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Trier

## Ventilation and Smoke Extraction in Large Garages

### Compliance with German federal regulations

*According to the Garage Ordinances of the various German states (Länder), large enclosed parking facilities for motor vehicles must be equipped with appropriate ventilation and smoke exhaust devices. In general, ventilation is to be ensured via two fans per ventilation system which provide the requisite volume flow when operating in combination. Natural ventilation is permitted in defined cases.*

*At the same time, preventive fire protection regulations have to be met. The requirements defined in this regard vary between the federal states. The ordinances tend to follow Model Building Codes of more or less recent vintage, but reflect varying empirical findings of the local fire brigades. Accordingly, the installation of sprinklers and powered smoke and heat exhaust installations is not generally required but both may be prescribed individually or in combination. The following article compares the Garage Ordinances of the individual German Länder in terms of their requirements on ventilation and smoke exhaust equipment. The actual technology of powered smoke and heat exhaust ventilation systems for large garages shall be examined in detail in the following article (chapter 8 in this book).*

The Working Group of German Länder Ministers in charge of Construction, Housing and Urban Development (ARGEBAU) adopted the new version of the Model Building Code (MBO) dated February 14, 1991, on February 21 and 22, 1991 [1;2]. This re-enactment of the MBO appeared



Type BVZAXN 12/56/650 two-stage axial-flow garage smoke exhaust fan for 400°C - 120 minutes (tested according to EN 12101, Part 3) in a multi-storey car park at Stuttgart airport

expedient as a first step toward ensuring a uniform implementation of a major regulatory instrument, the Building Products Directive, which had been adopted by European Community member states as part of the harmonization process. The MBO version dated May 4, 1990, had already served as a model for corresponding legislation in the East German Länder created upon re-unification and thus prevented a further divergent development of building regulatory law.

The Garage Ordinances forming part of the Länder building codes are likewise based on the ARGEBAU's model text. This rule applies, as it did previously, to the (now revised) Garage Ordinances of the new and old Länder alike, albeit with some regionally specific modifications and additions. The latter reflect the different consultation processes in place in the individual Länder, which have resulted in the integration of, e.g., empirical findings contributed by the fire brigades (thus, Baden-Wuerttemberg became the first Land to stipulate the use of smoke exhaust fans) or social policy objectives (such as when North Rhine-Westphalia became the first state to require non-secluded "Women Only" parking places in large garages).

In section 48 ("Parking Capacity and Garages") the Model Building Code

stipulates that the construction of buildings likely to generate access and exit traffic is permissible only if parking capacity and garages of adequate size and quality are provided at the same time [1]. Aside from constructional requirements, such facilities must meet fire protection rules. Moreover, garages and ancillary structures have to be equipped with ventilation systems.

To ventilate enclosed medium- and large-sized garages and ensure compliance with preventive fire protection regulations, it is necessary to provide powered air supply/extraction and smoke exhaust systems. The fans installed for this purpose either meet the two functions separately or are designed as a single unit with pole-changing motors for use in air or smoke extraction mode. Where smoke exhaust fans are employed, they must meet government standards regarding increased service temperature ratings and heat exposure resistance times.

Aside from mechanical (powered) equipment, specific building regulations also allow natural ventilation or natural smoke exhaust systems, depending on site conditions. Moreover, for closely specified applications the installation of sprinkler systems is described.

The present article compares the requirements on ventilation and preventive fire protection imposed by the Garage Ordinances of the German Länder. On a more application-specific note, it also reviews the experience gathered with axial-flow fans and their control systems in a garage ventilation context, and examines the economic efficiency of these units in comparison with centrifugal fans (please refer to Chapter 8).

## Garage Ordinances of the German Länder

**7** The Garage Ordinances of the individual Länder are published in each respective Land's "Law Gazette". The currently applicable ordinance versions and the publishing firms entrusted with their publication are summarized in **Table 1**. The building regulatory law of specific German Länder, including aspects of their Garage Ordinances, form the subject of numerous additional publications. An exemplary summary for the Federal Republic of Germany, with quotations for each federal state, is presented in the bibliographic references ([3 to 14] albeit without any claim to completeness. Corresponding compilations for the new Länder, sometimes drawn up as loose-leaf collections, are currently under preparation.

## Ventilation

The regulations of the various federal states concerning the ventilation of garages currently are still based on

two Model Building Codes dating from different periods. Nevertheless, the older ordinances (Berlin, Bremen, Saarland, Sachsen-Anhalt) and their more recent counterparts (Baden-Württemberg, Bavaria, Brandenburg, Hamburg, Hesse, Mecklenburg-Vorpommern, Lower Saxony, North Rhine-Westphalia, Rhineland-Palatinate, Saxony, Schleswig-Holstein, Thuringia) share a number of common basic elements.

### Classification of garages acc. to their useful surface area

1. Small garages: up to 100 sq.m.
2. Medium-sized garages: 101 – 1000 sq.m.
3. Large garages: > 1000 sq.m.

All garage ordinances stipulate that enclosed medium-sized and large garages must be equipped with powered air exhaust systems. At the same time, such garages are required to have large, appropriately distributed make-up air inlet openings. Where adequately sized openings of this type cannot be provided for structural reasons, powered air supply systems must be provided as well.

However, under specified conditions, the ordinances allow natural ventilation, not only for open but also for enclosed-type large garages, if such systems are designed to ensure a consistent and adequate cross-ventilati-

on or if the expected volumes of access and exit traffic are small enough to generate CO loads that will not exceed a certain low (defined) limit.

The stipulated basis of assessment for all cases (i.e., enclosed and open-type large garages) is that the mean volumetric concentration of carbon monoxide in the air, taking into account expected peak traffic loads, will not exceed 100 ppm (equivalent to 100 ccm per m<sup>3</sup>).

Definitions of the mean value, and of the measuring technology to be employed, vary between ordinances.

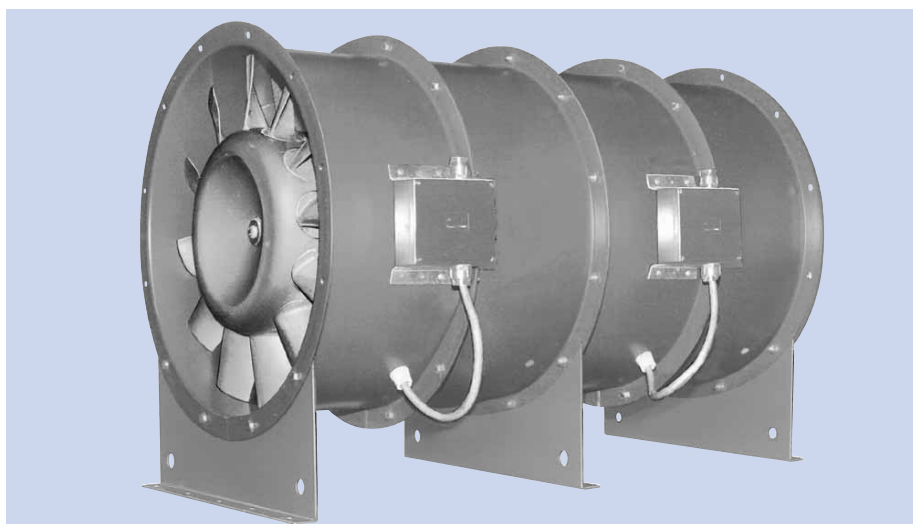
Thus, the garage ordinances following the older pattern stipulate that readings must be taken over one hour at a point situated 1.50 m above floor level. Under the other ordinances, except for that of Hesse, the mean value is usually calculated over 30 minutes (so-called "half-hour mean"). As a common feature, readings must generally be taken continuously over a period of at least one month.

The requirements on enclosed garages are generally deemed to be fulfilled if the powered air exhaust system extracts an hourly volume of

- at least 6 m<sup>3</sup> per sq.m of useful garage surface area in the case of garages with low access/exit traffic;
- at least 12 m<sup>3</sup> per sq. m. of useful garage surface area in the case of all other garages (with the exception of Hesse, which stipulates an hourly 50 ppm threshold and 8 m<sup>3</sup> or 16 m<sup>3</sup> of extracted air, respectively, per sq.m.).

Where particularly high traffic peaks are encountered regularly, evidence of compliance with these performance demands on the air exhaust system may have to be submitted.

Throughout Germany, enclosed garages with more than low levels of access and exit traffic must be equipped with CO measuring, control and warning systems. As a rule, these CO monitoring devices will issue an alarm when the CO concentration begins to exceed 250 ppm.



Type ZAXN 12/56/500 two-stage axial-flow garage smoke exhaust fan

This alarm is given in conjunction with an instruction to motorists to turn off engines and to leave the garage without delay. One exception is Hamburg, where a response is made mandatory if the half-hour mean rises above 100 ppm. Hesse defines air CO levels of 85 ppm over 15 minutes as its alarm criterion.

The process technology of powered air exhaust systems has remained unchanged:

- Each ventilation system must comprise at least two equally sized fans which will jointly deliver the specified overall volume flow when operating concurrently.
- Each fan in a powered air supply or air exhaust system must run on its own power circuit to which no other equipment is connected.
- Each branch or auxiliary circuit of a powered air supply or air exhaust system must be designed such that an electrical fault will not result in a failure of the entire ventilation system (Bavarian Garage Ordinance).
- If the ventilation system is intended to operate temporarily on a single fan only, the fan circuit must be designed such that if one fan fails, the other will come automatically on stream.

#### Preventive fire protection - government regulations

A comparison of the safety standards enshrined in older and more recent garage ordinances initially reveals a coincidence in the maximum useful surface areas allowed per fire compartment or smoke zone on underground and above-ground enclosed garage levels. (For open garages, only the older ordinances specify useful surface areas per fire compartment and level). Limits are imposed as follows (e.g., in the Saxonian Garage Ordinance, section 11):

- for above-ground enclosed garages: 5000 sq.m per level
- for other enclosed garages: 2500 sq.m. per level

More recent ordinances (e.g. the Garage Ordinance of North Rhine-Westphalia, section 11) allow smoke zones to extend to several building levels. Needless to say, fire resistance ratings for the walls which partition the garage into fire compartments are specified in all ordinances.

Importantly, an enlargement of fire compartments or smoke zones to almost twice their size is deemed acceptable. The installation of automatic fire extinguishing equipment is mandatory if, and only if, this option is used. Further, section 9 of the Garage Ordinance of Baden-Wuerttemberg states some interesting alternatives in this context:

Smoke zones may be extended to a maximum of twice their size if they comprise the following features:

1. smoke and heat exhaust openings or shafts (having a total unobstructed cross-sectional area of 1000 cm<sup>2</sup> per garage parking space, and set no more than 20 m apart);
2. powered smoke and heat exhaust systems;
3. automatic fire-extinguishing equipment with spray nozzles distributed

Max. temperature load	300°C
Exposure duration:	60 min.
Air change rate:	10 / h
Max. volume flow	70.000 m <sup>3</sup> /h
<small>(in Baden-Wuerttemberg only)</small>	
Withstand time of electrical wiring	60 min.
Over and above the foregoing, a sufficient supply of make-up air must be ensured.	

over the surface area (this last provision also appears in other garage ordinances).

In Baden-Wuerttemberg, empirical observations gathered by fire-fighting organizations (refer also to the discussion below) have led to the adoption of the following provision (section 9):

“Where garage levels of buildings not exclusively dedicated to parking use

are located more than 4 m on average below the natural ground surface, smoke zones may be increased to twice the stipulated size only if

- powered smoke and heat exhaust installations **as well as** sprinkler systems are provided, or
- smoke and heat exhaust openings/shafts are provided **in addition to** sprinkler systems. “

Additional general provisions concerning the use of fire-extinguishing systems and smoke/heat exhaust installations are set forth in a separate section. Naturally, the latter is of specific interest to manufacturers of automatic fire-extinguishing installations (i.e., sprinkler systems) and of powered ventilation and smoke/heat exhaust equipment (i.e., centrifugal and axial-flow fans). Here again, a comparison between older and more recent garage ordinances reveals a number of differences, as well as some variations between the provisions of the more recent ordinances themselves.

Thus, the Garage Ordinance of Berlin (considered here as a representative of the older type of ordinance) stipulates in section 16 that large garages situated on parking levels below the building's uppermost basement floor must have automatic fire-fighting systems with spray nozzles distributed throughout the garage, such as sprinkler installations.

Moreover, standards are imposed with regard to the distribution of wall hydrants and the availability of fire extinguishers.

However, some of the more recent garage ordinances contain certain restrictions regarding the use of automatic fire-extinguishing equipment.

First of all, these ordinances (e.g., the Garage Ordinance of Hamburg, section 15) likewise contain the requirement that only large garages on building levels situated more than 4 m (on average) below the natural ground surface (“Large underground garages” within the meaning of section 17 of the North Rhine-Westphalian Garage Ordinance, or “Levels be-



low the first underground floor” within the meaning of section 15 of the Bavarian Garage Ordinance) must have automatic fire-extinguishing systems with spray nozzles distributed over the surface area.

However, this stipulation applies only to buildings not intended exclusively for garage use. Fire-extinguishing systems are not deemed mandatory if the garage is unconnected to building levels dedicated to other uses. Under the Bavarian Garage Ordinance, the type of fire-extinguishing system to be installed must be coordinated with the fire brigade on a case-by-case basis. On the other hand, the existence of wall hydrants at prescribed points of the stairwell enclosure is mandatory in medium-sized and large garages. Fire extinguishers are, or may be, specified.

With regard to powered smoke and heat exhaust systems, the Garage Ordinance of Baden-Wuerttemberg (section 14), contains the following supplementary clause:

“In buildings not exclusively dedicated to parking use, the parking levels of large garages having a floor situated more than 4 m on average below the natural ground surface, the alternative requirements set forth earlier in the section on “Doubling of Smoke Zones” shall be met separately, i.e with regard to

- smoke or heat exhaust openings or shafts;
- powered smoke and heat exhaust systems; or
- sprinkler systems.”

A number of ordinances enacted or revised later than the Garage Ordinance of Baden-Wuerttemberg also contain specifications for powered smoke and heat extraction systems. The following alternative may be cited here by way of example:

Enclosed large garages must have defined smoke and heat exhaust openings (1000 cm<sup>2</sup> per parking place, max. distance between openings: 20 m) connecting to the outdoors, or else be equipped with powered smoke

State	Publication	Version	Available from
Baden-Wuerttemberg	Law Gazette of the State of Baden-Wuerttemberg (Gesetzblatt für Baden-Württemberg - GB)	Garage Ordinance (GaVO) dated September 13, 1989	Staatsanzeiger für Baden-Württemberg GmbH Breitscheidstr. 69 70176 Stuttgart Phone 07 11/6 6601-32/39 Fax 07 11/6 66 01-34
Bavaria	Bavarian Law Gazette (Bayrisches Gesetz- und Verordnungsblatt BGVBL)	Garage Ordinance (GaVO) dated November 30, 1993 (spring 1998 edition stipulates exclusive use of accredited experts for inspections)	Max Schick GmbH Druckerei und Verlag Karl-Schmidt-Straße 13 81829 München Phone 0 89/42 92 01-02 Fax 0 89/42 84 88
Berlin	Law Gazette for Berlin (Gesetz- und Verordnungsblatt für Berlin)	Garage Ordinance (GaVO) dated December 12, 1973	Kulturbuch-Verlag GmbH Sprosserweg 3 12351 Berlin Phone 0 30/6 61 84 84 Fax 0 30/6 61 78 28
Brandenburg	Law Gazette for the State of Brandenburg (Gesetz- und Verordnungsblatt für das Land Brandenburg - GVBl)	BbgGSStV dated October 12, 1994	Brandenburgische Universitätsdruckerei und Verlagsgesellschaft Potsdam mbH Karl-Liebkecht-Straße 24-25 14476 Golm b. Potsdam Phone 03 31/5 68 90 Fax 03 31/56 89 16
Bremen	Law Gazette of the Free Hanseatic City of Bremen (Gesetzblatt der freien Hansestadt Bremen - Brem. Gbl)	BremGaVO dated November 10, 1980	Verlag Carl Ed. Schünemann KG Zweite Schlachtpforte 7 28195 Bremen Phone 04 21/3 69 03 71 Fax 04 21/3 69 03 39
Hamburg	Hamburg Law Gazette (Hamburgisches Gesetz- und Verordnungsblatt - GVBl)	Garage Ordinance (GarVO) dated April 17, 1990/ Amendment of November 20, 1994 (combined in a special offprint, 1995)	Lütcke & Wulff Buchdruckerei und Verlag Heidekampsweg 76 B 20097 Hamburg Phone 0 40/2 35 12 90 Fax 0 40/23 27 86
Hesse	Law Gazette of the State of Hesse (Gesetz- und Verordnungsblatt für das Land Hessen- GVBl)	Garage Ordinance (GarVO) dated November 16, 1995	A. Bernecker Verlag GmbH Unter dem Schöneberg 1 34212 Melsungen Phone 0 56 64/94 90 30 Fax 0 56 64/94 80 40
Mecklenburg-Vorpommern	Law Gazette of Mecklenburg-Vorpommern (Gesetz- und Verordnungsblatt für Mecklenburg-Vorpommern)	Garage Ordinance (GarVO) dated November 10, 1993	cw Obotritendruck GmbH Schwerin Münzstraße 3 19055 Schwerin Phone 03 85/55 85 20 Fax 03 85/55 85 222
Lower Saxony	Law Gazette of Lower Saxony (Niedersächsisches Gesetz- und Verordnungsblatt - GVBl)	Garage Ordinance (GarVO) dated September 4, 1989	Schlütersche Verlagsanstalt und Druckerei Hans-Böckler-Allee 7 30173 Hannover Phone 05 11/85 40-430 Fax 05 11/85 50-400
North Rhine-Westphalia	Law Gazette for the State of North-Rhine-Westphalia (Gesetz- und Verordnungsblatt für das Land Nordrhein-Westfalen- GVBl)	Garage Ordinance (GaVO) dated November 2, 1990 Amendment dated January 1, 1996	August-Bagel-Verlag Grafenberger Allee 100 40237 Düsseldorf Phone 02 11/96 82-241 Fax 02 11/96 82-229
Rhinland-Palatinate	Law Gazette for the State of Rhineland-Palatine (Gesetz- und Verordnungsblatt für das Land Rheinland-Pfalz - GVBl)	Garage Ordinance (GarVO) dated July 13, 1990 Amendment dated July 16, 1997	Landeshauptarchiv Rheinland-Pfalz Karmeliterstraße 1-3 56068 Koblenz Phone 02 61/91 29-158 Fax 02 61/91 29-112
Saarland	Official Gazette of the Saarland (Amtsblatt des Saarlandes - Amtsbl)	Garage Ordinance (GarVO) dated August 30, 1976 (June 1995 and 1997 building law amendments to be taken into account)	Verlag Rauaiser GmbH St. Johanner Markt 30 66111 Saarbrücken Phone 06 81/3 79 18-0 Fax 06 81/3 79 18-50
Saxony	Saxonian Law Gazette (Sächsisches Gesetz- und Verordnungsblatt)	SächsGarVO of January 17, 1995	Sächsisches Druck- und Verlagshaus GmbH Tharandter Straße 23-27 01159 Dresden Phone 03 51/4 20 31 82 Fax 03 51/4 20 31 86

**Table 1:** Garage Ordinances/Codes in the Federal Republic of Germany (valid as of September 1997)

and heat exhaust systems meeting the following requirements:

- automatic activation in the case of smoke emission;
- max. load withstand temperature of 300 °C during 1 hour exposure time;
- air change rate of 10 / hr;
- electrical wiring systems must remain operative for at least 1 hour under the influence of an exterior fire.

These regulations can be found in the Garage Ordinances of the following German states:

- **Bavaria:** section 15, "Fire-extinguishing equipment, extraction of smoke and heat"
- **Hesse:** section 17, "Fire-extinguishing equipment, extraction of smoke and heat"
- **Thuringia:** section 16, "Fire-extinguishing equipment, extraction of smoke and heat"
- **Saxony:** section 16, "Fire-extinguishing equipment, extraction of smoke and heat" (departing from the above in that it stipulates functional integrity at 300°C, 10 air changes / hr. and 30 minutes withstand time; ventilation equipment may serve for extraction if suitable for that purpose).

Other regulations already impose more stringent specifications on powered air exhaust systems in their "Ventilation" sections (in these cases, the standard section on "Fire-extinguishing equipment, extraction of smoke and heat" merely addresses fire-extinguishing systems).

- **Brandenburg:** section 16, "Ventilation" (conditions correspond to the above, except that an air change rate of 10 / hr. is not mentioned)
- **Hamburg:** section 14, "Ventilation" (no numbers are specified, the text merely states that "powered air exhaust systems must be suitable for ensuring an effective extraction of smoke in the case of fire").

### Discussion and research results

An expert consulting report on the dimensioning and effectiveness of smoke and heat extraction systems for large underground garages with and without sprinkler systems was prepared by the Technical University of Karlsruhe's Fire Protection Technology Unit under a contract of the Institute of Building Technology, Berlin. The report has been available since November 1985 [15].

The study examined the basic case of three burning passenger cars. It is clear from the results that, when it comes to ensuring fire protection, powered smoke and heat exhaust systems and sprinkler installations provide two highly suitable instruments. They are particularly effective when used in combination. Smoke exhaust fans designed for maximum burning rates and hence, maximum smoke volume flows, are less effective in isolation. It is the additional use of a sprinkler system which restricts the propagation of fire and the development of smoke.

It follows that the requirement of section 17 of the Model Building Code [1], stipulating that structures must be designed to facilitate the rescue of humans and animals and effective fire-fighting operations in the event of a fire, is best met by a combination of the two systems.

As noted above in the section on "Preventive Fire Protection", the Garage Ordinances in force in the Federal Republic of Germany prescribe the use of sprinkler systems only in defined cases for large underground garages. This is not fully consistent with the experience and results reflected in the above-quoted consultancy report. The law defines the most economic route, refraining from imposing regulations that would raise safety levels further.

A study has shown that powered smoke and heat exhaust systems, although permitted in all garages, are not a mandatory requirement for this type of structure. On the other hand, the experience of fire-fighting organizations should not be ignored. A case in point is the Garage Ordinance of

Baden-Wuerttemberg, which was the first to envisage smoke exhaust fans as an alternative solution. Other federal Länder have adopted similar clauses (Bavaria, Hesse, Saxony, Thuringia) or raised the severity of standards for exhaust air fans (Brandenburg, Hamburg). The Garage Ordinances of other German Länder do not contain such provisions; it remains for the approving fire brigade to formulate a case-by-case request related to the specific garage project.

### Status of industrial research

Powered smoke and heat extraction systems have become a fixture in preventive fire protection strategies today. The advanced capabilities of the current generation of smoke exhaust fans reflect 20 years of industrial experience. As pointed out elsewhere [16], such fans are used in essentially three forms designed as centrifugal or axial-flow units. Roof-mounting and wall-mounting smoke exhaust fans of the centrifugal type are the most commonly employed devices. In underground garages, the use of axial-flow fans has become standard by now.

These fan ranges for preventive fire applications have been further refined and adapted to improve their performance over their standard-use counterparts. In official testing of smoke exhaust fans, stringent standards were applied from a very early date to ensure compliance with the law in the context of EC-wide harmonization efforts.

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## VDI Guideline versus Laender regulations

*Reader's comment on the article "Powered smoke and heat exhaust ventilation systems for large garages"*

**In HLH 8/98, Prof. Dr.-Ing. Jürgen Apelt and Dipl.-Ing. (FH) Herbert Eidam address the subject of powered smoke and heat exhaust ventilation systems for large garages. HLH reader Dipl.-Ing. Klaus-Dieter Spinzig, Hamburg, misses a reference to VDI Guideline 2053, 2.2 ("Guidelines for the Determination of Outdoor Air Demand") in the authors' discussion of the requisite make-up air volumes. Below, we publish our reader's letter on this subject as well as the authors' response.**

### Letter from Dipl.-Ing. K.-D. Spinzig

I was interested to read your item on powered smoke and head extraction systems for large garages. However, among the air demand calculation modes mentioned early in the article under 'Air throughput of powered air exhaust systems', I find no mention being made of the calculation method for determining outdoor air demand (equal to the air exhaust volume) as described in VDI 2053, 2.2 "Guidelines for the Determination of Outdoor Air Demand". The volume rates obtained by this calculation method are clearly lower, at times by as much as 50 %, than the global values set forth in the Laender codes.

Your article thus fails to identify a significant energy and cost saving potential. I believe that the above facts would warrant a supplement to the "Ventilation of Large Garages" article.

### Reply from Dipl.-Ing. (FH) H. Eidam

First of all, I am grateful for your expert comment. Our subject article is based on the item "Ventilation and Smoke Extraction in Large Garages, Review of Nationwide Regulations" originally published in HLH, vol. 49 (1998) No. 5, pp. 53-58. In this paper, Prof. Dr.-Ing. Apelt addresses the problems springing from the fact that

the building code legislation authority in Germany rests with the individual Länder. According to his survey, a total of 13 Garage Ordinances and Codes of at times varying content are in force in the Federal Republic of Germany.

In his comment, Mr. Spinzig contrasts these regulations with VDI 2053, sheet 1, 8.95 (Air Handling Systems for Garages and Tunnels). The outdoor air demand calculated from these guidelines is much lower, at times by as much as 50%, than the figures given in the Garage Ordinances.

Let me start out with the following two comments:

- The Garage Ordinances and Codes enacted by the federal Länder are law supplementing the Building Ordinance.

- VDI sheets are technical guidelines possessing no legal force.

In the federal states, it is a prerequisite for building approval of air exhaust systems designed to ventilate and extract fumes and smoke from large garages that they conform to the applicable Garage Ordinances and Codes. Consequently, the article referenced above deals exclusively with the Garage Ordinances and Codes of the various federal states. It should be noted, moreover, that the working groups charged with drafting these Garage Ordinances and Codes include experienced representatives of professional fire-fighting organizations.

In Mr. Spinzig's view, the use of the calculation values stated in VDI 2053 would yield a significant savings potential. Needless to say, this potential cannot simply be ignored.

I therefore propose and request that Springer-VDI-Verlag should ask the head of the VDI 2053 editorial team to contact the editors of the Garage Ordinances of the individual federal states with a view to addressing these differences. This would be the only way to harmonize the different calculation values or air flow figures, respectively.