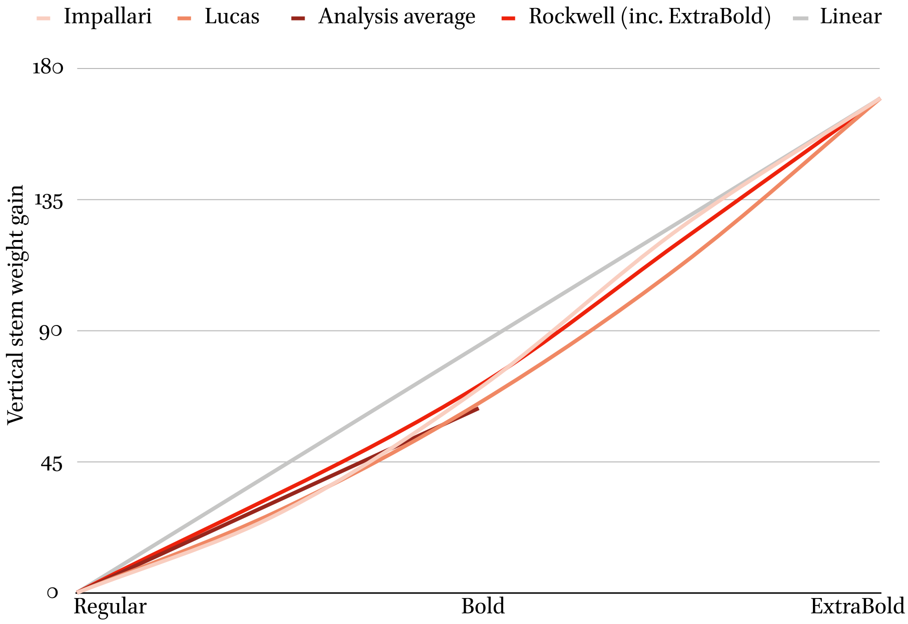


Figure 2
Vertical stem weight gain for the uppercase H at 24pt. Impallari, Lucas and Linear curves drawn from forum post by Lee, A. (February 2017) *Proper weight instance progression for a multiple master* Online at https://typedrawers.com/discussion/1991/proper-weight-instance-progression-for-a-multiple-master. Analysis average and Rockwell (inc. ExtraBold) curves are drawn from the data table in Appendix C.

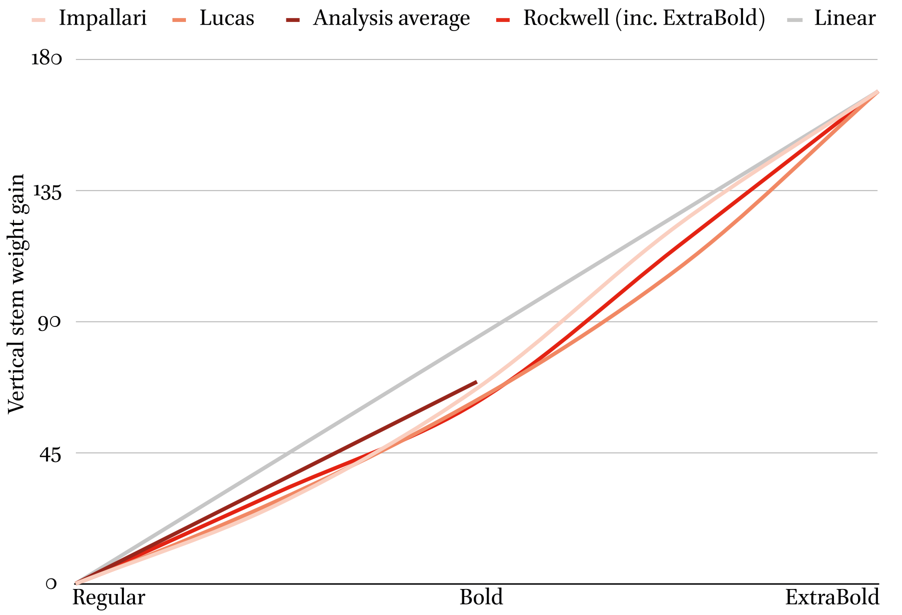
Figure 3
Vertical stem weight gain for the uppercase O at 24pt. Impallari, Lucas and Linear curves drawn from forum post by Lee, A. (February 2017) *Proper weight instance progression for a multiple master* Online at https://typedrawers.com/discussion/1991/proper-weight-instance-progression-for-a-multiple-master. Analysis average and Rockwell (inc. ExtraBold) curves are drawn from the data table in Appendix C.



the Lucas and Impallari curves. The similarities between all of these curves are shown in the graph (Figure 2).

The vertical stem weight gain for the uppercase O at 24pt also followed a comparable pattern with existing theories for adding weight to letters (see Figure 3). The overall average from the study is approximately the same as the Lucas curve, while as with 12/13pt uppercase H, Rockwell follows a similar pattern to the Impallari curve.

Figure 4
Vertical stem weight gain for the lowercase n at 24pt. Impallari, Lucas and Linear curves drawn from post by Lee, A. (February 2017) *Proper weight instance progression for a multiple master* Online at https://typedrawers.com/discussion/1991/proper-weight-instance-progression-for-a-multiple-master. Analysis average and Rockwell (inc. ExtraBold) curves are drawn from the data table in Appendix C.



The vertical stem weight gain for the lowercase n at 24pt followed an approximately similar pattern as the previous letters analyses (see Figure 4). However, notably the average from the study was more in-tune with the Impallari curve while Rockwell showed a slightly less than average rate of gain up to bold. However, between bold and extra bold, Rockwell begins to follow a similar plateauing curve more in line with Impallari.

7.2 Overshoot

In order that letters appear the same height as one another, curved letters (O, C, G, a, e, c, o et al) must be optically adjusted so that the curves protrude slightly over below the baseline, above the x-height or caps line[1]. In this study this feature was called overshoot.

The overshoot of uppercase O and lowercase o was measured in all fonts in the study – see Appendix C for full data table. However, in the conclusions drawn from the results (chapter 6) overshoot is not referred to. This is because the method of measuring in this study, as described in chapter 5, did not collect metrics from which conclusions could be drawn.

Figure 5
Averages across all serif fonts

Serif terminals	12/13pt Avg. %>	24pt Avg. %>
Uppercase O	11.4	17.8
Lowercase o	7.9	10.6

At 12/13pt the average overshoot for the uppercase O was 11.4% (see Figure 5), and 24pt the average overshoot was 17.8% between regular and bold. Similarly, the lowercase o followed a similar pattern with 7.9% at 12/13pt and 10.6% at 24pt respectively. These results showed an increase in overshoot at larger sizes.

However, across the range of results there was a large disparity between fonts which suggested no trend. For example, with the 24pt uppercase O, Plantin had a result of 50% increase in overshoot and Times had a similar increase of 42.5%. Garamond and Baskerville however had overshoot increases of 0% and 7.3% respectively. Between these four fonts at 24pt, there was a large difference in results. At 12/13pt, the uppercase O in Bodoni had a -11.7% decrease, as did Gill Sans with -15% at the same size. While the uppercase O in Plantin at 12/13pt had an increase of 40%[2]. These disparate results suggested a flaw in the measuring.

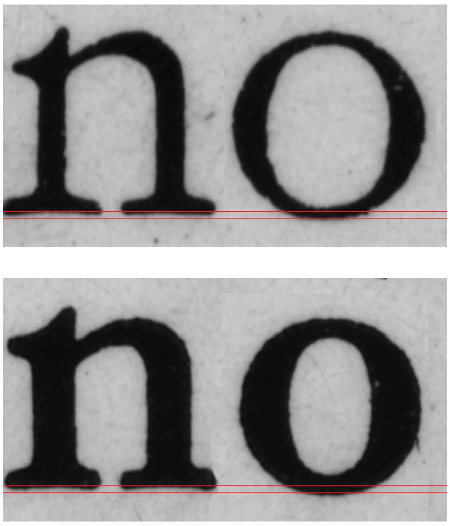


Figure 6
Distance measured when measuring overshoot. Shown in the image is Garamond 13pt. The lines overlaid on both images are the same distance apart. Even a small change in distance between these lines would produce a large percentage increase result. Image collected by the author.

The distance measured when recording overshoot is small (see Figure 6). Even an extra pixel measured can greatly affect the results. For example, the regular result is 10px overshoot, and the bold result is 12px. The percentage increase calculated from these results is 20%. However, if the regular result is 10px overshoot and the bold result is 15px, just 3px more, the percentage increase is 50%. A jump of 30%. With small measurements the method of describing percentage increase in this study created unstable results. It should be noted that overshoot was the smallest of the distances measured in this study. All other measurements were larger and produced more consistent and repeatable results as described in chapter 6. A continuation of this study would require a revised method of measuring the overshoot of curved letters.

1 Unger, G. (2018) *Theory of Type Design* nai010, Rotterdam, pp.119
2 see Appendix C for full data table

8. Conclusion

This paper showed that existing theories on drawing bolds are useful but limited in scope. In its analysis of stem weight gain, (chapter 6) and of Rockwell ExtraBold (chapter 9) this study has produced results which correlate with the existing theories of stem weight gain (chapter 4). However, this study expanded on existing theories and methods with a more in-depth investigation into the topography of individual letters and the component parts of Latin letterforms.

Prior to this study, detailed analysis of topographical aspects of letterforms such as proportional width had rarely been defined in the literature on drawing bold fonts. This study demonstrated that the gain in proportional width from regular to bold varied in letters with different topographical features. For example, on average letters with straight stems expanded in proportion while letters with curved stems on average lost width. The conclusions drawn from the external vs internal weight gain metrics showed that letters with straight stems analysed expanded outwards, while curved stems expanded inwards. Also noted, was the difference in weight gain between straight, curved and angled letterforms.

Similarly, a methodology which analyses letterforms and provides a range of comparable and contrastable topographical metrics has so far been lacking in published literature on drawing bold letters. This paper has demonstrated that these methods of analysing and describing bold letters are repeatable and are a useful contribution to the field of type design.

This research contextualises how typeset bold is often used. It was shown that the sparing use of bold (on a page largely set in a regular weight) to add emphasis, distinction and hierarchy is a common practice, and that this context helps a typeface designer understand how their fonts will be used.

Further consideration should be given to bolds from the phototype and digital eras. Additionally, there are more metrics which could be considered in the topography of Latin letterforms and other writing systems. As well as reflection on the counter-implication of the 'designers eye' in deciding on what is a 'well drawn letter'.

It is the conclusion of this study that using detailed metric analysis of existing fonts can generate a relevant understanding of why then how to draw a bold to accompany a regular and that this paper provides the context, a methodology and advice on how to do this.

Acknowledgements

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III.
Appendices

Appendix A: Methods of measurement

This appendix explains the process and methods of two types calculation made in the study.

A.1 Vertical stem – external expansion : internal expansion

Stem expansion is a useful metric, but it does not demonstrate a rate of expansion. Most letters in the lowercase Latin alphabet (with the exception of 'single' vertical stroke letters like i, f, j, l ,t, r) can be drawn around a skeleton of a cuboid (h, n, m, u), ovoid (c, e, o, s) triangle (v, w, y) or a combination of all three (a, b, k, *etc*). In other words, the majority of letters in lowercase (and uppercase) Latin have two sides and space in the middle. Therefore just measuring the vertical stem expansion of a character is insufficient to understand how the letter actually gains weight and, by necessity, width. When a letter gains weight around its stem, this weight is distributed unevenly internally and externally (see Figure 1).

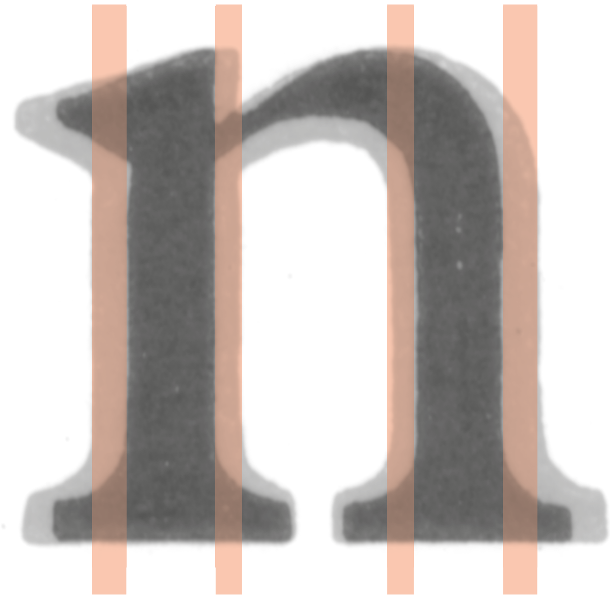


Figure 1
24pt MT Plantin n. In the bold, the letter n spreads outwards so more weight is added to the external stem than the internal stem. This difference can be calculated in an number of ways. Image by the author.

For example, if a bold n only gained weight externally, it could appear expanded, or vice versa internally appear condensed. Similarly, prior to the study the assumption of the author was that weight gained would not be evenly balanced, as in 50% expansion internally and externally around a stem. This would make a letter appear condensed as the 'skeleton' of the letter[1] and the horizontal space it takes up in a line would remain the same (this does happen in some type designs and is known as duplexing[2], but is not the focus of this study).

Therefore, in order to measure this increase a metric called vertical stem expansion was recorded. An aim of this study was to produce results which are useful for designers and can be easily parsed into general advice. So, a metric which could be easily understood as explaining the rate of internal and external expansion of a stem was devised.

In order to create consistent results, a measurement was only taken of the left-most stem of any letter. The presentation of this data (see Appendix C) always shows the external vs internal gain. However, this result could be presented in several ways. Four methods of collating this data were tested until a final method was settled upon as the most adequate means of demonstrating the results. As explained below:

1. As a ratio, *ie* 2:1

Ratios had been used by Lucas de Groot (see chapter 4) in explaining regular to bold weight gain. This seemed like a logical method. However, this resulted in hard to visualise complex ratios, for example 7:39. As in, for every 7 external gain there was 39 internal. Also, ratios did not follow the percentages used in other areas of the study. This method was abandoned and another solution sought.

2. Percentage showing the difference, *ie* -32.5%

This method used percentages, which appear elsewhere in the study. It assumes that an exactly equal gain externally and internal will equal 0%. Any uneven weight gain will result in a positive or negative percentage. However, because the method produced negative percentages if the expansion shifts outward, the results were not be entirely clear whether weight would be added or taken away.

1 Zajac, F. (2017) *Skeleton type design explained* Online at https://medium.com/letterink/skeleton-type-design-explained-d443f146de97 Accessed 18 July 2019
2 Brown, T. (2016) *Retina from Frere-Jones Type available to host on Typekit* Online at https://blog.typekit.com/2016/10/05/retina-from-frere-jones-type-available-to-host-on-typekit/ Accessed 18 July 2019

3. Skeleton and percent, *ie* 60% – 40%
Using a percentage based result made sense, but the result needed to explain external and internal weight gain separately. So, similar to the ratio method, the results were recorded as percentage increases from the skeleton (direct centre) of the regular letter. However, the problem with this method was that the skeleton is more of a theoretical principle of a letter. It can be hard to find accurately in a digital type design program which deals primarily with outlines of letters.

4. Division of the percentage increase, *ie* stem vertical stem expansion = 66% ∴ external vs internal = 20% – 46%
The total increase of the stem width (formed in another calculation) divided by the results of gains either side of the regular stem, created more understandable results. That is to say, the percentage stem expansion was already calculated. This number was then divided by the the total of the external and internal gain (similar to how a typical percentage from 100 would be calculated). That result was then multiplied by the external gain and the internal gain, and appears as two percentages, which when added together equal the total vertical stem expansion.

Vertical stem expansion / (external + internal gain) = n
n × external : n × internal = % external gain : % internal gain

This method of calculating rate of external vs internal expansion was used.

A.2 Percentage density coverage
Bigelow and Holmes (see chapter 4) in their study of Lucida suggested that percentage gain across a line of text would be a useful metric when calculating how bold a bold should be[3]. So, using the Measurement Log tool in Photoshop[4] this study gathered data on the percentage increase of ink/pixels in regular to bold. Bigelow and Holmes suggested for Lucida that an increase of 10% darker pixels (or ink) would be suitable for a bold.[5] This metric was used to help decide which method of percentage density coverage would yield the most useful results.

The calclation was done with the Measurement Log tool. The mean gray value is a measurement of lightness (when the image is set to 32/Bits Channel) so is a value less than 1.0. The percentage increase was calculated as so:

1 – regular Gray Value (Mean) = x
1 – bold Gray Value (Mean) = y
y – x = n, *then* (n/Regular value) × 100 = % increase

For testing the three approaches of percentage density coverage 12/13pt MT Plantin was used. The three approaches devised are explained below:

1. Measure and individual letter?
The study measured different topographical aspects of indivudal letters. However, the percentage increase from letter to letter proved overly too dark and erratic, and to gain a usable average the study needed to analyse multiples of letters. This was not feasible given the time scale of the project. The results from testing a measurement of individual letters were:

3 Bigelow & Holmes (2015) *On font weight.* Online at https://bigelowandholmes.typepad.com/bigelow-holmes/2015/07/on-font-weight.html Accessed 20 June 2019
4 Adobe, (2019) *About measurement* Online at https://helpx.adobe.com/uk/photoshop/using/measurement.html Accessed 17 July 2019
5 Bigelow & Holmes (2015) *On font weight.* Online at https://bigelowandholmes.typepad.com/bigelow-holmes/2015/07/on-font-weight.html Accessed 20 June 2019

Figure 2
Images analysed by Measurement Log tool. 24pt MT Plantin. Image by the author.

/ n /
Regular =0.401583
Bold =0.456171
=(light to dark %increase) **13.6%**

/ o /
Regular = 0.596649
Bold = 0.540071
=(light to dark %increase) **14%**

/ d / (see Figure 2)
Regular = 0.559744
Bold = 0.487031
=(light to dark %increase) **16.5%**

/ g /
Regular = 0.522287
Bold = 0.426056
=(light to dark %increase) **20.1%**

2. Measure a word?

For reasons of time efficiency measuring individual words was also tried. However this approach did not take into account the space between words as a key factor in percentage density increase across a line of text. The results meant that the percentage increase was darker than Bigelow and Holmes par result:

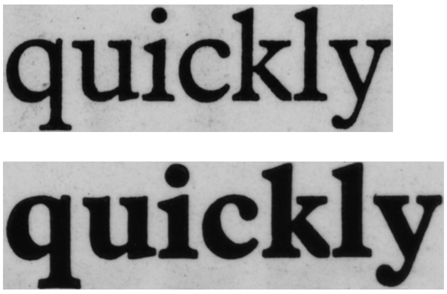


Figure 3
Images analysed by Measurement Log tool. 24pt MT Plantin. Image by the author.

/ quickly / (see Figure 3)
Regular = 0.420314
Bold = 0.487582
=(light to dark %increase) **16%**

/ latio /
Regular = 0.42473
Bold = 0.486535
=(light to dark %increase) **14.5%**

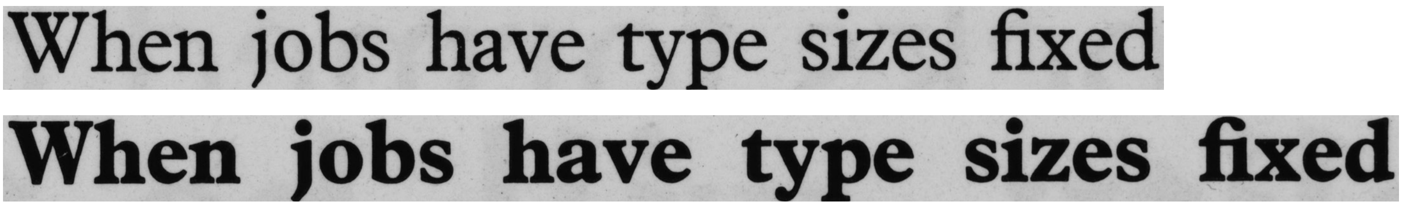
3. Measure a sentence?

In order that result would be consistent and applicable to real-world reading environments, where lines and paragraphs of text contain regular in combination with bold letters (for hierarchy, emphasis, distinction – see chapter 4) with spaces between words, the study measured full lines of text to assertain density increase:

/ When jobs have type sizes fixed /
(See Figure 4)
Regular = 0.380519
Bold = 0.431001
=(light to dark %increase) **13.2%**

/ determining calculations /
Regular = 0.406334
Bold = 0.466617
=(light to dark %increase) **14.8%**

Figure 4
Images analysed by Measurement Log tool. 24pt MT Plantin. Image by the author.



Appendix B: Type specimens used in the study

B.1 On choosing specimens

In order to gain a larger set of results, the study used type samples from the hot metal era (see chapter 5). These samples contain optically sized types as well as bold. By analysing bolds from these sample books the study was also be able to demonstrate some optical differences in weight gain.

Figure 5
Comparison to show the difference in specimen style between ATF (left) and Monotype (right). Monotype has a larger set of characters and sizes and is better suited for the study. American Type Founders (1960) *Handy Type Index,* American Type Founders. Image by the author.

Additionally, the study used type foundry published specimens because they provided a better an overview of a letter set, rather than an in-use example does. Similarly, in specimens, exact sizes of the type are clear.

One problem with type samples is their inconsistency in style across foundries. For example, samples published by the American Type Foundry (ATF) do not demonstrate a full range of the alphabet available (see Figure 5). So in order to analyse font families published by ATF such as Bodoni (1911) and Cheltenham (1904) that contain early examples of families which contain bold, other examples of these types were found. When an original was not available a Monotype (MT) specimen books was used because these specimens show a greater number of characters within the alphabet. In order to make sure that the ATF Bodoni was the same cut letter as the MT Bodoni, random selections of letters were compared to demonstrate their similarities (see Figure 6).

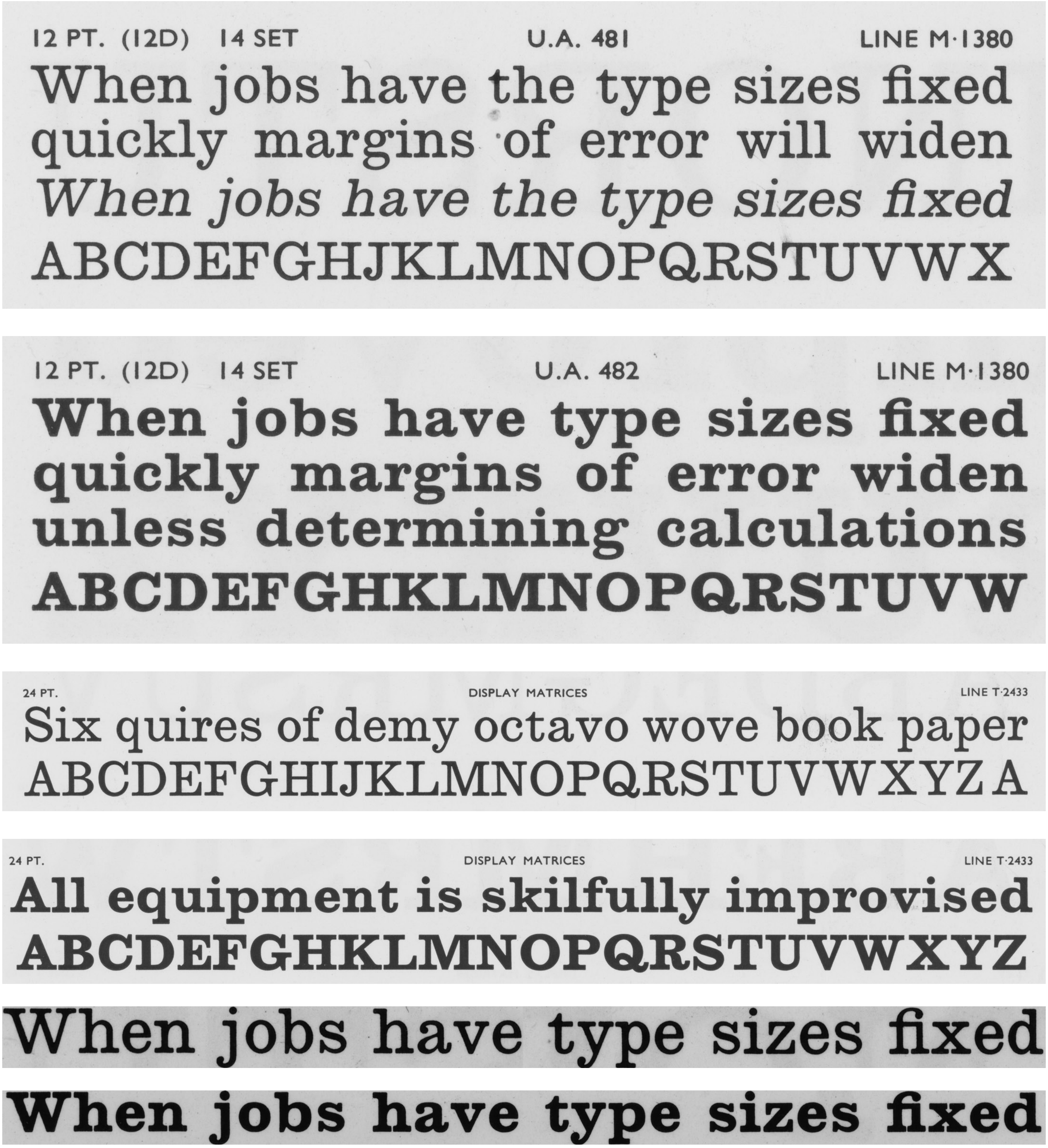
Another consideration was the different naming systems across foundries. When a foundry would design a type family and sell that design on, the purchaser would sometimes change the naming system of the typeface. For example, Deberny & Peignot's Univers (1957) was bought by Monotype, the numbering system of weights and widths was abandoned in favour of a more standard system of regular, bold, condensed *and so on.* Similarly, ATF's Ultra Bodoni was bought by Monotype and renamed Bodoni Ultra Bold.

By visually comparing original samples with Monotype samples it was possible to make sure that the same comparable regulars and bolds were used in the study.

Figure 6
Comparison to show fidelity is suitable enough to be compared with the original design. 24pt ATF Bodoni overlayed with 24pt MT Bodoni. Note the minor (and not relevant to this study) difference in design in the leg of the R. Image by the author.

B.2 Images of specimens used

New Clarendon 12 & 24pt. Monotype, (1960) *Desk Catalogue of 'Monotype' Faces,* The Monotype Corporation Limited. Image collected by the author.


12 PT. (12D) 14 SET U.A. 481 LINE M·1380
When jobs have the type sizes fixed
quickly margins of error will widen
When jobs have the type sizes fixed
ABCDEFGHJKLMNOPQRSTUVWX

12 PT. (12D) 14 SET U.A. 482 LINE M·1380
When jobs have type sizes fixed
quickly margins of error widen
unless determining calculations
ABCDEFGHKLMNOPQRSTUVW

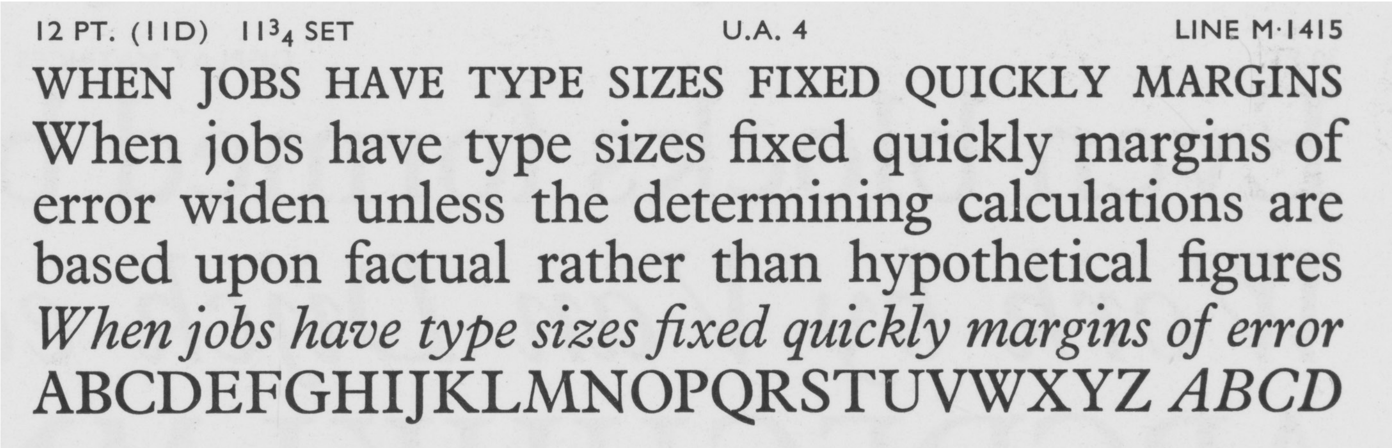
24 PT. DISPLAY MATRICES LINE T·2433
Six quires of demy octavo wove book paper
ABCDEFGHIJKLMNOPQRSTUVWXYZ A

24 PT. DISPLAY MATRICES LINE T·2433
All equipment is skilfully improvised
ABCDEFGHKLMNOPQRSTUVWXYZ

When jobs have type sizes fixed

When jobs have type sizes fixed

Plantin 12 & 24pt. Monotype, (1960) *Desk Catalogue of 'Monotype' Faces,* The Monotype Corporation Limited. Image collected by the author.

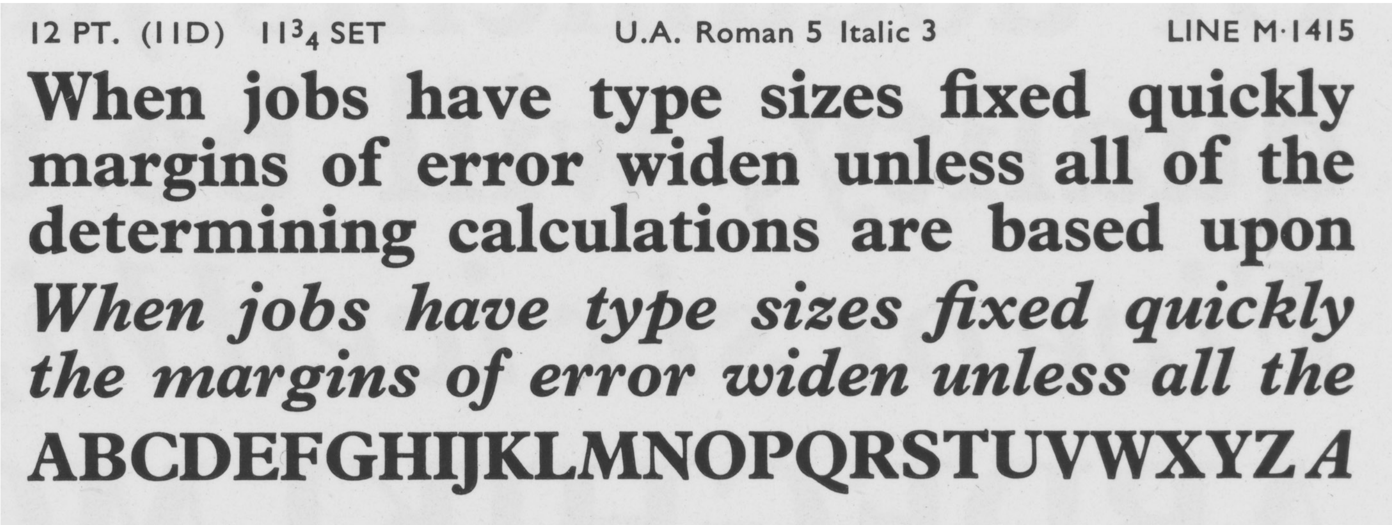

12 PT. (11D) 11¾ SET U.A. 4 LINE M·1415

WHEN JOBS HAVE TYPE SIZES FIXED QUICKLY MARGINS

When jobs have type sizes fixed quickly margins of error widen unless the determining calculations are based upon factual rather than hypothetical figures

When jobs have type sizes fixed quickly margins of error

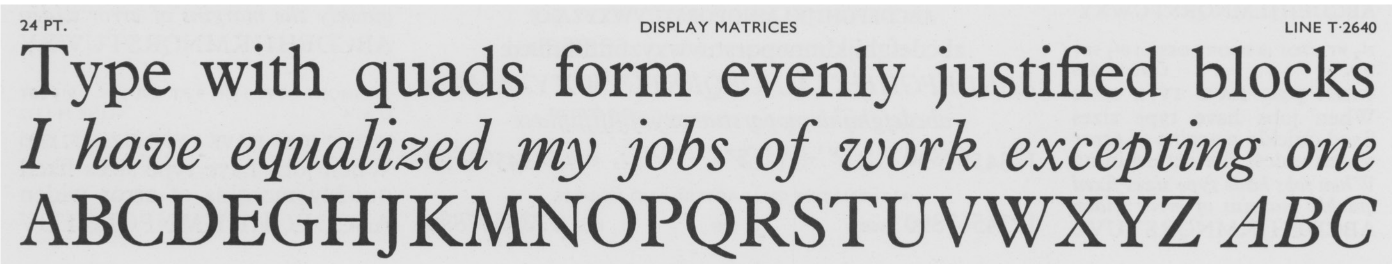
ABCDEFGHIJKLMNOPQRSTUVWXYZ *ABCD*


12 PT. (11D) 11¾ SET U.A. Roman 5 Italic 3 LINE M·1415

When jobs have type sizes fixed quickly margins of error widen unless all of the determining calculations are based upon

When jobs have type sizes fixed quickly the margins of error widen unless all the

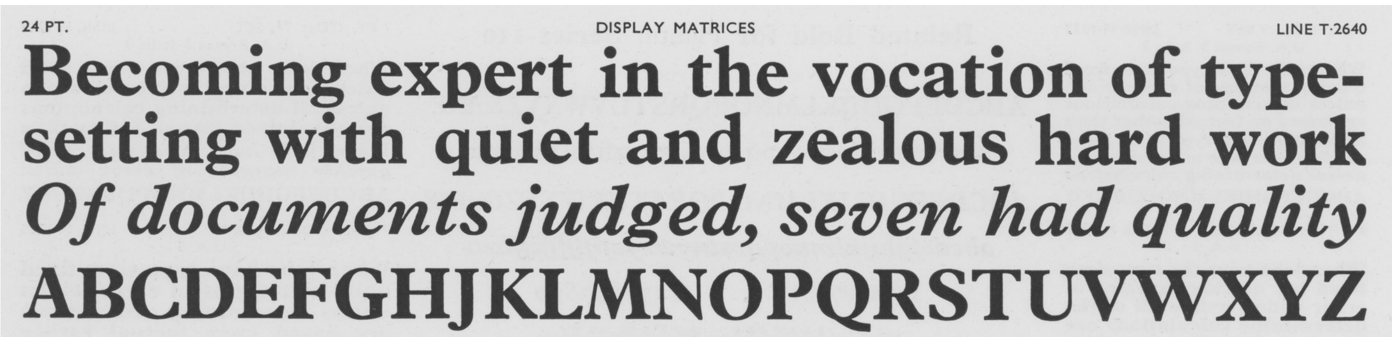
ABCDEFGHIJKLMNOPQRSTUVWXYZ ***A***


24 PT. DISPLAY MATRICES LINE T·2640

Type with quads form evenly justified blocks

I have equalized my jobs of work excepting one

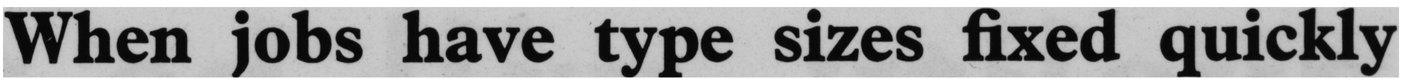
ABCDEGHJKMNOPQRSTUVWXYZ *ABC*

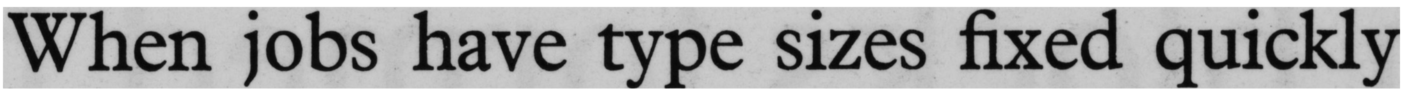

24 PT. DISPLAY MATRICES LINE T·2640

Becoming expert in the vocation of type-setting with quiet and zealous hard work

Of documents judged, seven had quality

ABCDEFGHJKLMNOPQRSTUVWXYZ


When jobs have type sizes fixed quickly


When jobs have type sizes fixed quickly

Times 12 & 24pt. Monotype, (1960) *Desk Catalogue of 'Monotype' Faces,* The Monotype Corporation Limited. Image collected by the author.

12 PT. (12D) 12 SET U.A. 325 LINE M·1420

WHEN JOBS HAVE TYPE SIZES FIXED QUICKLY MARGINS
When jobs have type sizes fixed quickly margins of error widen unless the determining calculations are based upon factual rather than hypothetical figures
When jobs have type sizes fixed quickly margins of error widen unless the determining calculations are
ABCDEFGHJKLMNOPQRSTUVWXYZ *ABCDEF*

12 PT. (12D) 12 SET U.A. Roman 324 Italic 325 LINE M·1420

When jobs have type sizes fixed quickly the margins of error widen unless the determining
When jobs have type sizes fixed quickly margins
ABCDEFGHIJKLMNOPQRSTUVWXYZ *AI*

24 PT. DISPLAY MATRICES LINE T·2640

Two documents having quality will take prizes
Quads form even blocks
ABDEGHJKMNQRT

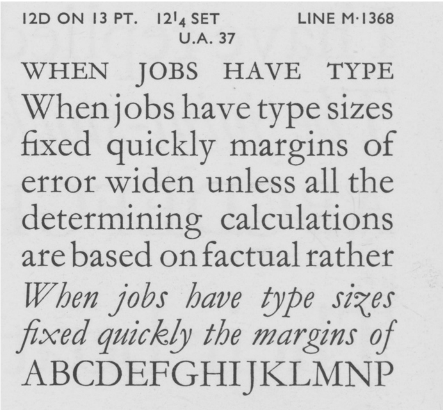
24 PT. DISPLAY MATRICES LINE T·2640

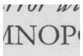
Dexterity in the vocation of typesetting may be acquired by every judicious and zealous worker
Becoming expert in the vocation of typesetting
ABCDEFGHIJKLMNOPQRSTUVWXYZ *AI*

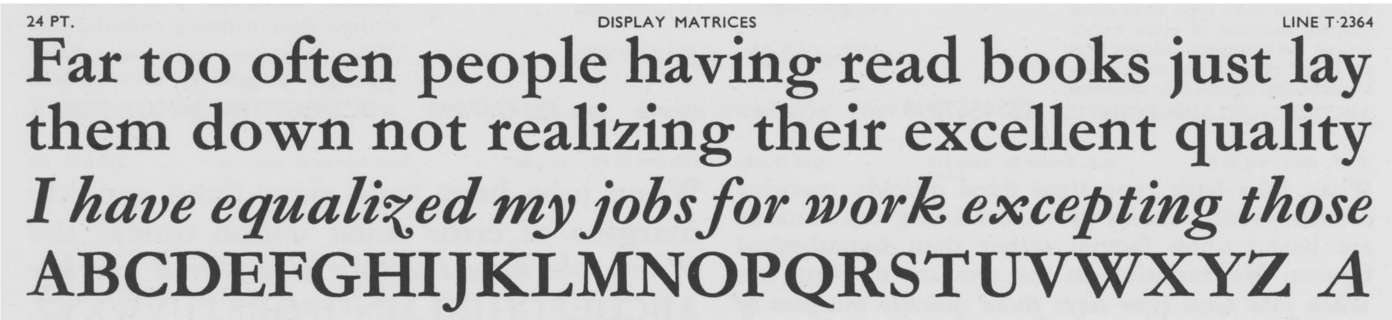
When jobs have type sizes fixed quickly

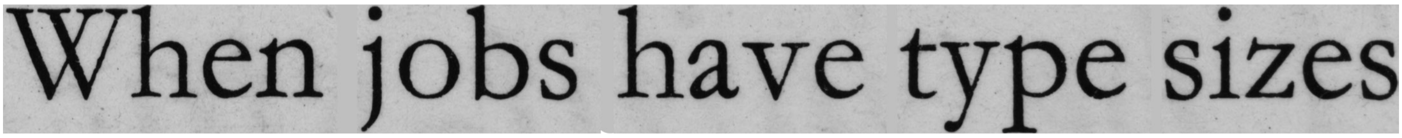
When jobs have type sizes fixed quickly

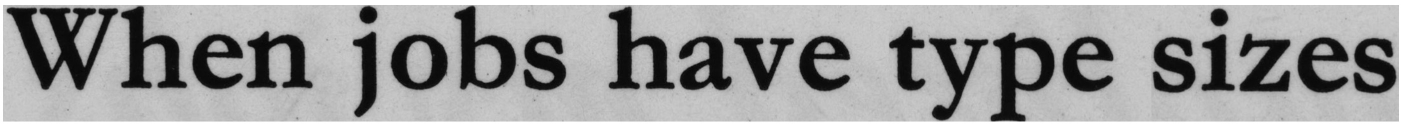
Garamond 13 & 24pt. Monotype, (1960) *Desk Catalogue of 'Monotype' Faces,*
The Monotype Corporation Limited. Image collected by the author.



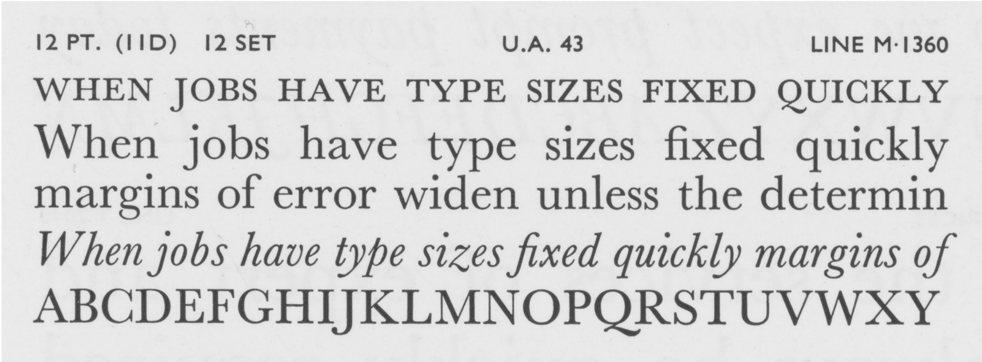






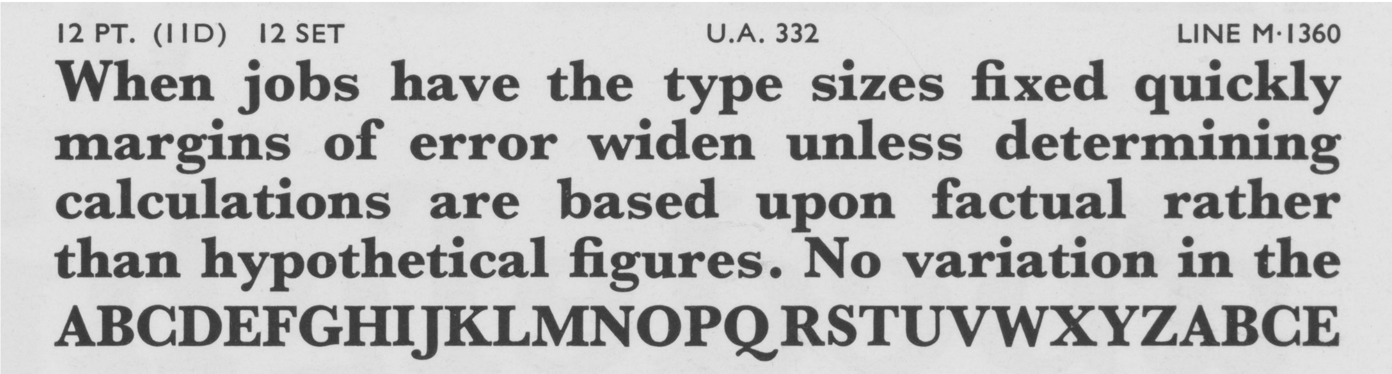


Baskerville 12 & 24pt. Monotype, (1960) *Desk Catalogue of 'Monotype' Faces,*
The Monotype Corporation Limited. Image collected by the author.



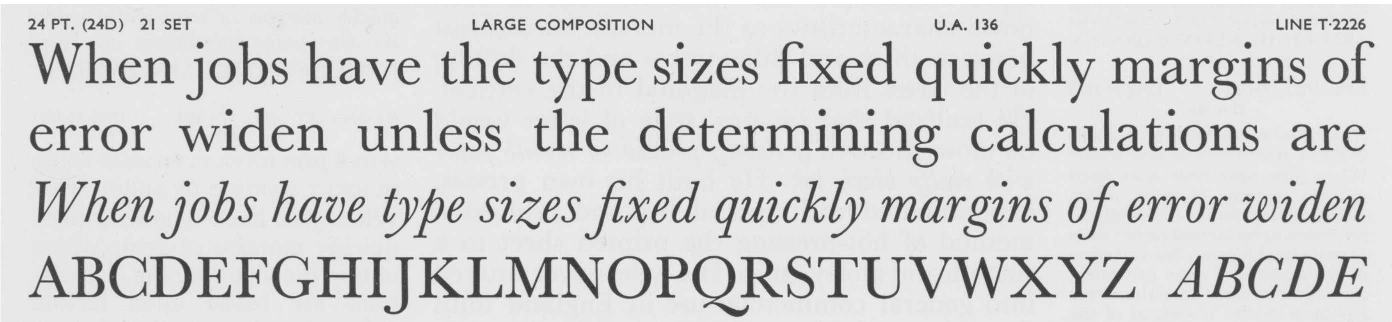
12 PT. (11D) 12 SET U.A. 43 LINE M·1360

WHEN JOBS HAVE TYPE SIZES FIXED QUICKLY
When jobs have type sizes fixed quickly
margins of error widen unless the determin
When jobs have type sizes fixed quickly margins of
ABCDEFGHIJKLMNOPQRSTUVWXY



12 PT. (11D) 12 SET U.A. 332 LINE M·1360

When jobs have the type sizes fixed quickly margins of error widen unless determining calculations are based upon factual rather than hypothetical figures. No variation in the
ABCDEFGHIJKLMNOPQRSTUVWXYZABCE

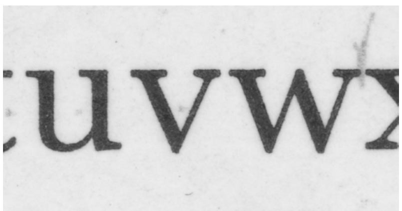


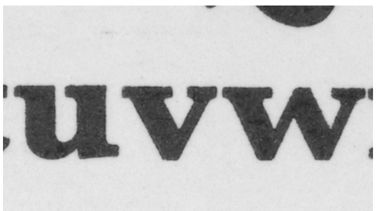
24 PT. (24D) 21 SET LARGE COMPOSITION U.A. 136 LINE T·2226

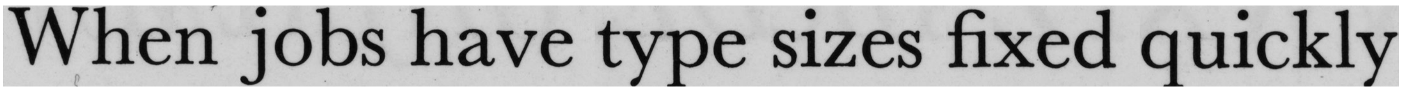
When jobs have the type sizes fixed quickly margins of
error widen unless the determining calculations are
When jobs have type sizes fixed quickly margins of error widen
ABCDEFGHIJKLMNOPQRSTUVWXYZ *ABCDE*

24 PT. DISPLAY MATRICES LINE T·2226

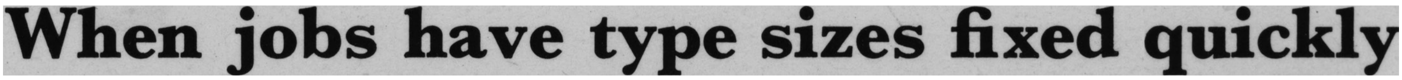
Sixteen demy quarto pages with zinco blocks
ABCDEFGHIJKLMNOPQRSTUVWXYZABF





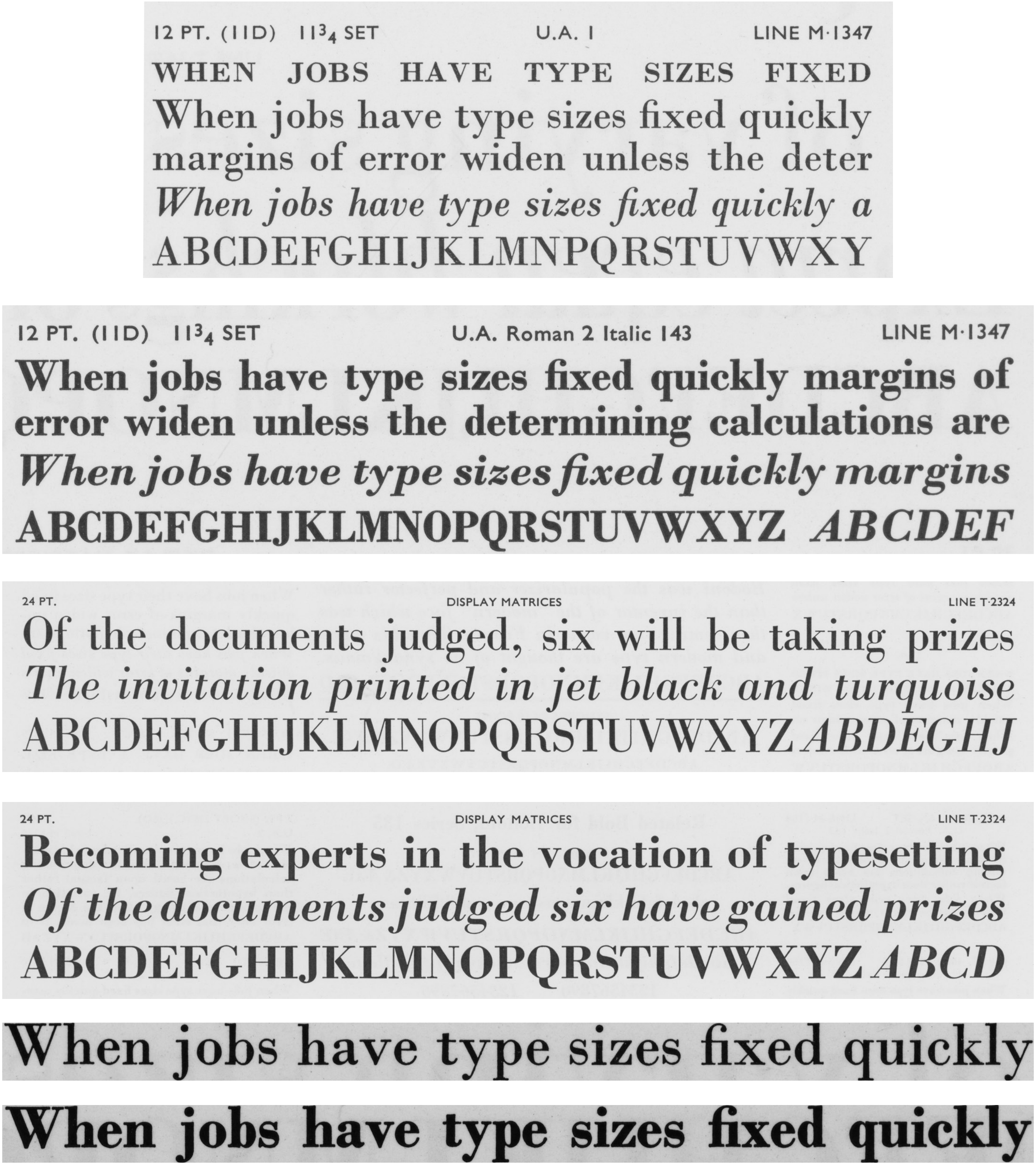


When jobs have type sizes fixed quickly



When jobs have type sizes fixed quickly

Bodoni 12 & 24pt. Monotype, (1960) *Desk Catalogue of 'Monotype' Faces,*
The Monotype Corporation Limited. Image collected by the author.



12 PT. (11D) 11¾ SET U.A. 1 LINE M·1347

WHEN JOBS HAVE TYPE SIZES FIXED
When jobs have type sizes fixed quickly
margins of error widen unless the deter
When jobs have type sizes fixed quickly a
ABCDEFGHIJKLMNPQRSTUVWXY

12 PT. (11D) 11¾ SET U.A. Roman 2 Italic 143 LINE M·1347

When jobs have type sizes fixed quickly margins of
error widen unless the determining calculations are
When jobs have type sizes fixed quickly margins
ABCDEFGHIJKLMNOPQRSTUVWXYZ *ABCDEF*

24 PT. DISPLAY MATRICES LINE T·2324

Of the documents judged, six will be taking prizes
The invitation printed in jet black and turquoise
ABCDEFGHIJKLMNOPQRSTUVWXYZ *ABDEGHJ*

24 PT. DISPLAY MATRICES LINE T·2324

Becoming experts in the vocation of typesetting
Of the documents judged six have gained prizes
ABCDEFGHIJKLMNOPQRSTUVWXYZ *ABCD*

When jobs have type sizes fixed quickly

When jobs have type sizes fixed quickly

Univers 13 & 24pt. Monotype, (1960) *Desk Catalogue of 'Monotype' Faces,* The Monotype Corporation Limited. Image collected by the author.

12D ON 13 PT. 15 SET U.A. 483 LINE M·1468

When jobs have type sizes fixed quickly
margins of error will widen unless all the
determining calculations are based upon
factual rather than hypothetical figures
When jobs have type sizes fixed quickly
margins of error will widen unless all the
determining calculations are based upon
ABCDEFGHIJKLMNOPQRSTUVWXYZ

12D ON 13 PT. 15 SET U.A. 486 LINE M·1468

When jobs have the type sizes fixed
quickly margins of error will widen
unless determining calculations are
based on the factual rather than the
When jobs have the type sizes fixed
quickly margins of error will widen
ABCDEFGHIJKLMNOPQRSTUVWX

22D ON 24 PT. (AVAILABLE SHORTLY) DISPLAY MATRICES LINE T·2538

Size, x-height, leading and measure are
all related to type-area in a page design
Several easily recognizable type faces
ABCDEFGHIJKLMNOPQRSTUVWXYZ

22D ON 24 PT. (AVAILABLE SHORTLY) DISPLAY MATRICES LINE T·2538

Size, x-height, leading and measure must
all be related when a book page is designed
Several easily recognizable types of design
ABCDEFGHIJKLMNOPQRSTUVWXYZ *AB*

When jobs have type sizes fixed

When jobs have type sizes fixed

MT Grotesque 13 & 24pt. Monotype, (1960) *Desk Catalogue of 'Monotype' Faces,* The Monotype Corporation Limited. Image collected by the author.

13 PT. (12D) 12½ SET U.A. Roman 65 Italic 401 LINE M·1495

When jobs have their type sizes fixed quickly
margins of error widen unless the determining
When jobs have type sizes fixed quickly margins
ABCDEFGHIJKLMNOPQRSTUVWXYZ *ABC*

13 PT. (12D) 12½ SET U.A. Roman 66 Italic 440 LINE M·1495

**When jobs have type sizes fixed quickly
margins of error widen unless the deter-
mining calculations are based upon factual
rather than hypothetical figures. Variations**
***When jobs have type sizes fixed quickly
margins of error widen unless determining***
ABCDEFGHIJKLMNOPQRSTUVWXYZA

Dexterity is acquired by zealous workers
Adequate recognition by the twelve experts
ABCDEGHJKMNQRSTUVWXYZ*ABCDEGI*

**Dexterity is gained in the vocation of
typesetting by zealous and quiet work
ABCDEGHIJKLMNOPQRSTUVWXYZ**

When jobs have type sizes fixed quickly

When jobs have type sizes fixed quickly

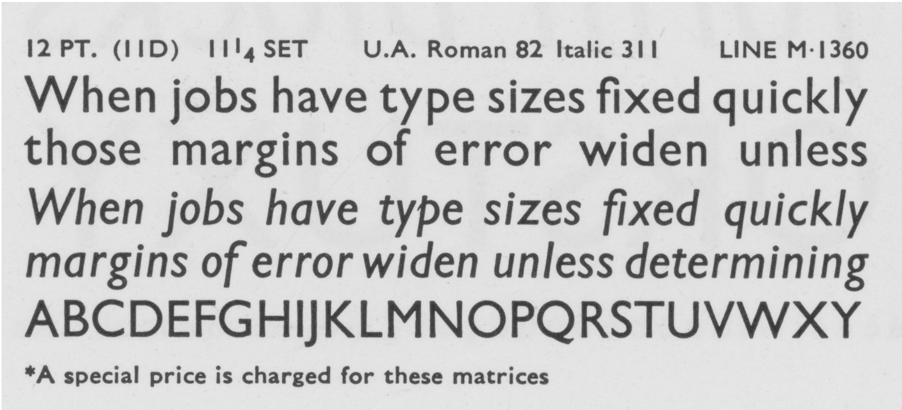
Gill Sans 12 & 24pt. Monotype, (1960) *Desk Catalogue of 'Monotype' Faces,*
The Monotype Corporation Limited. Image collected by the author.

12 PT. (12D) 11¼ SET U.A. Roman 93 Italic 302 LINE M·1360

When jobs have type sizes fixed quickly margins of error widen unless the determining calculations

When jobs have type sizes fixed quickly margins of

ABCDEFGHIJKLMNOPQRSTUVWXYZ *ABCDE*



12 PT. (11D) 11¼ SET U.A. Roman 82 Italic 311 LINE M·1360

When jobs have type sizes fixed quickly those margins of error widen unless

When jobs have type sizes fixed quickly margins of error widen unless determining

ABCDEFGHIJKLMNOPQRSTUVWXY

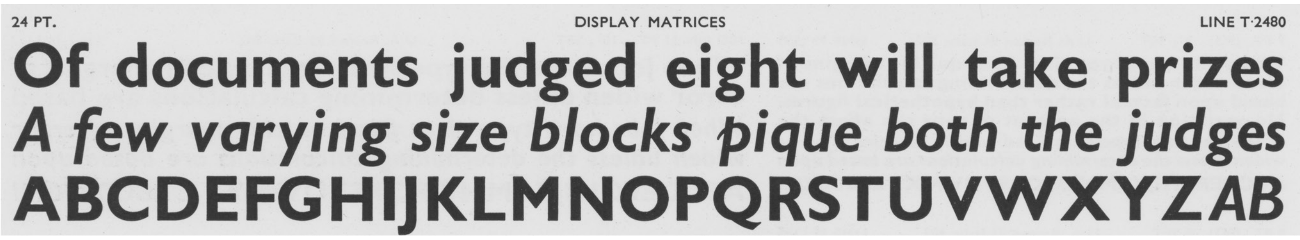
*A special price is charged for these matrices

24 PT. DISPLAY MATRICES LINE T·2480

Of all the documents judged eight will take prizes

A few mixed varying size jobs pique both the judges

ABCDEFGHIJKLMNOPQRSTUVWXYZ *ABCDEG*

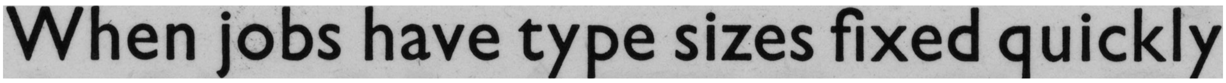


24 PT. DISPLAY MATRICES LINE T·2480

Of documents judged eight will take prizes

A few varying size blocks pique both the judges

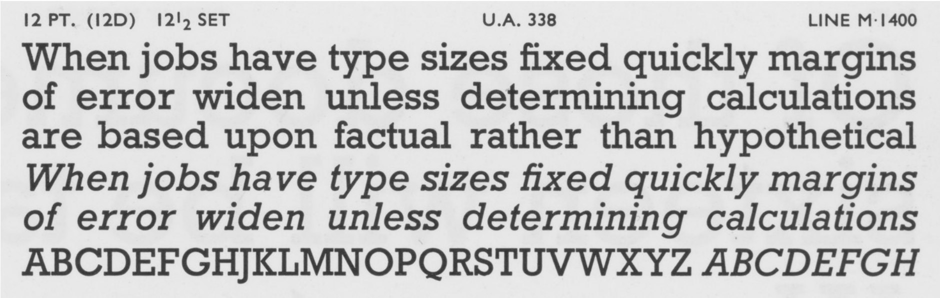
ABCDEFGHIJKLMNOPQRSTUVWXYZ*AB*



When jobs have type sizes fixed quickly

When jobs have type sizes fixed quickly

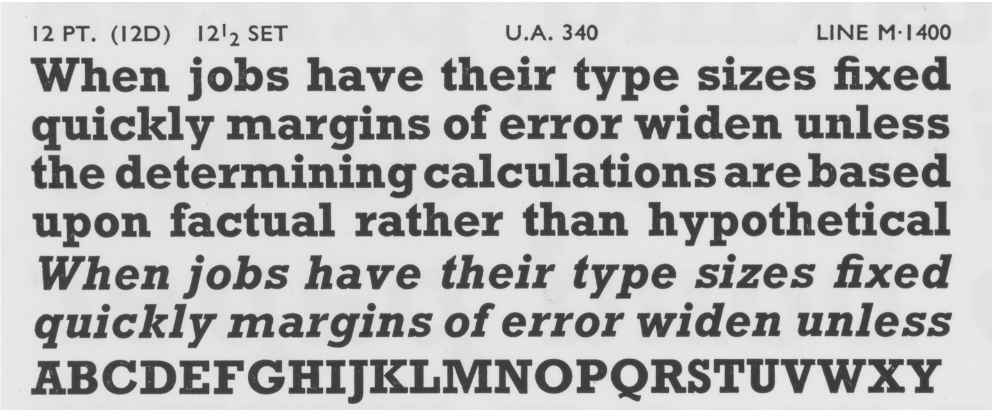
Rockwell 12 & 24pt. Monotype, (1960) *Desk Catalogue of 'Monotype' Faces,* The Monotype Corporation Limited. Image collected by the author.


12 PT. (12D) 12½ SET U.A. 338 LINE M·1400

When jobs have type sizes fixed quickly margins of error widen unless determining calculations are based upon factual rather than hypothetical

When jobs have type sizes fixed quickly margins of error widen unless determining calculations

ABCDEFGHJKLMNOPQRSTUVWXYZ *ABCDEFGH*


12 PT. (12D) 12½ SET U.A. 340 LINE M·1400

When jobs have their type sizes fixed quickly margins of error widen unless the determining calculations are based upon factual rather than hypothetical

When jobs have their type sizes fixed quickly margins of error widen unless

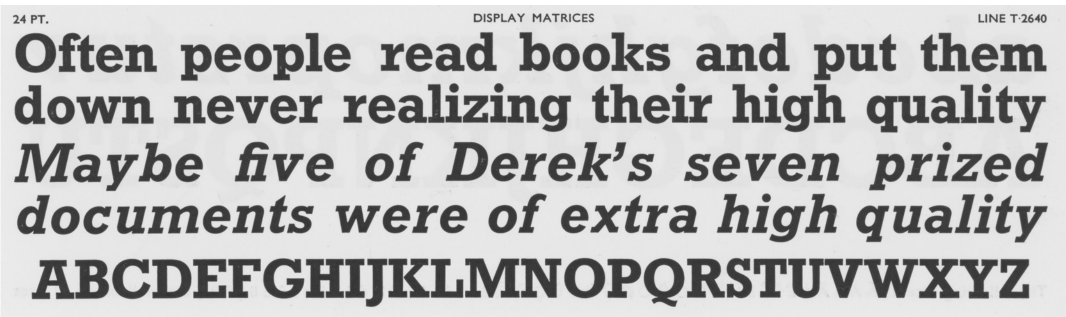
ABCDEFGHIJKLMNOPQRSTUVWXY


24 PT. DISPLAY MATRICES LINE T·2640

Much too often people read books and yet never realize their excellence and quality

We have equalized our jobs for working

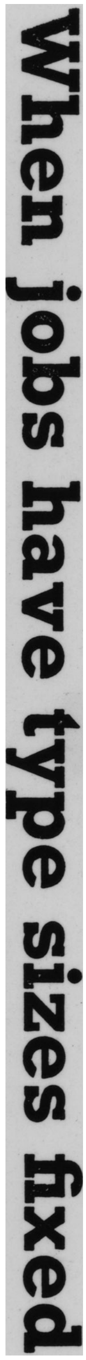
ABCDEFGHIJKLMNOPQRSTUVWXYZ *ABI*

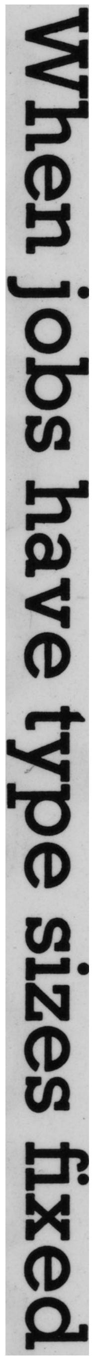

24 PT. DISPLAY MATRICES LINE T·2640

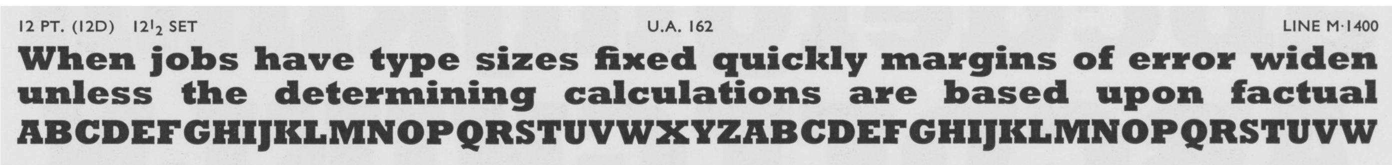
Often people read books and put them down never realizing their high quality

Maybe five of Derek's seven prized documents were of extra high quality

ABCDEFGHIJKLMNOPQRSTUVWXYZ






12 PT. (12D) 12½ SET U.A. 162 LINE M·1400

When jobs have type sizes fixed quickly margins of error widen unless the determining calculations are based upon factual

ABCDEFGHIJKLMNOPQRSTUVWXYZABCDEFGHIJKLMNOPQRSTUVW


24 PT. DISPLAY MATRICES LINE T·2640

I have equalized all my jobs for work excepting those over there

ABCDEFGHJKLMNPQRSTUVWXYZ

Appendix C: Data table (pt.1)	MT New Clarendon 12pt	MT New Clarendon 24pt	MT Plantin 12pt	MT Plantin 24pt	MT Times 12pt	MT Times 24pt	MT Garamond 13pt	MT Garamond 24pt	MT Baskerville 12pt	MT Baskerville 24pt	Bodoni 12pt	Bodoni 24pt	Univers 13pt	Univers 24pt	MT Grotesque 13pt	MT Grotesque 24pt	Gill Sans 12pt	Gill Sans 24pt	Rockwell 12pt	Rockwell 24pt	Rockwell (Regular-ExtraBold) 24pt
Vertical stem gain																					
Uppercase H	86.5	66.9	66.0	62.3	53.1	45.0	70.6	52.6	61.9	91.0	50.4	38.2	57.4	55.7	81.6	67.6	85.7	78.6	65.0	61.1	159.0
Uppercase O	72.9	66.9	65.0	59.0	37.4	45.2	66.0	54.9	74.8	82.0	56.0	37.4	47.8	47.8	79.0	80.7	78.4	88	76.3	71.0	169.7
Uppercase A	90.8	67.4	66.4	76.7	32.0	37.2	94.0	58.2	85.2	99.4	51.6	32.5	56.9	52.2	78.0	74.3	71.8	78.8	56.4	55.6	138.7
Lowercase n	61.3	74.6	76.0	67.4	61.4	61.8	90.3	67.7	113.0	121.0	42.8	33.5	54.2	53.6	69.4	77.7	61.4	73.3	66.3	62.3	169.0
Lowercase o	60.1	63.0	68.0	60.3	59.3	54.0	60.0	45.5	114.3	118.5	43.3	33.3	46.5	44.7	71.3	83.8	57.8	78.4	54.2	68.9	143.0
Lowercase v	62.3	65.9	82.0	68.2	43.8	63.2	55.5	47.0	104.0	131.7	49.5	31.3	41.0	45.0	80.0	66.3	68.0	54.7	57.3	66.6	180.7
Stem weight gain: external expansion vs internal expansion																					
Uppercase H	59.7 – 26.8	46.5 – 20.4	29.7 – 36.3	53.0 – 9.3	28.3 – 24.8	24.0 – 21.0	58.3 – 12.3	36.4 – 16.2	28.9 – 33.0	70.2 – 21.6	21.5 – 28.9	38.2 – 0.0	43.0 – 14.4	37.0 – 18.7	50.0 – 31.8	58.0 – 9.6	62.6 – 23.1	51.5 – 27.5	14.2 – 50.8	9.0 – 52.1	93.0 – 66.0
Uppercase O	47.4 – 25.5	49.3 – 17.6	32.5 – 32.5	25.3 – 33.7	13.5 – 23.9	17.0 – 28.2	0.0 – 66.0	25.2 – 29.7	0.0 – 74.8	31.5 – 50.4	6.5 – 49.5	21.8 – 15.6	31.5 – 16.3	29.3 – 18.5	25.6 – 53.4	30.5 – 49.2	45.3 – 33.1	31.8 – 56.2	25.2 – 50.4	20.2 – 50.8	37.3 – 132.4
Lowercase n	35.3 – 26.0	62.8 – 11.8	42.8 – 33.2	42.8 – 30.7	16.7 – 44.7	10.0 – 51.8	60.0 – 30.0	48.9 – 18.8	48.4 – 64.6	80.7 – 40.3	29.5 – 13.3	24.7 – 8.8	37.0 – 13.0	39.0 – 14.6	44.7 – 24.7	36.4 – 41.3	61.4 – 0.0	46.6 – 26.7	27.7 – 38.8	27.6 – 34.7	131.5 – 27.5
Lowercase o	43.3 – 16.8	37.5 – 25.5	34.0 – 34.0	25.8 – 34.5	-8.4 – 67.7	-15.6 – 71.6	0.0 – 60.0	33.3 – 12.2	38.1 – 76.2	55.8 – 62.7	15.0 – 28.3	24.3 – 9.0	31.2 – 14.6	16.2 – 28.5	29.6 – 41.7	28.3 – 55.5	16.5 – 51.3	22.0 – 56.4	0.0 – 54.2	6.0 – 62.9	62.2 – 81.1
Angle of thick stem																					
Uppercase A	-3.0°	-3.1°	1.0°	2.0°	-3.0°	-0.8	3.0°	2.8°	1.5°	2.5°	1.7°	0.0°	0.5°	1.5°	3.5°	1.4°	0.0°	0.6°	3.0°	2.0°	3.0°
Lowercase v	-2.0°	-2.7°	4.0°	6.0°	-2.5	-2.1°	0.5°	1.3°	2.3°	-4.3	0.0°	-2.2	1.0°	0.0°	-5.1°	-0.5	-0.5°	-0.6	-0.9°	2.0°	-8.0°
Contrast increase																					
Uppercase H	86.6	68.0	69.5	62.0	50.0	47.3	78.6	65.0	69.3	96.2	48.7	36.8	47.9	54.9	73.5	69.2	75.0	64.5	55.0	44.6	107.8
Uppercase O	70.3	64.3	72.3	58.0	45.0	39.0	68.9	59.2	79.0	91.4	56.7	33.4	40.8	39.4	75.0	75.0	70.0	78.4	61.3	50.7	122.4
Lowercase t	52.7	69.0	72.0	93.0	67.8	68.6	49.7	53.6	118.0	141.8	43.1	36.9	56.8	25.3	65.8	71.3	54.3	44.5	46.0	55.2	147.9
Lowercase o	63.3	60.1	60.5	74.0	50.4	44.3	43.5	41.7	106.0	110.8	44.3	37.2	43.2	39.2	56.8	72.0	36.0	50.8	43.0	56.5	107.8
Proportional width																					
Uppercase H	5.9	8.0	-2.3	8.7	2.3	0.6	7.9	8.7	0.0	10.3	-3.0	11.0	4.4	4.6	5.7	11.2	15.0	5.1	-10.5	-11.0	5.9
Uppercase O	5.0	7.6	0.2	-2.5	-2.1	-1.6	-9.6	0.5	-12.9	-3.3	-11.5	2.3	2.5	1.2	-5.0	3.0	2.0	-2.8	-4.8	-5.3	-19.8
Uppercase A	4.7	8.4	-3.6	-7.7	-15.3	-16.0	-3.0	-6.0	-15.0	-1.0	-1.1	-6.4	-2.0	-2.4	-8.6	-2.6	6.9	7.2	-17.3	4.1	-7.2
Lowercase n	1.8	13.4	1.1	3.5	-9.1	-13.3	5.6	6.5	2.0	10.6	2.8	5.2	5.4	4.9	4.3	1.0	19.8	5.4	-3.2	-2.2	30.3
Lowercase o	6.6	4.1	-3.9	-1.0	-17	-20	-10.0	-3.6	-7.3	0.0	-3.5	5.6	4.5	-3.4	-1.6	-5.2	-5.5	-7.6	-15.0	-12.4	-4.4
Lowercase d	17.2	16.1	0.0	0.0	-20.5	-20.2	5.2	7.3	0.5	20.3	-13.9	6.0	11.6	-2.8	2.6	1.4	11.8	6.9	-7.4	-14.2	2.9
Lowercase v	2.6	12.5	19.0	21.2	14.1	10.8	5.6	7.0	14.3	20.4	-7.9	8.5	3.8	-1.0	23.9	10.1	-1.0	0.7	13.6	13.0	55.6
Serif height																					
Uppercase H	44.9	56.3	40.0	34.7	34.7	43.0	104.6	68.0	86.5	83.8	65.0	0.0							32.6	19.4	77.6
Lowercase baseline n	36.7	54.8	32.5	28.0	58.0	45.0	95.0	68.0	137.0	82.3	32.0	0.0							20.0	20.6	71.0
Lowercase x-height n	36.7	54.8	18.0	8.6	50.0	44.4	73.0	61.9	103.5	90.2	37.0	0.0							26.0	32.6	71.0
Lowercase ascender	40.6	61.0	27.6	9.6	23.3	55.0	59.0	46.6	57.0	78.8	36.0	0.0							26.0	16.8	49.0

Appendix C:
Data table (pt.2)

	MT New Clarendon 12pt	MT New Clarendon 24pt	MT Plantin 12pt	MT Plantin 24pt	MT Times 12pt	MT Times 24pt	MT Garamond 13pt	MT Garamond 24pt	MT Baskerville 12pt	MT Baskerville 24pt	Bodoni 12pt	Bodoni 24pt	Univers 13pt	Univers 24pt	MT Grotesque 13pt	MT Grotesque 24pt	Gill Sans 12pt	Gill Sans 24pt	Rockwell 12pt	Rockwell 24pt	Rockwell (Regular-ExtraBold) 24pt
Serif width																					
Uppercase H	-12.5	-3.0	-18.6	-18.4	-2.8	-4.6	-4.3	1.9	-10.3	-5.9	-21.3	0.0							9.5	0.0	-49.7
Lowercase baseline n	-5.5	0.3	-8.5	-8.2	-39.3	-43.7	-23.0	-9.7	-9.6	11.38	-17.0	-2.4							-14.0	-8.0	-21.0
Lowercase x-height n	-5.5	0.3	-5.6	0.6	-19.0	-42.0	5.8	9.5	-9.5	3.8	-17.0	0.0							-14.0	-8.6	-21.0
Lowercase ascender	-6.3	0.0	-4.9	5.6	-34.0	-20.0	-5.9	0.0	-6.3	11.1	-10.9	0.0							-12.0	-21.0	-36.0
Joint (curve meets stem)																					
Lowercase n	32.0	42.5	43.0	53.0	89.5	104.0	77.0	50.0	57.1	70.6	33.0	0.0	28.6	11.0	27.0	23.6	24.0	14.0	18.6	30.4	50.5
Terminal serifs																					
Ball serif a	26.7	24.3	69.8	69.2	49.5	39.9	68.8	32.5	66.0	97.6	41.3	53.2									
Ball serif c	34.0	31.7	61.2	71.4	30.0	40.0	37.5	35.8	70.6	104	51.1	27.4							29.5	40.3	76.6
Change in spacing																					
Lowercase HI	-11.7	-5.4	-32.7	-10.4	-12.5	-10.6	-13	4.8	-33	-30.4	-31.8	-3.4	-10.0	2.2	-5.0	11.4	22.7	5.9	12.6	10.9	-20.6
Lowercase ni	2.4	0.9	-1.2	-9.8	-31.0	-39.4	-3.8	11.6	-16.7	-11.6	-28.9	-10.9	0.0	-9.4	-8.0	1.6	-16.8	-14.9	2.1	-2.9	-8.5
Tittle gain																					
Lowercase (i)	59.6	56.5	59.8	55.6	53.8	50.0	55.2	35.4	62.7	70.8	38.7	53.0	50.0	53.6	69.4	77.7	48.5	54.0	37.0	35.3	121.2
X-height gain																					
Lowercase x	2.0	0.0	1.4	1.0	1.0	1.7	3.6	4.8	0.7	4.8	3.4	1.1	0.0	0.0	0.0	0.0	0.0	6.2	0.0	0.0	0.0
Ascender height gain																					
Lowercase l	0.0	-0.9	1.45	1.4	-5.7	-2.3	-1.3	2.2	0.3	0.0	2.0	3.5	0.0	0.0	-1.3	-0.2	-0.8	1.0	1.0	-1.4	0.0
Caps height gain																					
Uppercase H	0.0	-0.7	0.8	-0.6	0.8	-1.0	3.7	3.5	-1.4	1.1	2.4	2.0	0.0	0.0	-1.0	0.9	0.0	2.1	-0.5	-1.0	0.0
Descender line gain																					
Lowercase p	-1.7	-0.8	0.9	0.2	0.0	-1.5	0.0	-12.6	0.0	18.9	0.0	3.4	0.0	0.0	1.4	-8.6	3.0	5.0	0.0	1.0	0.0
Aperture changes																					
Uppercase C	-3.0	3.6	-16.6	-16.0	0.0	1.1	-21.8	18.7	-17.9	0.0	-2.9	-1.6	-16.2	-19.0	-31.3	-28.5	-31.0	-30.0	-22.0	-19.5	-28.4
Lowercase c	-25.0	-19.6	-32.4	-27.9	16.8	5.3	-39.0	18.3	-37.8	-41.9	-9.4	-10.4	-16.2	-13.2	-27.7	-20.0	-13.9	-6.6	-28.8	-29.4	-33.5
Overall density increase																					
Sentence	10.9		13.2		10.4		11.7		34.9		21.2		11.0		13.3		10.9		8.7		
Overshoot change																					
Uppercase O	28.6	18.7	40.0	50.0	33.0	42.5	23.6	0.0	0.0	7.3	-11.7	0.0	15.0	30.0	0.0	30.0	-15.0	-6.0	0.0	5.0	12.0
Lowercase o	29.1	24.0	12.5	38.0	18.2	28.0	-10.0	15.0	14.0	-17.5	0.0	0.0	0.0	8.6	0.0	0.0	9.0	0.0	6.0	10.0	-16.6