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Advanced drive systems for traction sheave elevators with V-belts

Summary

Higher elevator speeds, greater loads, more stringent safety requirements and modern advances in control technology are just some of the developments that are forcing us to reconsider accepted approaches to elevator drive design. Added to this is the ever-increasing pressure to reduce both manufacturing and operating costs.

In the light of these trends, this paper takes a detailed look at the V-belt drive system and shows that it has considerable advantages over the other approaches currently available on the market.

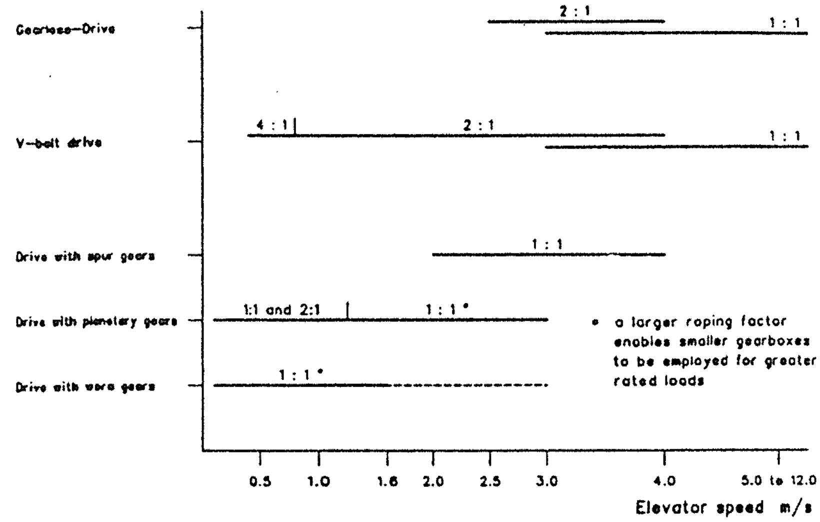
Introduction

Since the 1950s – after a new V-belt design (the wedge belt) had been introduced – V-belt drives have been employed in elevator and escalator construction. Thousands of such drives have been built since that time. One elevator manufacturer in the north of Germany, well-known for the particular quality of its products, still successfully uses this drive system today for its entire range of traction sheave elevators (up to 5000 kg rated load and up to a speed of 4 m/s). The V-belt drive has always been one of the company's significant competitive advantages!

Modern V-belt designs and the rapid advances in control technology make the V-belt drive more and more interesting as an elevator drive system. Thanks to the development of a patented tensioning device and the adaptation of the machine to the requirements of EN 81 [1], this drive has in the meantime matured into a technical approach that commands a growing degree of respect on the European elevator market.

As the V-belt drive can be used in place of both interlocking gears (worm gears, spur gears, planetary gears) and gearless drives (see Fig. 1), its special characteristics are demonstrated in the following sections with reference to these two conventional approaches.

This comparison deals with the essential characteristics of an elevator drive system: *quality, safety* and *costs*. It is preceded by a brief description of the modern V-belt drive.

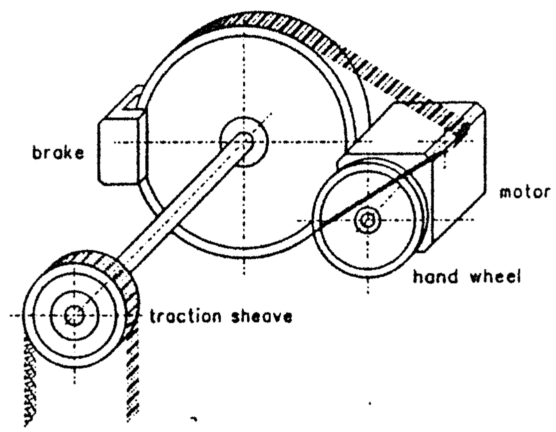


Drive systems for electric traction sheave elevators
operating ranges (approximate)

Fig. 1

Description of the V-belt drive

The V-belt drive involves a single-step transmission: the motor shaft is connected directly with the traction sheave shaft (see Fig. 2).



Schematic representation of the V-belt drive for elevators

Fig. 2

The pinion that drives the V-belt is located on the motor shaft and its minimum diameter is determined by the belt profile selected (e.g. a minimum of 50 mm for an XPZ profile). Diameters ranging from 630 to 1250 mm are available for the large V-belt sheaves. Theoretically this gives transmission ratios of up to a maximum of 1:25; however, economic considerations mean that in general transmission ratios of up to 1:12 are designed. By altering the roping of cabin and counterweight (on the block and tackle principle) drive systems can then be constructed for all conceivable speeds and carrying capacities (as illustrated in Fig. 3).

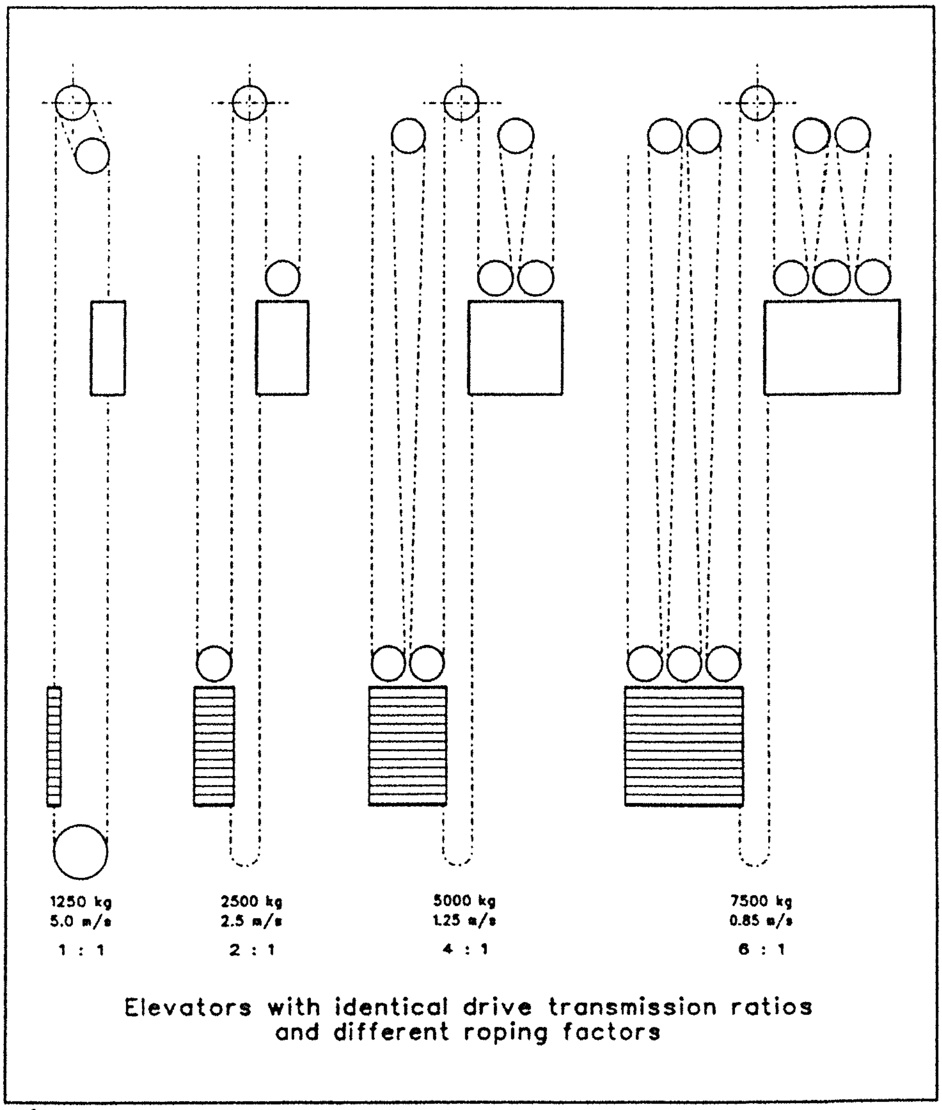
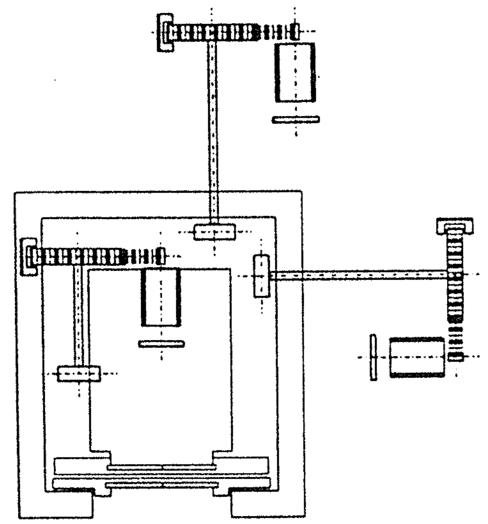


Fig. 3

Extending the length of the traction sheave shaft enables the drive system to be arranged in any desired relationship to the hoistway (see Fig. 4).

Motor shaft and traction sheave shaft are mounted on a common frame, together with the elements that insulate the elevator from the building. An additional machine frame is not required.



Mounting options for the V–belt elevator machine

Fig. 4

The latest type of V-belt is distinguished by a special belt-tensioning device, which has been filed as a patent in a number of countries. In accordance with the regulations of EN 81 Part 1 (BS 5655: Part 1) [1] the service brake here is mounted directly on the traction sheave shaft.

Elevator drive systems in comparison

Quality

The quality of the drive is manifested by its low operating noise and high degree of safety in service.

The advantages of the *V-belt drive* here are unmistakable:

From the very beginnings the particularly low operating noise of the V-belt drive was the main reason for its being introduced. This feature does not alter over time: the oldest V-belt drive system that I know of, dating from 1954, runs just as quietly today as a new drive system of the same construction!

With the new patented tensioning device the belts are adjusted once on commissioning and the operating safety is then guaranteed without any further alterations or inspections for the entire life span of the V-belt. The calculated life span is generally 25,000 operating hours, which, depending on how often the elevator operates, may mean a life of up to 25 years. However, owing to the material used (primarily rubber) V-belt manufacturers only guarantee a life span of approximately 10 years, but experience shows that effective life spans achieved in service are in many cases considerably higher. If a set of V-belts should happen to wear out, it can be renewed with the minimum of effort and expense, with the machine then continuing to operate as quietly and safely as before.

The frictional connection of the V-belt drive has an inherent degree of slippage, which under correct tension is very low. However, the motor and traction sheave are constantly linked, irrespective of the direction of travel or the load in the cabin, even when the strain on the drive changes, as for example when applying the brake.

The vibrating system of the V-belt drive is very simple: vibrations can only come from the motor (caused by rotating parts being out of balance or possibly oscillation from the electrical control) or from the slow-running traction sheave being out of balance. However, the motor and traction sheave shafts can be easily and inexpensively balanced to a high standard.

In contrast, all interlocking gears have to be lubricated. Additional vibrations result from the meshing of the teeth, with spur gears being considerably more critical than worm gears owing to their geometry. If several transmission stages exist, such as with spur gears and planetary gears, the number of possible vibration frequencies becomes even greater. With interlocking gears, therefore, very high manufacturing precision is required in order to avoid vibration.

Even if all modern interlocking elevator gearboxes are calculated over their life span, during operation alterations in the intermeshing teeth come about with time, which over a long operating period give rise to play in the gearbox and result in noise, which becomes audible in the cabin.

It is therefore important to ensure correct gearbox lubrication. This begins with filling the gearbox: if the installation engineer uses an inappropriate lubricant, gearbox failure can result within a very short period of time. Further regular oil inspections are unavoidable over the course of the years, as are oil changes at prescribed intervals.

The V-belt drive is comparable in quality with the *gearless* drives. Admittedly the former has an additional vibrating system as a result of the second – high-speed – motor shaft, but the motors can be balanced so well that no impairment of the running properties is generated. Furthermore, the airborne noise from the high-speed motor is only audible in the machine room, it is not transmitted to the building and the hoistway.

Safety

The V-belt machine has hitherto been constructed exclusively in compliance with the stringent German elevator safety code [2]. As this standard will shortly be superseded by EN 81 [1], the latest version of the machine is designed according to the European standard. In the meantime confirmation has been received from several European safety organs (TÜV [Technical Control Board) in Bavaria, the Amt für Arbeitsschutz [Safety at Work Office] in Hamburg, Urzad Dozoru Technicznego [Technical Control Board] in Poland) that the requirements of EN 81 are fulfilled.

In terms of safety too, the *V-belt machine* has distinct advantages over the gearbox drives: in accordance with EN 81 the service brake is located directly on the traction sheave shaft; this is mounted on two sets of bearings and designed to exclude the possibility of failure. The open construction of the V-belt machine leaves all the parts that are important to safety easily accessible: belt tension and brake adjustment are particularly easy to inspect. Furthermore, the bearing mountings are also accessible and can be examined individually for noise and heat. The correct design of the V-belt transmission is given to the inspecting official so that the calculations can be verified, as laid down in the relevant standards [3,4,5].

As interlocking gearboxes have to be oil-tight, they are closed on all sides. None of the connections with an important safety function (e.g. worm wheel with its rim) are open to view. The official responsible for inspecting the elevator has only the elevator manufacturer's own figures on which to base his assessment as to whether the gears have been correctly calculated, are of the required quality level and have been selected to match the loads. The brake is mounted on the fast-running drive shaft (motor or worm shaft) and it is assumed that the interlocking connection between motor and traction sheave drive is secure. That this is often enough not the case is demonstrated by the accident figures [6] and the additional safety equipment that since been brought onto the market [7,8].

In terms of safety there are no differences between the V-belt and *gearless* drives as the latter also has the service brake mounted directly on the traction sheave shaft.

Costs

In terms of costs V-belts also have many advantages, which are given detailed treatment here. For clarity the various different costs are dealt with separately as follows:

1. costs of development and introduction,
2. manufacturing costs (material, tooling and labour),
3. transport and installation costs,
4. operating costs (maintenance, energy consumption).

1.. <u>Costs of development and introduction</u>

The current design of the V-belt machine is based on many years of experience. Even though the drive principle might appear to be very simple, without this wealth of experience it is still possible to make many mistakes and pay a lot of money in the learning process. If one takes advantage of my expertise, great savings can be made when introducing this design.

In order to cater for the entire operating range of elevators, a modular principle has been adopted for V-belt drive machines that enables the greatest possible range of applications to be covered with a small variety of parts. This applies not only to the required output graduations but also for any special machine constructions required (e.g. for extended traction sheave shafts with side-mounted machines).

When introducing the V-belt drive systems it is necessary to reconsider the entire concept of elevators. For even with an elevator having a rated load of only 300 kg and a rated speed of 1.0 m/s the roping of car and counterweight must be in a 2:1 ratio, since the transmission ratio of the V-belt drive alone is too low. Yet, this type of arrangement also has numerous other benefits. For instance, there are no further problems with the angle of wrap being too low at the traction sheave, since 180° is always guaranteed. Only small rope diameters are needed (for this example: 3 ropes of diameter 8 mm) and consequently low traction sheave and rope pulley diameters. As it is not necessary to accommodate diverting pulleys in the machine room, problems with height are eliminated. Mounting the machine underneath also becomes considerably easier.

2. Manufacturing costs (material, tooling and labour)

The V-belt machine includes many standard parts that can be obtained from specialist dealers in drive elements. This is especially true of the V-belt pulleys, the V-belts themselves (Note: my experiences with various makes of V-belt have been very varied!) and possibly clutches. The brake solenoids and motors are supplied by firms specializing in the needs of the elevator industry. However, it is also possible to mount any desired special motor onto the machine, for example motors with particularly low current consumption (special induction motors or also synchronous motors), d.c. motors, motors for use in areas with an explosion hazard, etc.. As a result of my proposed modular design principle, storage costs can be kept to a minimum.

If many parts can be bought in, tooling and setting-up costs become very small. The simple design of the drive obviates the need for complicated gear cutting to very fine tolerances. Consequently no expensive machine tools are required. This means that a high-quality elevator machine can be produced as a V-belt drive in a small engineering workshop without great difficulty. Experience in Poland shows that local elevator manufacturers are able to remain competitive without major investment against the massive force of international competitors trying to penetrate the market. However, if large production runs are to be manufactured at particularly low prices, reasons of cost make it necessary for the company to produce many parts itself instead of buying them in. In addition, devices for welding and assembling the machine parts have to be built in order to reduce the labour input.

Latest studies have shown that, if purchasing prices are reasonable and parts can be produced in series, V-belt drive systems for elevators operating at 630 kg/1.0 m/s can be offered in medium-sized quantities for the same prices as conventionally available worm gearboxes. Added to this is the fact that *any* conceivable elevator machine can be custom-built as a one-off item, and the higher the motor output, the greater the savings will be over the corresponding interlocking gearboxes.

In comparison with worm gears benefits are seen in the higher speed ranges, even when small manufacturing quantities are involved. For instance, a V-belt drive system for 630 kg/1.6 m/s only differs from the equivalent 1.0 m/s machine by the price differential of the motors. For greater drive outputs, as required for higher speeds (e.g. 2.5 m/s) and also for higher rated loads (e.g. 5000 kg), the high efficiency of the V-belt drive enables motors to be selected that are several sizes smaller. The savings on the difference in the motor price alone cover a large part of the cost of the V-belt transmission system.

This is especially true of fast-running elevators, for which gearless drives have been used exclusively to date. Here a V-belt drive system is less expensive from the very beginning owing to the lower cost of the four-pole motor. There is also the added factor that the frequency control at 50 Hz costs less.

3. Transport and installation costs

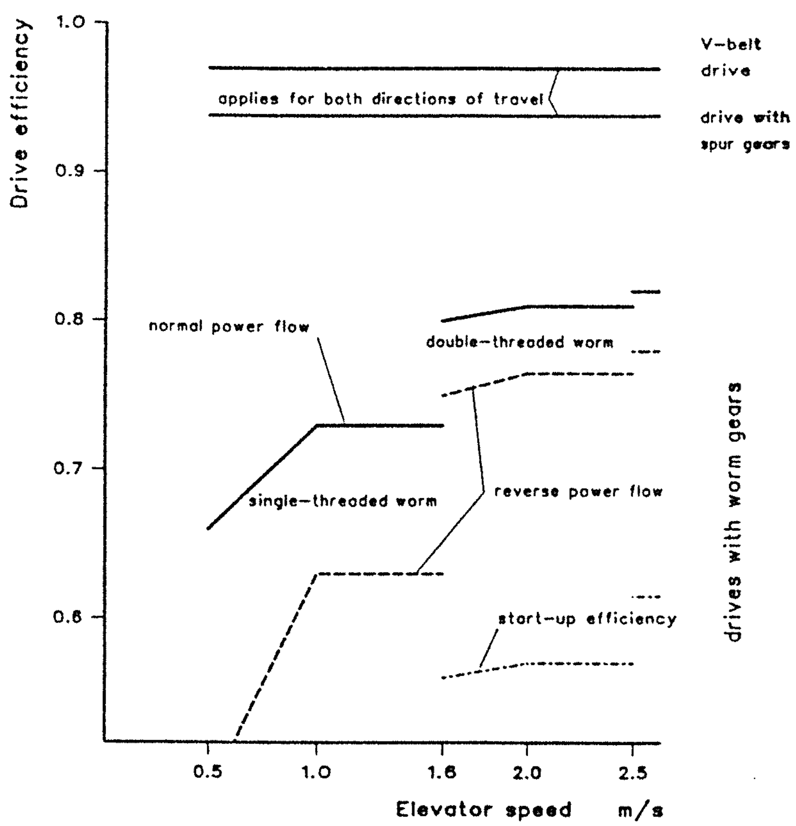
V-belt drives systems have no great inherent weight and with straightforward equipment can be dismantled into several parts for transport to the machine room. As they are delivered complete with frame and insulation, no additional installation costs are involved. Adjustment of the belt tension and brake can easily be carried out with the instructions supplied.

4. Operating costs (maintenance, energy consumption)

Once the machine has been set up, servicing merely involves inspecting whether the settings have altered during operation. In drive systems with automatic control technology (ACVV and VVVF), the brake does not engage until the brake disc has come to a standstill. In this case no further wear of the brake pads is to be expected.

In terms of energy consumption the V-belt drive is unrivalled! There is *no* other drive system with such low current consumption figures. In comparison with gearbox drives this can be seen directly from the degree of efficiency of the individual drive types (see Fig. 5).

However, gearless drives also have significantly high current consumption figures because of the greater losses in the motor (see Fig. 6) and control.



Comparision of efficiency for the various drive systems

(at rated load and machine speed of approx. 1400 r.p.m.)

Fig. 5

Even the latest gearless design with a synchronous motor, as is now available for small passenger elevators, does not draw less mains current than the V-belt drive. This argument does not merely concern the customer's operating costs since the low current consumption enables smaller switching equipment and control systems to be included in the design, which in turn produces additional savings.

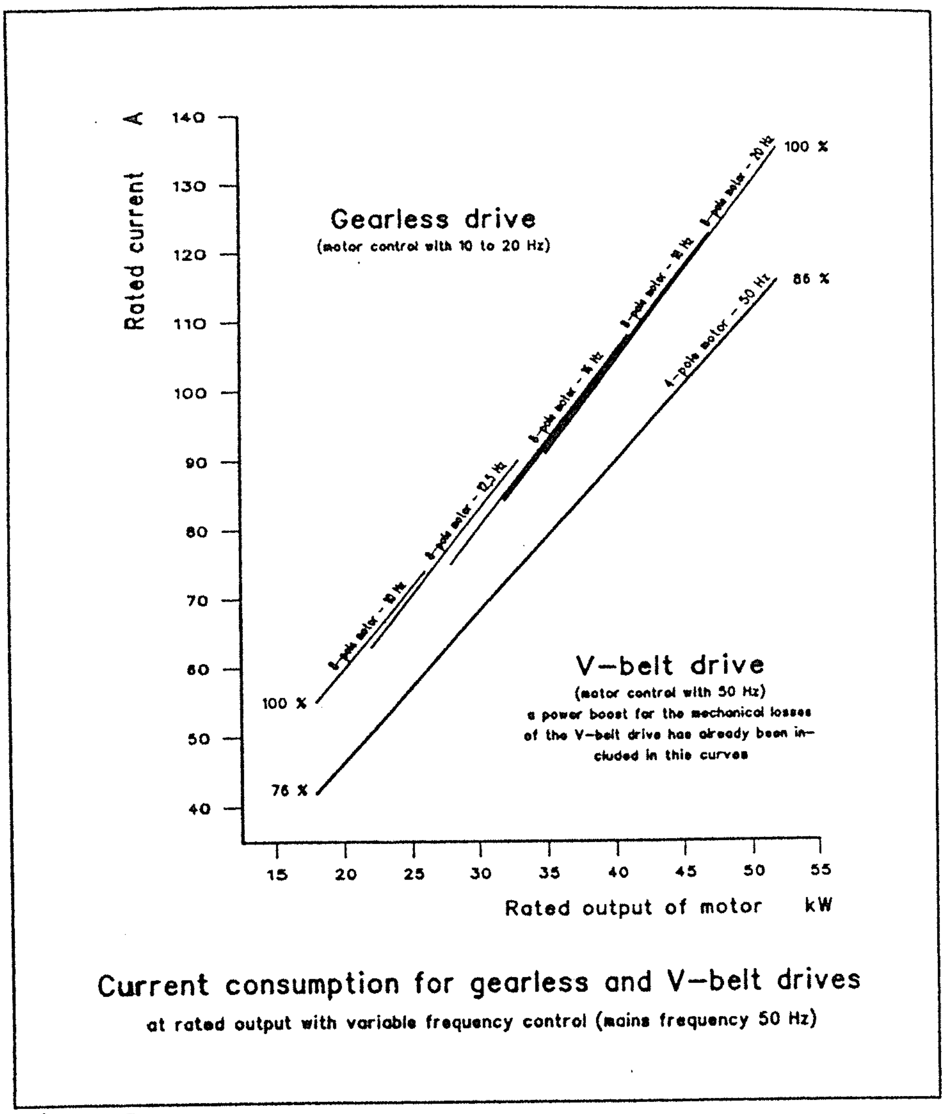


Fig. 6

Concluding Remarks

The above comparison of the various drives systems shows that with the current and foreseeable state of technology there is no better drive system for traction sheave elevators than the V-belt drive. This concerns not only the quality but also the safety and cost aspects of the drive system. Since the system is backed up by decades of experience, no risk is attached to the introduction of this design.

The most up-to-date V-belt drive designs – veritable advanced drives for traction sheave elevators – have in the meantime reached full maturity. The first 10 machines of this new design are in service and prove that the underlying concept is correct.

Improve your competitiveness by introducing the most up-to-date drive system technology. My expertise is at your disposal.

References

[1] EN 81 : Part 1 : 1985 (BS 5655 : Part 1 : 1986)

[2] TRA 200 Technical Rules for Elevators : May 1992 (Germany)

[3] DIN 7753 : Part 2 : April 1976 (Germany)

[4] BS 3790 : 1981

[5] ANS - RMA IP - 22 1991 (USA)

[6] Die Aufzugsunfälle der Jahre 1958 bis 1986 [Elevator accidents from 1958 to 1986], Technische Überwachung [Journal of the Technical Control Board TÜV] 10/1960 - 11/1963 - 3/1967 - 5/1979 - 10/1983 - 6/1988

[7] J. A. Nederbragt: Sicherheit gegen unkontrollierte Fahrbewegungen des Aufzuges [Protection against uncontrolled elevator movement] Lift-Report 4/1990

[8] G. Schiffner: Sicherheitskonzept und -einrichtungen zur Verhinderung unkontrollierter Fahrbewegungen bei Aufzügen mit Treibscheibenantrieb [Safety concepts and devices to prevent uncontrolled movement in elevators with traction sheave drive systems] Lift-Report 5/1991

About the author

Dipl.-Ing. Roland Stawinoga has been involved in the design of elevators (and escalators) for more than 42 years. He is a member of the IAEE and well-known for his technically authoritative lectures (ELEVCON'93 in Vienna, LifTech'94 in Brussels, ELEVCON'95 in Hong Kong, London Lift Seminar 1995, ELEVCON'96 in Barcelona), which have also been published in the most important elevator trade journals (Elevator World, Elevatori, Lift-Report), as well as for his other contributions to elevator engineering in Lift-Report.

In 1973 he took charge of the Technical Department in the firm of G. A. Koch in Hamburg, where he first became acquainted with V-belt drive systems and played a decisive role in their further development. 1990 saw the founding of his own engineering office, where fully equipped with the latest CAD technology, he employs his extensive and expert knowledge in assisting elevator companies to construct high-quality installations. His special interest continues to focus on the design and development of elevator drive systems in general and on the V-belt drive in particular.