1927 - The Year That Set the Direction of Traction Lift Engineering for a Century

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Keywords: lift, history, traction, lift engineering

Abstract. Nearly a century ago in 1927, F. Hymans and A. H. Hellborn published their famous book "*Der neuzeitliche Aufzug mit Treibscheibenantrieb*" (*Modern elevator with traction sheave drive)*, which had a major impact in the introduction of traction sheave lifts to the European Market and laid the groundwork of modern lift engineering. The book explains the function of traction sheave lifts, the theory of traction calculation and several other key principles of lift engineering.

A less known, but likewise important book, was published on the same year by H. Donandt. His dissertation "*Über die Berechnung von Treibscheiben im Aufzugbau" (On the calculation of traction sheaves in elevator construction)* touched some of the same topics as Hymans' and Hellborn's book, but merits independent recognition.

A major handicap in understanding the background of modern lift engineering is that to this day neither of the books have been translated into English for the wider lift engineering audience.

This article gives an overview on the content of these books and explains how these two books differ in their approach. The article also briefly introduces the authors and the historical framework behind these books. Sections of these books that have had larger significance to this day are given specific attention.

1 LIST OF SYMBOLS

α	Undercut angle	b	Acceleration/Deceleration of the lift
γ	Angle of submersion of rope in the groove (Also wedge angle for wedge shape groove)	d	Rope diameter
φ	1-sided contact angle between the rope and the groove	D	Traction sheave diameter
μ	Apparent friction coefficient (friction factor)	N	Normal force
μ_0	(Actual) Friction coefficient	g	Gravity acceleration
		p	Groove pressure
		S	Rope tension
		W	Friction force

NOTE! There is some inconsistency in the symbols in figures due to original source images.

2 INTRODUCTION

The later part of 19th century and the beginning of 20th century was a period of fast development in the building and industrial sectors. As construction techniques improved and buildings got taller, so did the demand for higher lift travels. The USA had assumed a leading position in the construction of tall buildings, and it was only logical that the Americans were also in the forefront of lift engineering. A key paradigm shift was the transition from drum lifts to traction lifts, which changed the lift industry as profoundly as the invention of the safety gear a half-century earlier.

The transition to traction lifts had an impact on the way lifts were engineered and there was a need to raise awareness of these new engineering principles. A book by F. Hymans and A. H. Hellborn "*Der neuzeitliche Aufzug mit Treibscheibenantrieb*" (The modern elevator with traction sheave drive) rose to the occasion and became a cornerstone for lift engineering for decades. The book is not without shortcomings though. As the writers were working for Otis, revealing the full extent of their knowledge was not necessarily within their interest. One can speculate that the motivations of two Otis employees to write a book in German was not just raise the general level of knowledge, but also to advertise the state of American engineering and to gain wider acceptance to their engineering principles to help the sales of Otis products overseas.

Already prior to the publication of *Der neuzeitliche Aufzug*, the benefits of traction lifts had been seen in Germany. To study some of the key engineering problems, a doctoral dissertation was launched in the Technical University of Karlsruhe. One of the supervisors was Dr. G. Benoit, who was an influential figure in the German lift association at the time. This dissertation by H. Donandt was published at the same time as *Der neuzeitliche Aufzug* and addressed some of the same topics as Hellborn and Hymans, but without the ulterior motives of a commercial nature. Donandt's publication has had much less recognition than his American counterpart but some of his conclusions have had long lasting implications.

3 HISTORICAL CONTEXT

In the introduction of *Der neuzeitliche Aufzug* it is mentioned that traction sheave lifts were first introduced in the American market circa 1890, but at that time they could not compete with drum type lifts due to the double wrap construction and lower market needs [1]. In an earlier article by Hellborn it is mentioned that "full-wrap traction" (double wrap) (Fig. 1a) had been used in New York skyscrapers for years and that "half-wrap traction" (single wrap) (Fig. 1b) had been found in England for a long time [2]. The year 1919 is also referenced as a turning point from drum type to traction type lifts.

In his dissertation Donandt is making references to earlier publications concerning Koepe hoist [3]. The Koepe hoists are used in the mining industry and are also based on the traction sheave principle. The Koepe hoist had been patented in many European countries in 1887 [4], however, the traction sheaves with wood and leather inserts used in Koepe hoists made the design unfeasible for lift applications.

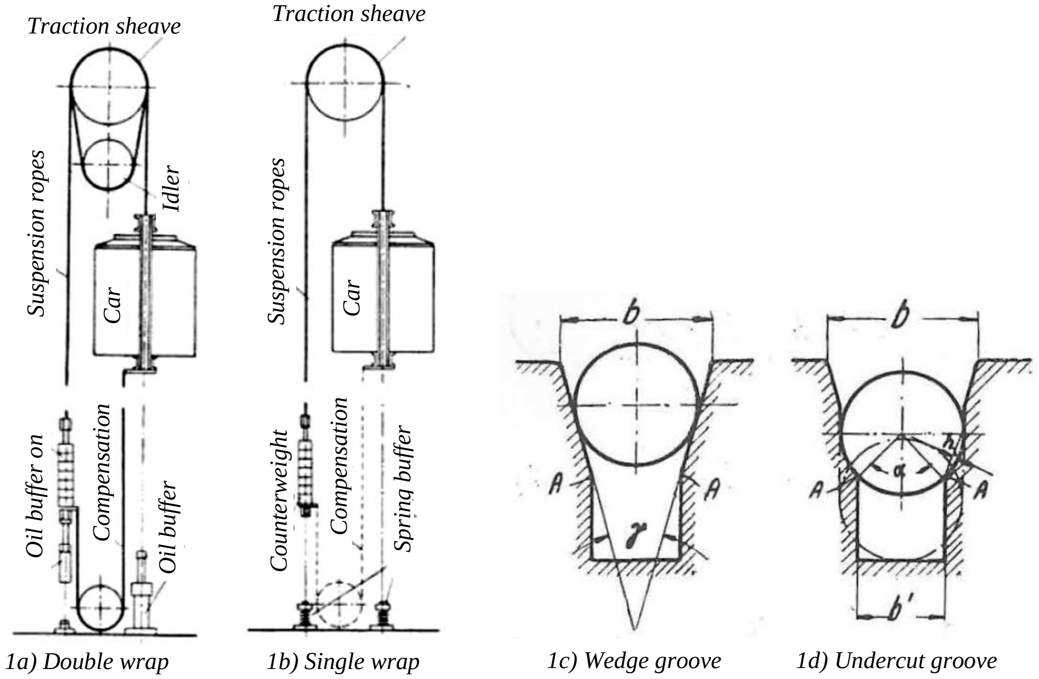

Figure 1 Illustration of double and single wrap lifts [1] **and wedge and undercut rope grooves** [3].

Although a lot of proprietary experimental data must have been available in 1927, a theoretical basis was needed quantify the traction capacity. This was the problem that Hymans, Hellborn and Donandt set out to resolve[1]. Attention was especially paid to the single wrap configuration where traction is not so abundantly available, and to the relatively novel undercut rope groove design (Fig. 1d).

The most well-known of the three authors is undoubtedly Frederick (Fred) Hymans and his biography is well covered in two articles by Gibson [5] [6]. Here it suffices to say that Hymans made an extensive career in OTIS and American Society of Mechanical Engineers (ASME), published two books in addition to the *Der neuzeitliche Aufzug*, wrote several articles published in ASME Transactions and within OTIS internally and participated actively in overall technical discourse during the first part of 20th century.

Less is known about Hymans' co-writer Axel Hellborn. Based on Gray [7] he appears to have only made a short career in OTIS, but it is worthwhile to notice that the article that predates *Der neuzeitliche Aufzug* was written solely by Hellborn, albeit he gives credit to Hymans in one footnote. Later – after the Second World War - Hellborn was contracted by the Finland Industry Delegation War Compensation (Soteva) to rationalize industrial production across multiple companies (incl. KONE), to improve Finland's ability to meet its obligations to the Soviet Union [8], but there are no records of his involvement in lift engineering since *Der neuzeitliche Aufzug*.

Prior to his dissertation Hermann Donandt worked for R. Stahl A.G. in Stuttgart where he had his introduction to the lift industry [3]. Later he made a career in the Karlsruhe Institute of Technology (KIT), where his supervisor Georg Benoit had founded a chair for lift and transport machines. Donandt is credited in particular for rebuilding the department after the Second World War. He was the director of Institute for Material Handling and Logistics in KIT during 1947 – 1966. Industry legend Klaus Feyrer, for instance, studied there during his leadership period. He was also influential in the development of the lifts to the Moscow TV-tower, which were a substantial engineering achievement at the time [9]. In addition, he acted as director of the testing centre of the German lift committee, was involved in the development of safety gears and carried out studies into stresses in wire ropes [10].

4 THE MOST RELEVANT TOPICS

Rope traction is obviously the main topic that both books have in common, but there are other related areas where comparison is possible. *Der neuzeitliche Aufzug* also covers areas which are not part of Donandt's dissertation, including a section contributed to the standardization of the lift designs.

4.1 Rope traction theory

In his forewords, Donandt writes that "*the previous publications do not offer sufficient background in form or content for calculation of elevator with traction sheave,"* referring primarily to literature concerning Koepe hoist systems and the framework of his dissertation is to correct this deficiency. The book by Hellborn and Hymans was not available to him at the time of writing.

4.1.1 The force ratios

It is interesting to note that already in his introduction to the traction theory, Donandt mentions the dynamic rope force ratios over the traction sheave, which indicates that this was an acute problem in traction dimensioning. It is also here that the first link to present day lift standards can be seen; both books conclude – based on slightly different argumentation - that a properly dynamically dimensioned lift can be safely overloaded with about 1/3 of the nominal load and that if the lift speed is not too high (and overload condition not too frequent), the small possible slip during acceleration would not be harmful. This is still reflected in chapter of A17.1 concerning the carrying of one-piece load [11].

[1] The significance of rope traction of lifts at the time is highlighted by the fact that C.C. Clymer also published an article in November of 1927 in General Electric Review, which addressed the topic.

4.1.2 The traction factor

Concerning the traction factor, Donandt commences from equations available for Koepe hoists at the time and uses a finite wedge-shaped linear object placed in a corresponding groove as a basis of his derivation. Donandt specifically mentions that he is aware of Hymans's formula (Eq.1) from Hellborn's article, but that the derivation was not commonly known.

$$\mu = \mu_0 \frac{4(1 - sin\alpha/2)}{\pi - \alpha - sin\alpha} \tag{1}$$

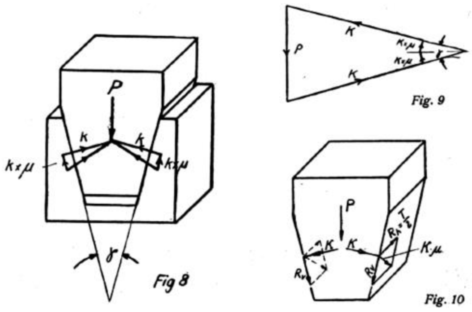

Figure 2 The engagement of wedge-shaped linear object placed in corresponding groove [3].

Donandt first formulates the equation for a round rope in wedge shape groove and then solves his equation for the specific case of circular rope seat (Eq. 2). In case of a rope positioned fully in the groove $\frac{\alpha}{2} + \varphi = \frac{\pi}{2}$, the equation can be simplified to Hymans's formula (Eq.1).

$$\mu = \frac{4 \cdot \mu_0 \cdot \left[\sin\left(\frac{\alpha}{2} + \varphi\right) - \sin\frac{\alpha}{2}\right]}{sin(\alpha + 2\varphi) - sin\,\alpha + 2\varphi} \tag{2}$$

In comparison to *Der neuzeitliche Aufzug*, it is interesting to note that Donandt goes to some lengths to justify the usage of uncompressible rope in his derivation by presenting an alternative derivation for a compressible rope, referencing an earlier publication "*Die Drahtseilfrage" (The wire rope question)* [12], where the topic is discussed, and later reflecting his results against both formulas. Figure 2 shows the engagement of a wedge-shaped linear object in a corresponding groove, which Donandt used in his derivation for elastic ropes.

The approach in *Der neuzeitliche Aufzug* is somewhat different. Overall, the topic of specific pressure in the groove is considered first and the derivation is based directly on a rope in an undercut groove. The basic definitions are listed in the beginning as follows:

1. The rope groove forms a non-elastic surface
2. The load does not cause any change in the cross-section of the rope
3. The rope can be considered as a smooth cylinder.

The fourth assumption is that vertical component of pressure must have the same value at each contact point because the vertical wear is observed to be the same everywhere (see 4.1.3).

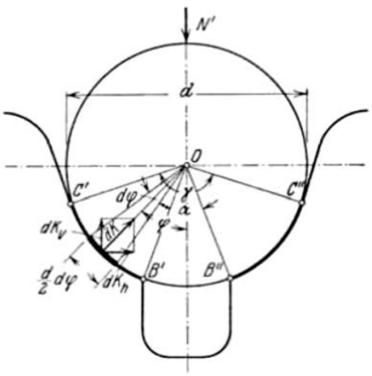

Figure 3 The determination of the size of the contact forces [1]

The derivation starts by determining the equilibrium conditions for a finite rope element, which is under the influence of the contact forces between rope and groove and the compressive force (Fig. 3). This gives the possibility to derive the magnitude of compressive force and, based on the relationship imposed by the four earlier assumptions, to determine the relationship (Eq. 3) between pressure, rope tension (*S*), groove geometry and the diameters of the rope (*d*) and the undercut traction sheave (*D*). To solve the formula for the friction force against rope slip (*W*), this is then integrated over the entire contact length (Eq. 4).

$$p = \frac{8 \cdot \cos\varphi}{\gamma - \alpha + \sin\gamma - \sin\alpha} \cdot \frac{S}{d \cdot D} \tag{3}$$

$$W = \mu_0 \cdot d \int_{\alpha/2}^{\gamma/2} \frac{8 \cdot \cos\varphi}{\gamma - \alpha + \sin\gamma - \sin\alpha} \cdot \frac{S}{d \cdot D} \cdot d\varphi = 8\frac{S \cdot \mu_0}{D} \cdot \frac{\sin\gamma/2 - \sin\alpha/2}{\gamma - \alpha + \sin\gamma - \sin\alpha} \tag{4}$$

Since by definition the normal force over the traction sheave can be given as $N = \frac{2S}{D}$, the friction force is $W = \mu \cdot N$and as $\gamma = \pi$ for a rope positioned fully in the groove, the later equation can be transformed using the equation given in Hellborn's article (Eq.1) for the relationship between actual and apparent coefficient of friction.

It is particularly important to note that the authors are critically aware of the limitations of their derivation. Firstly, they discuss the impact of the size of the undercut and conclude that with centre angle values above 120° the groove geometry does not correspond to the derivation anymore. Secondly, the influence of assumed rope shape versus the actual contact between the groove and individual wires within the rope strand is considered and it is proposed that a correction factor should be applied based on the construction of the rope.

4.1.3 The specific pressure between rope and groove

As mentioned, *Der neuzeitliche Aufzug* treats the topic of specific pressure before deriving the traction factor. The chapter starts by declaring that the destruction of the grooves is caused by wear, and wear is caused by rope creep and rope slip. It is also stated that since the vertical wear of the groove is the same everywhere, the vertical pressure component ($p = p_0 \cos\varphi$) must also be the same at each point of contact.

Since the presumption is that the wear is determined by the number of roundtrips, the lifts are classified in to four distinct groups depending on their usage. These classes are 1) Passenger lifts for 8-10 hours of usage per day, 2) Passenger lifts for intermittent traffic, 3) Goods lifts similar for intermittent traffic, but longer loading times and 4) Goods lifts that are used rarely.

Subsequently, the permissible surface pressure is given for each class based on experiments (Fig. 4), but the details of these experiments are not given. It is also stated that these limits apply for round stranded ropes with a Regular lay and that for Lang's lay these values can be exceeded by 25%.

Later, an adaptation of these limits was applied in German TRA 003 lift regulation [13] from where it got copied to EN 81-1 for a brief period between 1986 and 1989.

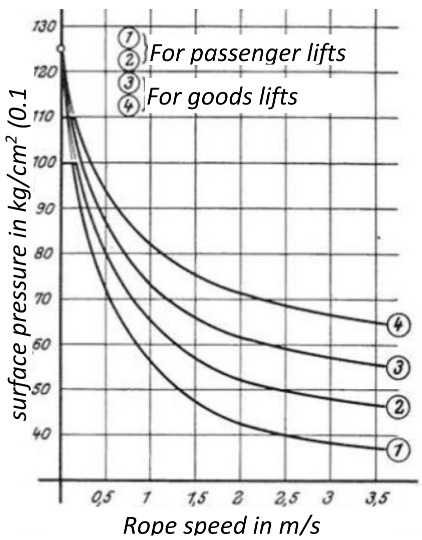

Figure 4 Permissible surface pressure between rope and groove for a round strand rope with Regular lay and groove rim from mixture of grey cast iron and scrap steel [1]

According Donandt, the concept of limiting the permissible groove pressure was relatively new at the time and the conventional approach was to select quantity of ropes solely based on strength calculations. When Donandt was writing his dissertation, he did not have the full explanation of *Der neuzeitliche Aufzug* available, however he made some observations based Hellborn's article. He was concerned that the pressure (at point α/2) used in the derivation of pressure formula is not changing in relation to the width of the undercut and he had doubts about the pressure distribution assumption. He also raises questions about the impacts of cross-sectional resistance, wire thickness and strand construction of the ropes, as well as the impact of the hardness of the sheave, but concludes that these questions can only be answered by obtaining more experimental data.

More significantly though, Donandt claims, based on his own experiments, that rope slip alone cannot explain the wear of traction sheave. For his tests, he attempted to create a rope seat in a traction sheave by slipping a rope over it but had great difficulties in achieving symmetric wear as seen in Figure 5. As a supplementary explanation he proposes that a part of the wear mechanism are the changes in the material due to load changes caused by the movement of the lift.

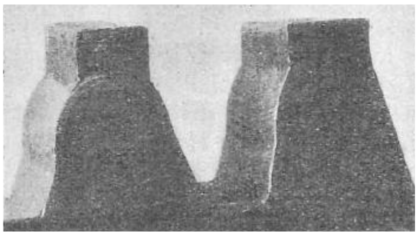

Figure 5 Asymmetric wear documented by Donandt [3].

But while there is some disagreement on the wear mechanism and on the determination of the permissible pressure, Donandt concludes that it was advantageous not to let the pressure become too high due to rope and sheave lifetime considerations.

4.2 Rope safety factor

In the beginning of the 20th century the question 'which safety factor should be applied?' was very much open. Donandt reports that there was an on-going discussion in the German lift association whether to base the safety factor calculation solely on the tensile stress or to also take the bending stress into account. *Der neuzeitliche Aufzug* gives a table with a foreword that safety factors applicable in USA can be read directly from the maximum rope load curves. As reference, Grierson [14] reports that in England the safe working load was one twentieth of the breaking load and explains that the differences in safety factor are at least partly due to rope materials used in different markets.

Table 1 Rope safety factor according Hellborn and Hymans [1]

	Lifting speed (m/s)	0.5	1.0	1.50	2.0	2.50
Min. safety factor:	Passenger lifts	8	8.6	9.2	9.7	10.2
	Freight lifts	7	7.6	8.2	8.65	9.1

The significance of safety factor in conjunction with the introduction of surface pressure limits is that both Donandt and Hellborn together with Hymans conclude that safety factor calculation becomes partially redundant if pressure limits are followed. Donandt goes as far as to formulate a relationship between the safety factor of contemporary German ropes and undercut angle for different d/D-ratios (Fig 6).

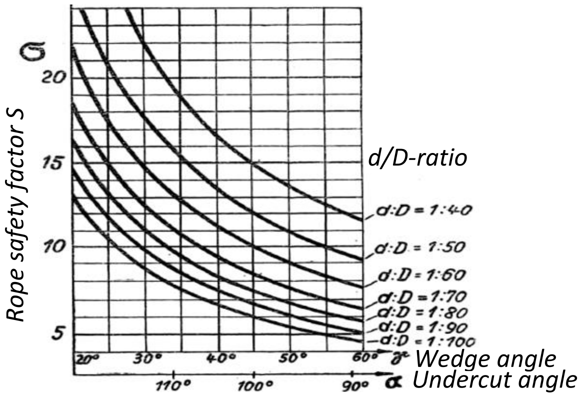

Figure 6 A safety factor chart for all loads and rope-to-traction sheave-ratios [3].

An interesting reflection to modern European regulations is that groove pressure is no longer considered, and it has been replaced by a complicated calculation for a minimum rope safety factor [15]. This compulsory requirement in practice only influences hoisting configurations with a large amount of relatively small pulleys, while in many applications, such as high-rise, only the absolute minimum safety factor of twelve has relevance. Also, this calculation does not consider decades of development in rope technology, which may lead to excessive groove pressure [16].

4.3 Coefficient of friction

Der neuzeitliche Aufzug explains explicitly the difference between apparent and actual friction coefficient and how the relationship is formulated. As already mentioned, the formula (Eq. 1) was known to Donandt from Hellborn's earlier article. To verify their friction calculation method, Hellborn and Hymans present measurement results done with ordinary round strand ropes using two different sized traction sheaves with different undercuts (Fig. 7). For the rope slip results, the sliding speed was 2.5 m/s. Their conclusion of these results can be summarized as follows: The difference in friction between before and after the rope slip is due to lubrication, which is effective only after there is movement between the rope and the sheave and the tension ratio becomes independent of the load at relatively high loads due to the stiffness of the rope (the rope diameter used in the tests is not specified). Finally, they compare actual friction coefficient values from these calculated tests (μ_0 = 0.080 and 0.083) to earlier tests conducted with semi-circular groove (μ_0 = 0.084) and present this as proof of the correctness of their mathematical analysis.

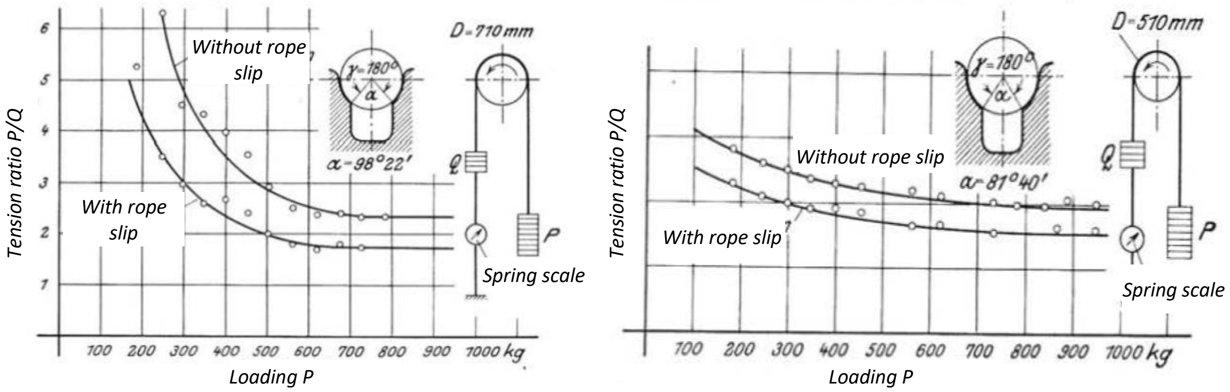

Figure 7 Friction test arrangement and results by Hellborn and Hymans [1]

While *Der neuzeitliche Aufzug* treats the topic of actual friction coefficient relatively briefly, a substantial portion of Donandt's dissertation is focusing on tests to understand the dependence of rope friction on four parameters: surface pressure, lubrication, sliding speed and surface quality. His test arrangement is in principle similar to Hellborn and Hymans, but one difference is clear from the onset; the diameter of the traction sheave is only 400 mm, and with a 16 mm rope Donandt is only able to achieve d/D-ratio of 25. But he states - in direct contradiction to Hellborn and Hymans - that the test results did not show that the rope stiffness would be influential even with small loads.

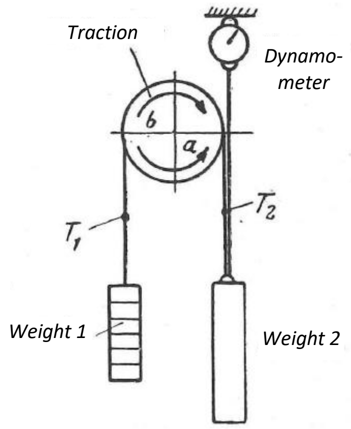

Figure 8 Friction test arrangement by Donandt [3]

Donandt makes the following prepositions based on these four testing parameters:

1. The question of the dependence of μ_0 on the diameter of the ropes and on the size of the support surface is the same as the question of the dependence on **the pressure**. In otherwise unchanged conditions, an increase of rope diameter or support surface will only result in a reduction of the specific pressure. The study of different rope diameters can thus be ignored.
2. Dependence of friction on **the lubrication** can only be significant for the state of rest. As soon as the rope begins to slide, the lubricants on the wires and the sheave will be displaced from the contact so that they become ineffective.
3. Concerning **the sliding speed,** it is known that the friction in rest is greater than in sliding. In the normal operation, the friction value at rest is decisive because the rope is in rest in relation to the sheave, but if due to acceleration or braking situation the ropes start to slip, the smaller dynamic friction applies, and it must be taken as a basis for the traction calculations.
4. **The quality of the groove surface** has an influence on the magnitude of friction. The reduction of friction due to running-in is relevant because the initially rough grooves will be smoothened by the ropes over time. The question of whether friction is dependent on the material of the sheave could be seen only when the pressure of the wires became so great that they left impressions in the sheave.

Again, Donandt's second claim is in direct contradiction to the statement by Hellborn and Hymans.

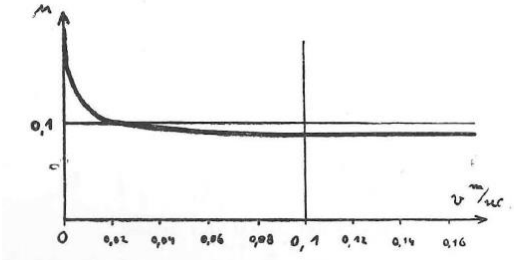

Figure 9 Dependence of friction on sliding by Donandt [3]

After conducting hundreds of individual tests, divided into 21 test sets in three distinct groups, Donandt made the conclusion that the static friction varied between 0.104 and 0.184 and sliding friction between 0.09 and 0.160 for rope speed exceeding 0.1 m/s (Fig. 9). And that the smallest of these values, $\mu_0 = 0.09$, should be used in calculations.

Here, it is interesting to note that according to Gibson the friction coefficient value published in *Der neuzeitliche Aufzug* was widely in use in the lift industry at least during the 1990s (Table 2) [16], and Donandt's value lived on, first in the German lift regulation TRA 003 [13] and later in the European standard EN 81-1:1985. The reason why Donandt's friction coefficient was abolished from later versions of EN 81-1 was the introduction of speed dependent friction coefficient formula, at least partly due to influence by KONE [17]. The speed dependency allowed initial friction coefficient value to be set to 0.1, which is close to Donandt's lower static bound.

Table 2 Rope friction factors by Gibson [16]

Source	μ_0
Otis	0.084
Haughton	0.084
Millar	0.084
Westinghouse	0.094
Schindler	0.094
Dover	0.100
EN 81-1:1985	0.090
EN 81-1:1998 EN 81-50:2020[1]	0.100
[1] Addition by Author	

4.4 Deceleration and acceleration of lifts

Determining the upper bound of the deceleration and acceleration of lifts is a relevant question when determining the needed traction. Also, before the age of computers, it was convenient to produce one calculation that would cover both static and dynamic load cases with the least amount of calculation, which resulted in simplified dynamic factor $\frac{g+b}{g-b}$, where g is the gravity acceleration and b is the acceleration or deceleration.

Table 3 Acceleration/deceleration in respect to lifting speed according to Hellborn and Hymans [1]

v (m/s):	0.65	1.0	1.5	2.0	2.50	3.0	3.5
b (m/s^2):	0.65	0.85	1.15	1.40	1.65	1.88	2.10

Donandt was concerned in particular about the deceleration during braking as the lifts in Germany at the time were also stopped in normal operation by a mechanical brake, which could cause harsh stopping, whereas many contemporary American lifts performed gradual stopping using the motor. The claim is supported by the table from *Der neuzeitliche Aufzug* (Table 3), which gives very specific deceleration rates. After conducting a series of field measurements – including one notoriously unpleasant lift in Stuttgart - Donandt concludes that the maximum deceleration was 0.3 g, but that 0.2 g would be sufficient for traction calculation if dynamic friction coefficient was applied. It should be noted that Donandt’s values can also be considered as maximum values for emergency braking condition.

By today’s standards any values above ca. 1.4 m/s^2 would be considered excessive in normal use and thus the dependency between speed and acceleration given in Table 3 is no longer relevant.

4.5 Dimensioning of oil buffers

Der neuzeitliche Aufzug contains a wide variety of topics, which are beyond the scope of Donandt’s dissertation. One of these topics, which should not be dismissed, is dimensioning of oil buffers, because of its long-lasting implications.

Already prior to the publication of *Der neuzeitliche Aufzug* Hymans had been actively solving design challenges concerning buffers [1] and had written about the buffer stops of lifts published in ASME Transactions in the previous year [18]. He also discussed at length the topic of buffers again in The Electric Elevators, Book I [19] in ca. 1930.

To start with, *Der neuzeitliche Aufzug* makes the statement that tests have shown that greater deceleration than 2.5 g causes discomfort to passengers, and that decelerations above 3 g are considered dangerous, but no further details are provided. Later, in reference to oil buffers, it is mentioned that in general the buffers are designed to decelerate the maximum rated load with an average deceleration of 1 g. Some contexts where these limits have appeared are listed in **Table 4**.

Table 4 Some buffer deceleration limits

Deceleration limit [g]	Source	Author	Year
“Equal to velocity height” = 1.0 g (?)	Passenger Elevators	Brown	1904
64.4 ft/s^2 = 2.0 g	Electric Elevator Equipment for Modern Buildings	Grierson	1924
1 g (average) 2.5 g (maximum)	Der neuzeitliche Aufzug mit Treibscheibenantrieb	Hellborn, Hymans	1927
80.5 ft/s^2 = 2.5 g	Electric Lifts	Phillips	1961
25 m/s^2	NEN 1081 Safety regulations for electric lifts	Nederlands Normalisatie-instituut	1971
1 g (average) 2.5 g (peak)	Der Aufzugbau	Franzen, Englert	1972
9.81 m/s^2 (average) 24.5 m/s^2 (peak)	ASME A17.1/CSA B44	The American Society of Mechanical Engineers	1971 2019
1 g (average) 2.5 g (peak)	EN 81-1 EN 81-20	European Committee for Standardization	1986 2020

Indeed, 2.5 g was regarded as the safety limit for passengers and the 1 g limit was needed to ensure that the deceleration of the descending body matches that of the ascending body. The significance of this can only be understood by reading the earlier ASME paper by Hymans, which highlights the importance of ropes slipping during buffer run to maintain a safe top clearance and the significance of slack hoist rope produced as a result of buffer run.

Parallels can be drawn from here to Donandt’s 1963 article “*Die Bremskraft der Fangvorrichtungen von Schnellaufzügen und das Springen der Gegengewichte beim Fangen*” (*The braking force of the safety gear of high-speed elevators and the counterweight jump during gripping*) [20] where he analyses the same phenomenon from the perspective of safety gear engagements. The conclusions concerning counterweight jump have defined the engineering of high-speed lifts to this day.

It is also worthwhile to consider that due to the influence of *Der neuzeitliche Aufzug* the 1 g limit for buffers became the industry practice and, in addition, most likely directly affected the requirement for safety gears [21].

4.6 Standardization of lifts

The subtitle of Hellborn's and Hymans' book is "*Charakterisierung, Theorie, Normung"* (Characterization, theory, standardization) and as the subtitle suggests, one main theme is to explain the impact of traction sheave drives to the standardization of lift design. The section – probably written mostly by Hellborn – explains the "typification", which is the principle of constructing a series of complete products such as motors, controls, safety gears, etc., and the "standardization", which aids the economical selection of individual parts. The topic had already been introduced in Hellborn's 1924 article and in modern terms the approach could even be described as "systems engineering" as the aim is to design efficient lift systems. Overall, the possibilities for standardization were one of the reasons why traction lifts were such a paradigm shift and Hellborn's analysis would merit a much wider treatment than what is possible here.

5 DISCUSSION

Although the traction lift had already existed before the books by Hellborn, Hymans and Donandt were published in 1927, they acted as a catalyst in the major transition within the lift industry, by making the basic dimensioning principles available for a wider audience. The age of drum lifts was decidedly over.

Several of the dimensioning principles introduced in these books have lived on to this day. This was also influenced by the fact that Hymans and Donandt assumed significant positions in the lift industry in later years and were both involved in the development of lift safety standards.

Admittingly, these principles have *stood the test of time*, but it should also be recognized that these old principles should not go unchallenged. Already in 1927 Donandt disagreed with some of the claims made by Hellborn and Hymans, and the evidence to support some of the basic assumptions was not properly presented – at least by scientific criteria. On the other hand, one could also argue that on some points the original wisdom has been misrepresented in later years.

In the century after the books by Hellborn, Hymans and Donandt, the lift industry has faced other paradigm shifts, such as the introduction of machineroomless lifts and coated suspension members. The recent trend towards eliminating or minimizing pit and headroom heights may also become such a game changer – not to mention the impact of digital transition.

As general technology evolves and the requirements change, we must be ready to challenge the old assumptions. But to do that, one must first recognize why certain things have been the way they are. This is why it is so important to go back to the source - and therefore *Der neuzeitliche Aufzug mit Treibscheibenantrieb* and *Über die Berechnung von Treibscheiben im Aufzugbau* are still relevant today.

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