Final Report

STUDY ON THE METHODOLOGY TO ESTABLISH LEAKAGE RATES OF MOBILE AIR CONDITIONERS IN COMMERCIAL VEHICLES (TRUCKS AND BUSES)

(ENV.C.1/2004/SER-LEAKAGE RATES)

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by

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Study how to establish leakage rates of air conditioners of commercial vehicles

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Introduction

In the framework of the EU climate protection goals, a ban on refrigerant R-134a in mobile air conditioners (MACs) of passenger cars (M1) and low-weight Light Commercial Vehicles (N1, class 1) is scheduled from 2011 onwards. In this context, the EU Commission is reviewing the necessity of R-134a in MACs of trucks and buses based on knowledge about their leakage rates, which have to be established first.

In the following report, the contractor of this preceding study on the methodology, Öko-Recherche, outlines for trucks and buses the basic features of two different approaches to establish MAC leakage rates: analysis of service records and extra measurements according to a uniform measurement protocol.

Section 1 shows basic data on commercial vehicles in the EU. After that, in both vehicle segments criteria for representative samples are described (sections 2 and 3). Subsequently, the different empirical data surveying approaches themselves are presented (sections 5 and 6). Section 7 (conclusions) recommends to the European Commission to allow for the two different approaches and undertake two separate studies, one on trucks and another on buses.

Interviews with sector experts in the course of this preparing study, especially the Brussels meeting with representatives of the European automotive industry, their association ACEA, and with experts from the EU Commission on 2 February 2005, as well as the comments of these stakeholders on the draft final report in June 2005[1], lead to the suggestion that the forthcoming empirical studies shall focus on the diversity in MAC design as far as possible. There was general agreement (substantiated by the previous EU-study on MACs of passenger cars), that driving time, mileage per year, or climatic conditions in the EU does not play a major role in leakage.

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[1] Written comments were given by representatives of the companies DaimlerChrysler, EvoBus, Konvekta, MAN, Renault, Scania, Volvo (directly or via ACEA) and by the independent expert Anders Lindborg (Sweden).

1. Basic data on Commercial Vehicles in the EU

To establish a leakage rate representative for the whole EU, the surveyed samples should be designed to mirror the size and composition of the MAC equipped commercial vehicle (CV) fleet in the EU. This is why knowledge about the real CV fleet should be as accurate as possible in order to select the samples before surveying field data as well as to compare gathered data with reality after the surveys in the process of analysis and evaluation.

1.1 CV-Vehicle Categories LCV, HCV, and Buses

Commercial vehicles are defined as those involved in the transportation of goods or the provision of commercial passenger road transport services. This is an extremely diverse market, including vehicles ranging from 1.5-tonne micro-vans to 44-tonne tractor/trailer combinations. Based on weight and end use, it is possible to break the market down into three main sectors:

- light commercial vehicles (LCVs) - goods-carrying vehicles with gross vehicle weight (GVW) less than 3.5 t
- heavy commercial vehicles (HCVs) - goods-carrying vehicles between 3.5 t and 44 t
- buses and coaches - city buses, intercity buses, touring coaches.

By far the largest segment in terms of registrations is light commercial vehicles Category N1 (LCVs) - vehicles weighing less than 3.5 t (GVW). They represent about 1 million units per year in the EU-25 in 2004 (after subtraction of 0.8 million N1, Class 1 LCVs such as Renault Kangoo, Peugeot Partner, etc. that are already subject to the EU directive on phasing out HFC-134a from mobile air conditioning systems).[2]

The other main sector is that of HCVs with annual registrations of 0.33 million units with GVW over 3.5 t (2004). As with LCVs, the market for HCVs can be further broken down into a number of different categories, based on weight and axle configuration. The largest of these segments is that of heavy trucks and semi-trailer tractors over 16 t GVW[3]. These vehicles stand for roughly 70% of all the new HCV registrations over 3.5 t GVW in the EU-25 (ACEA 2005).

Buses and coaches (class M2/M3, i.e. vehicles with more than 9 seats) comprise a small, specialist segment, representing some 25,000 new units over 8 t GVW in 2004.

1.2 Manufacturers and Models

Table 1 shows that the EU market and with that the fleet in principle is supplied by just 11 manufacturers. In 2004, each segment was dominated by seven (European) brands, which are not the same in all segments. Only three manufacturers (Mercedes, Fiat-Iveco, and Renault) are players in each category. PSA, Ford, Opel, VW are exclusively present in the LCV-

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[2] Light commercial vehicles Category N1 are divided into three weight classes. This classification is based on the *Reference Mass*, defined as the mass of the vehicle in running order less the uniform mass of the driver of 75 kg, and increased by a uniform mass of 100 kg. LCV with Reference Weight (RW) ≤ 1305 kg are vehicles of Class 1. Together with Passenger Cars (M1), LCV of Category N1, Class 1, are subject to the EU directive on phasing out HFCs from mobile air conditioning systems as agreed at the meeting of the Council (Environment) on 14 October 2004. See: Proposal of the European Parliament and of the Council.

[3] This mark, not the 12 t border between N2 and N3 vehicles, is used by ACEA statistics.

segment, whereas MAN, Volvo, Scania, DAF are players in the truck and bus sector, partly in form of Joint Ventures. In difference to Passenger Cars, make composition in the CV sector is lucid. This makes it easier to compile a survey sample accounting for every important brand.

Table 1: 2004 Market Shares of Makes in the EU-25 by CV-Segments, in %

	1. LCV (< 3.5 t)	2. HCV (>16 t)	3. Buses (> 8 t) *
Mercedes	8.1	19.9	28.0 (EvoBus)
MAN		14.9	14.5 (Neoman)
Fiat (IVECO)	12.8	11.1	7.2 (Irisbus)
Renault	15.2	11.0	10.4 (Irisbus)
Volvo		15.0	13.0
Scania		12.9	8.5
DAF		13.1	4.5 (VDL-Group)
Peug./Citroen	19.3		
Ford	12.0		
Opel/Vauxhall	7.3		
VW	8.3		
Others	16.6	2.1	13.9

Source: ACEA 2005; NEOMAN 2004. * January – July 2004.

Table 2 shows that even at the level of individual models consideration of all the important vehicles is no problem. (Please note the vehicles exclude buses and are not quantified).

Table 2: 2004 Models of the Leading Brands in the EU-25 by four CV-Segments*

	LCV (< 2.8 t)**	LCV (2.8-3.5 t)***	HCV (16-26 t)	HCV (18-41 t)
Mercedes	Vito	Sprinter	Axor	Actros
MAN			M2000	TGA
Fiat (IVECO)	Scudo	Ducato	EuroTech	Stralis
Renault	Trafic	Master	Premium	Magnum
Volvo			FM	FH
Scania			94/114	124/164
DAF			CF	XF
Peug./Citroen	Expert/Dispatch	Boxer/Relay		
Ford	Transit Connect	Transit		
Opel/Vauxhall	Vivaro	Movano		
VW	Transporter	LT		
Japan/Korea	4 models	4 models		

Source: Internet; VDA 2004. * w/o buses/coaches. ** Identical to N1, Cl. 2. *** Identical to N1, Cl. 3.

The variety of models is of manageable size in both the LCV and the HCV segments.(Buses and coaches, where the situation is a bit different, are considered later, in section 3).

Table 2 shows, that in the LCV sector (N1 classes 2/3) only 14 different models from seven EU carmakers represent more than 80% (cf. Table 1, col. "LCV < 3.5 t") of the 2004 market.

In the medium and heavy HCV segment over 16 t GVW each of the seven major manufacturers is represented with two models so that the total number likewise is 14.

2. Selection of a Representative Truck Sample

2.1 Exclusion of Light Commercial Vehicles from the survey

Stringent consequence of a primarily technical or design-related approach (see introduction) is the exclusion of LCVs from the upcoming survey. For, LCVs of the Transporter type (category N1, class 2/3, and the lower range of N2 up to 6 t) and passenger cars (PCs of N1, class 1) are of the same kind in essential technical features. Truck experts (e.g. Pochic 2005) point out that LCVs use PC technology not only in the drive, i.e. engines derived from PC programmes (displacement below 3 litres; rated speed below or equal to 3,800 rpm).

The experts at the Brussels meeting noted that likewise the MACs of LCVs are essentially the same as for PCs in that all components of the refrigeration circuit are affixed to the vehicle front section, and the refrigerant piping gets by on a minimum stretch of flexible lines. Thus, the leakage rates established in the earlier study could be transposed to LCVs (Minutes 2005).

2.2 Only Trucks over 6 t GVW of relevance for the survey

This is otherwise for trucks from roughly 6.5 t GVW upwards (upper range of N2, complete category N3). Different to PCs and LCVs, their drive is based on diesel engines with fewer revolutions per minute (< 2,200 rpm rated speed) and higher displacement (from 4 litres up to over 16 litres). The crucial factor for MAC design of EU trucks in difference to LCVs/PCs is, however, that the driver's cabin is not behind the engine compartment but sits above it. This makes movable ("tilting") cabins necessary, and consequently the MAC system requires fairly long refrigerant lines (4-5.5 metres), with comparatively long stretches (> 30%) of flexible hoses to connect compressor with chassis-mounted condenser and cabin-integrated evaporator (DCAG 2005a; Minutes 2005).

Manifestly longer flexible lines, significantly higher refrigerant charges, and with that the likelihood of leakage higher than from passenger cars require special empirical investigation into MAC leakage from trucks over 6 t GVW.

2.3. Concentration on MAC-equipped Trucks over 16 t

In 2004, the total of new registrations of literal trucks (> 6/6.5 t) in Western Europe amounted to 301,600 units (DC 2005). The number includes 232,000 or 77% medium and heavy trucks > 16 t (ACEA 2005) and only 23% light trucks (6.5 - 16 t). Since the MAC equipment rate of trucks over 16 t is about 2.5 times higher than of light trucks below 16 t (80% to 30%, in 2004), heavier trucks represent some 90% of the EU wide truck MACs in operation.

Therefore, the survey on truck MAC leakage should concentrate primarily on vehicles over 16 t GVW without taking a notable risk of a bias.

The light truck models (6/6.5 - 16 t) with low MAC quotas not considered this way are, according to internet research, Eurocargo (IVECO), Midlum (Renault), LF (DAF), Atego (Mercedes), L2000 (MAN), and FL 6 (Volvo).

2.4 Truck Sample by Makes and Models

The EU-study on PC-MACs has shown that for all fundamental identity in design there were wide differences in leakage rate by makes. A suchlike result cannot a priori be ruled out for truck MACs. Therefore, the relevant truck makers should be represented in the sample as far as possible with the share they really have in the market (table 1, col. 2) or, better, with their real share in the EU wide inventory of MAC equipped vehicles. The latter necessitates inquiries about truck makers' sales into the EU market over the last couple of years – in units of vehicles with and without MAC.

Ideally, the study should not only strive for an adequate make composition but also for a realistic model mix between medium and heavy trucks (GVW > 16 t). This means that at the maximum 14 different models from seven manufacturers (see table 2, right columns) come into consideration. (For comparison, the EU study on PC-MACs dealt with 102 models from 21 manufacturers.)

2.5 Construction trucks

Truck makers estimate the share of construction trucks in the overall truck inventory at about 30% (DC 2005). Their conditions of use are so extremely different from trucks applied in long haulage or delivery traffic that different leakage rates of their MACs would not be surprising. Usage patterns, driving time, mileage per year, or climatic conditions may not play a major role in MAC leakage in the EU. This statement, however, relates to road-going vehicles like passenger cars, buses, and most of the trucks. It is not yet tested for partly off-road conditions, and therefore it seems to be useful to include construction trucks in the survey, the more so as 30% of the inventory is not at all a negligible magnitude.

3. Selection of a Representative Bus Sample

Strictly speaking, buses and coaches comprise all the vehicles with more than nine seats below 5 t GVW (M2) and over 5 t GVW (M3). According to ACEA, more than 32,300 vehicles of this kind were new-registered in Western Europe, in 2004. Similar to trucks, neither the usual borderline between M2 and M3 class (5 t), nor the ACEA marks (> 3.5 t, > 16 t) are qualified to define the scope of literal buses. As a matter of principle, the latter are vehicles with rear-mounted engine with GVW from about 8 t upwards (MAN 2005). In 2004, about 25,600 buses and coaches of this type were new-registered in Western Europe (Setra 2005), making up about 80% of all M2/M3 vehicles. The overall sector for buses and coaches can be split with equal shares into city buses, intercity buses, and coaches (EvoBus 2005).

3.1 Exclusion of Mini-Buses from the Survey

Light buses below 8 t GVW, which represent 20% of the overall market, are called minis. They all have in common front engines, and their MACs are of LCV design. In fact, mini buses are essentially LCVs (N1, class 2/3, and N2, lower range) adapted to be used for passenger transportation (M2). Manufacturers and models are the same as shown in table 2: Mercedes Sprinter, Ford Transit, Renault Master, etc. In the upper mini range, M3 vehicles like Iveco Daily/Renault Mascott and Mercedes Vario should be mentioned. MACs of mini buses are LCV-MACs, and in that finally PC-MACs (see chapter on trucks). Thus, the leakage rates of PC-MACs established in the EU study can be transposed to mini-buses.

Admittedly, unlike usual PCs, the majority of mini buses have a second evaporator, which requires additional piping and additional refrigerant (Borgert 2005). Therefore, the leakage from minis must be assumed higher than from passenger cars. Nevertheless, the upcoming survey on buses should focus on leakage rates of vehicles with bus-specific MAC design.

3.2 Main features of MACs of buses over 8 t GVW

MACs of buses > 8 t differ from truck-MACs firstly in that their compressor is rear-mounted.

Secondly, purpose of a bus MAC is air conditioning of the whole passenger compartment including the driver's place in the front. Thus, its size and design is influenced by length and volume of the bus body. In contrast, a truck MAC is destined for the driver's cabin only, and variation in volume and length of the bodywork does not affect its size and function.[4]

Thirdly, suppliers of MACs for buses (see table 3, col. 3) are different from MAC suppliers for trucks who in turn are identical with the MAC suppliers for PCs and LCVs. None of the specialist suppliers of bus MACs is active in the PC or truck MAC sector. Some of them, however, deliver cooling aggregates for refrigerated vehicles where, similar to buses, large volume bodywork has to be cooled down, too. (Bus MAC Survey 2005).

In bus bodies, distances between the main components of the refrigeration circuit are long and so are their connecting lines. At the minimum, piping must be laid from rear (compressor) to the front (driver's place evaporator) and back, so that 20 metres is the minimum line length in

[4] According to MAN (2005) and EvoBus (2005), since 2000 in the city-bus sub-segment (only there) about 10% of new vehicles have not been equipped with MACs for the whole bus but only with much smaller systems for the driver alone. The semi-hermetic compressors of these MACs are electrically driven, i.e. not by the rear-mounted engine; thus refrigerant piping is short and presumably less emissive. Although MACs of this kind should be kept in mind they are of minor importance for a study on leakage rates of literal buses.

short buses. Clearly, 18 metres long articulated buses need at least twice the piping and refrigerant charge of 8-metre solo buses, under otherwise unchanging conditions.

3.3 The five main technologies for Bus MACs

Apart from bus length varying from 8 to 15 metres (solo) and even 18 metres (articulated), the main leakage risk factors like piping length, number of connections, refrigerant charge depend on the specific MAC technology applied. Currently, there are five technologies in use (Bus MAC Survey 2005). Table 3, col. 4, contains an estimate of their individual market shares.

1. By far mostly used for city buses, intercity buses, and coaches are systems with condenser and evaporator fitted to the rooftop, with partly flexible refrigerant lines connecting rooftop unit to (vibrating) compressor. From the rooftop unit, evaporator-cooled air is blown through the right and left air duct to the passengers. Overall piping length is 10, 20 metres, and a similar line length once again for air-conditioning the driver's place in the bus front (liquid line from rooftop condenser to driver place evaporator, suction line back to the compressor).[5]

2. Articulated city buses usually are fitted with two rooftop units. Differently to the condenser-evaporator-unit on the roof of the rear section, the roof unit on the front section includes only evaporators (no condensers). A big challenge to engineers is bridging the articulated joint between rear and forward section. Here, flexible hoses must be applied, which always raise the leakage risk (Sonnekalb 2005).

3. For some luxury coaches, split systems are applied with the MAC unit being invisible from outside. The condenser is mostly placed in the luggage compartment. From there, two lines (in case of double-deckers twice two lines) run forward and back through the air channels in order to provide an array of integrated evaporators with refrigerant. Against rooftop units where cool air is blown forward through the air duct, split-evaporators require additionally laid piping and more connections, increasing refrigerant charge (up to 25 kg) and leakage risk.

4. Compact rear fitted MACs as applied for selected coaches (single and double-deckers) do not need space on the roof, either. Condenser and evaporator are installed above the engine compartment, and cool air is blown from there forward through the air cannels. This system gets by on relatively short lines and little refrigerant for the primary circuit. Long refrigerant lines to the driver's place, however, are still necessary (MAN 2005; Bus MAC Survey 2005).

5. Since 2001, some bus makers use water chillers for coach MACs. Instead of refrigerant, cold water circulates through lines between a compact compressor-condenser-evaporator unit in the engine compartment and a number of heat exchangers on top of the passenger compartment, substituting split evaporator systems as described sub 3. The cold water also cools down the driver's place, so that the whole system can do with just some 5 metres piping (50% of which is non-metallic) and 4.5-6.5 kg refrigerant. (DCAG 2005b, MAN 2005)

3.4 High leakage risk due to long piping and numerous connections

Although there are different Bus-MAC technologies in operation, they all have in common:

- Long refrigerant lines (from 20 to 60 metres; only 5 metres by way of exception)
- High share of flexible hoses in piping (sometimes more than 30%)

[5] The MAC unit often sits on the roof over the rear axle. There is, however, a tendency to fit it more forward on the roof for better weight distribution amongst the axles. This requires longer refrigerant lines.

- Large number of connections
- High charges of refrigerant (from 5 to 25 kg).

Such systems are inherently susceptible to refrigerant leaks, predominantly from permeation through refrigerant hoses, braze/mechanical joints, and compressor shaft seals. Leakage rates far in excess of the passenger car level must be expected. The risks of refrigerant loss raise manifest with rising length of pipes and growing number of joints. Therefore, the survey sample in the bus-segment must consider, amongst others, variations in MAC design as far as different piping and hoses length and numbers of connections are concerned[6].

3.5 Criteria for sample composition

A fundamental request for the upcoming empirical survey is to consider adequately the varying MAC design as described above (sub 3.3) and in table 3 (with market shares). For, should the study bring different levels of leakage rate to light, the possibilities must be given to check the expert hypothesis of the connection with differences in design. Admittedly, inclusion of technology No. 5 (water chillers) is difficult as its use is still in its infancy so that a sample without it is nevertheless acceptable.

Concentration on design-related effects does not mean to ignore the existence of different bus makers[7] as well as different MAC suppliers on the EU market. It is, however, the position held in this study on methodology that possible differences in leakage rates by bus makers and MAC suppliers are of minor importance compared with differences by design. All the bus makers use MACs from the five European suppliers (table 3, col. 3) who in turn are in principle capable of providing every technical solution. It might be satisfactory for the sample to consider the most important makers of buses and of MACs (see table 3). After all, the representation of more than two relevant bus makers and MAC suppliers suffices to cover the majority of MAC-equipped buses (see table 3, col. 1, and 3).

However, it should be insisted upon considering all the three bus segments: city buses[8], intercity buses, and coaches. This demand seems to conflict with the perception that in the EU the usage pattern of road-going vehicles is of minor importance for MAC leakage – as it is likewise assumed for climatic, mileage, or driving time differences. The three bus segments, however, do not stand for three different application conditions for otherwise identical vehicles. In fact, the three bus classes vary in technical properties, especially bodywork (single or double decks, height of passenger deck above ground level, etc.) and interior equipment (constructed with areas for standing passengers or not, etc.). As table 3 shows, some MAC technologies are exclusively attributable to particular bus segments (two-rooftops to city buses, integrated split and compact systems to coaches). Consequently, connections between bus segment and MAC leakage rate cannot be excluded, and should be examined.

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[6] This was also a recommendation from the ACEA experts at the Brussels meeting on 2 Feb. 2005 (Minutes 2005). Even bus-MAC suppliers estimate annual (regular) loss at minimum 500 grams (Bus MAC Survey 2005). Recently – at a Washington Forum - an estimation of more than 2 kg/yr. was presented (Repice/Schulz 2004).
[7] In the first line, the bus makers in table 3, col. 1, are manufacturers of chassis, who sell them partly to independent bodybuilders for completion under different make. Statistically, all finished buses are attributed to chassis-manufacturers whoever the bodybuilder was. It should, however, be borne in mind that a relevant fraction of EU-manufactured buses (about a quarter) is fitted with bodyworks from manufacturers not listed in table 3. The consequences for MACs that are installed by external bodybuilders are not deepened here.
[8] In table 3, col. 2, the famous London or Berlin double-deckers are not at all overlooked in the city bus segment. Their air-conditioning, however, is first in the very beginning. There are, however, air-conditioned double-deckers in the coach segment (with compact or split rear-fitted MAC systems) to consider.

Table 3: Matrix New Buses and Coaches > 8 t GVW in the EU 2004 (25,600 Units). Estimates of Markets Shares by Öko-Recherche

1. Bus Maker (Market Share)	2. Bus Segment (Market Share)	3. MAC Supplier (Market Share)	4. MAC-System (Market Share)
EVOBUS (28.0%) - Mercedes (19%) - Setra (9%)	City-Bus* (33%): Solo (23%)	Carrier-Sütrak (40%)	**Standard Rooftop** (~77%) (City-Bus, Intercity-Bus, Coach)
IRISBUS (17.6%)	City-Bus* (33%): Articulated (10%)		
NEOMAN (14.5%) - MAN (10.5%) - Neoplan (4.0%)	Intercity-Bus (33%)	Webasto (30%)	
VOLVO (13.0%)			
SCANIA (8,5%) - Omni City/Interc. (4%) - Irizar Coaches (4,5%)	Coach (33%)	Konvekta (20%)	**Two-Rooftop** (< 8%) (Articulated City-Bus)
Dennis (5,5%)	mostly single-decker, few double-decker		**Compact Rear-Fitted** (Coach) (4%)
VDL Bova (4.5%)		ThermoKing (6%)	**Compact Water Chiller** (Coach) 4%
van Hool (3.0%)			**Integrated Split** (Coach) 8%
Solaris + Others (5.4%)		Hispacold (4%)	

- * Please note, this is the number of new registered buses, not of MAC equipped buses. The MAC quota of city buses is still substantially lower than of intercity buses and coaches where it is near to 100%.
- In each column, sub-sections exclusively show parameter-specific market shares of this column alone. The same level in different columns does not indicate interconnection of different sub-sections with each other.

4. Methodological Remarks preceding Surveying Proposals

In the previous sections, minimum data requirements for representative samples were described, both for trucks and for buses. Section 5 and 6 will set out how the two empirical surveys on leakage rates shall be practically implemented. Beforehand, three methodological issues in conjunction with leakage rate establishment shall be briefly discussed.

The leakage rate is generally defined as "grams of HFC-134a that have leaked in one year from a vehicle with air conditioner" (EU Commission). Both surveys shall be guided by the proven distinction of use phase emissions into regular and irregular emissions (Schwarz 2001; Schwarz/Harnisch 2003).[9]

4.1 Simple top-down method of limited use

No doubt, a simple relation of the annual refrigerant consumption (in kg) of a service shop to the total of MACs of its clearly delimited truck or bus pool results in a figure "grams per year and MAC" and with that in a kind of use-phase leakage rate. The high degree of aggregation, however, excludes conclusions on leakage rate determinants so that this figure is of limited use. Differentiated analysis as postulated in this study on methodology, demands vehicle-specific data collection and insofar a "bottom-up" instead of a "top-down" approach.

4.2 Refills do not always properly indicate emissions

An additional drawback usually associated with top-down-approaches is indirect determination of emissions by means of data on compensating refrigerant refills. One should be aware that in the automotive MAC sector (PCs and trucks) gradual refrigerant loss usually remains undetected over years so that its eventual top-up cannot act as indicator for emissions. Systematically, even complete records on top-ups produce an incomplete picture of (regular) emissions, so that the data evaluation would result in figures of little use.

The situation is otherwise for buses. Air conditioning is not only likely to be much leakier (see 3.4) but its proper work is also much more essential for bus operators as it belongs to the service passengers pay for. Controls and regular top-ups take place in so short intervals that time lag between refrigerant loss und effective refills is acceptably short (on average half a year) in case of regular loss, and practically not existing in case of irregular leakage.

4.3 Twice-measuring approach not feasible

From industry representatives the proposal had been brought forward to compile in the bus and the truck segment an EU representative fleet of some 150 vehicles each (reflecting different makes, models, age, climatic regions, etc.) and to measure the refrigerant in each single MAC. After one year of normal use, the same 300 vehicles should be measured again, so that the then determined refrigerant deficits could straight be used for establishing annual leakage rates.

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[9] “Regular leakage” takes place gradually from undamaged, intact MACs. This is quite different to "irregular emissions", attributable to system failures caused by internal and external reasons, often by accidents.

This study on methodology does not recommend such an approach that is, admittedly, charming at first glance. However, conditions applicable to a couple of selected prototypes cannot directly be transposed to some hundreds of vehicles. Apart from the minimum survey duration of a whole year, extremely high input of work force in logistics were necessary to accompany two heterogeneous fleets over a year and to bring the same vehicles to second measurement.

More important is that the uncertainties associated with the existing EU Measurement Protocol, which make it necessary to deal only with MACs in use over 12 months, would become unacceptably grave if two instead of one measurement had to be carried out within 12 months. Laboratory-like measurements according to the type of tests to control the Measurement Protocol at the Volkswagen AG (see Schwarz/Harnisch 2003, 11) could help and provide sufficient accuracy. The cost per one vehicle, however, would be about 40 times higher than with the existing Measurement Protocol.

5. Measurement-based Survey on MACs of Trucks over 16 t (at least 6 t)

As with MACs of passenger cars (PC), the refrigerant charges are too small to make service recording on truck MACs mandatory anywhere in the EU, yet. Thus, perennial vehicle-specific records on MAC refills acting as indicators for emissions cannot be analysed. It is recommended for the upcoming survey on truck MAC leakage rates to apply a method based on one-time measurements as used and proven in the recent EU study on PC MACs.

5.1 Focus on regular leakage rate

Like the PC MAC study, the survey on trucks shall concentrate on "regular leakage". Regular leakage or emission takes place gradually from undamaged, functioning air conditioners. The annual regular leakage rate is derived by relating the refrigerant loss measured (as difference between recovered quantity and standard ex-works charge), to the time (by single months) elapsed since the vehicle's first registration.[10] From the estimates for each individual MAC, an average of the total of different regular leakage rates is calculated.

5.2 Measurement Protocol for truck MACs

The Measurement Protocol developed for PC MACs (see Schwarz/Harnisch 2003, Annex I) was sent to all EU truck makers that participated in the Brussels expert meeting on 2 February 2005 to be commented on applicability for truck MACs (Minutes 2005). The responses were throughout positive. The Measurement Protocol contains specifications on measuring equipment (with weighing a usual service station before and after recovery on external scales as essential), on duration of refrigerant extraction, suction pressure, ambient temperature, parking time of vehicles before measurement, etc. and has to be adapted by the contractor of the upcoming survey to the specific conditions of truck MACs.

One important adjustment which the upcoming study has to implement is assessing the remainder of refrigerant that recovery stations are not able to extract from the MAC system (e.g. being solved in oil). This remainder should be used as correction factor when determining the real refrigerant deficiency in truck MACs. For that, it is recommended here to carry out a couple of test measurements at fresh-filled MACs made available by truck makers.

Yet in the course of this study on methodology, with the help of truck maker DaimlerChrysler preliminary control tests were conducted at young vehicles. The results suggest the method applied is capable of recovering the refrigerant mass from a full truck MAC except for average 25 g (see Annex I to this study). This amount should be verified at completely new vehicles.

5.3 Implementation at several large truck fleets

It was agreed at the Brussels expert meeting that the surveying method for leakage rate of MACs of Heavy Commercial Vehicles (HCV) shall be based on several HCV fleets. Moreover, the sample shall be large enough (about at least 150 units) and shall reflect the EU-

[10] The calculation is done by dividing the difference in grams by the number of months since first registration, and the calculated amount is multiplied by 12.

wide MAC-equipped HCV-fleet by relevant models and make (Minutes 2005). These requirements are in principle the same as sub 2.4 and 2.5 (this study) where the sample composition by makes and models and the consideration of construction trucks is set out.

In difference to passenger cars, in the HCV segment over 16 t large vehicle pools of more than 50 units under uniform management are no rarity, particularly not in heavy transnational long-distance traffic of truckage companies. Thus, the contractor of the forthcoming truck survey can fulfil the criteria sub 2.4 and 2.5 with measurements at just 5 to 10 different truck fleets. Unlike passenger cars, there is neither a necessity to carry out measurements at second-hand dealers who do not know much about the previous history of the vehicle pool they are displaying. Winning active fleet operators for the EU measurement programme is, admittedly, a bit more difficult but should not be a real barrier. The truck does not need to be moved, its engine does not need to run, the AC-loop does not need to be opened apart from being joint with recovery stations that extract and refill the refrigerant. After all, each of the measured MACs is gratis checked and topped-up to full charge by an air conditioning expert.[11]

5.4 Truck makers' cooperation necessary

Subsequently to the measurements, in the course of the evaluation of measured and additionally collected data (e.g. date of first registration) cooperation with truck makers gains in importance. Truck makers are the best in know not only about ex-works refrigerant charges but also about additional details of possible relevance.

To eliminate misunderstanding from the start, it must be pointed out that the upcoming study on behalf of the EU Commission first of all aims to establish the EU wide leakage rate of truck MACs in grams of HFC-134a per year. Statistical evaluation concentrates on dependencies of the leakage rate on those parameters that have served as selection criteria for the sample selection such as makes, models, age of vehicle, refrigerant charge, usage pattern (construction trucks!), etc. as listed above in section 2 and being open to the public.

In-depth analysis of the influence of specific MAC design and of technical parameters like compressor type, pipe materials, workmanship of components, tightness of valves or seal rings, etc. is out of the scope of the EU study, as this is clearly a matter of truck and MAC makers themselves. However, like in the case of the study on passenger cars, the Commission offers to give all measured data to the companies if they wish so, so that they can analyse them in terms of their own interest. Naturally, information of individual vehicles will be given only to the manufacturer in question.

At the Brussels expert meeting, EU truck makers and their association ACEA have confirmed their willingness to support the EU measurement programme on truck MAC leakage rate.

5.5 Begin and size of the truck MAC survey

Measurements of refrigerant deficit in truck MACs should begin not before April 2006. First after April, ambient temperatures will be high enough to allow appropriate refrigerant recovery. Facing the variety of makes, the split into medium and heavy models, and the

[11] On the other hand, cooperation with fleet operators is advantageous for the study. Finally, only the operator or the MAC workshop he is frequenting, can know for sure whether a MAC has been refilled or even repaired previously. This may be very useful information in case of doubt.

inclusion of construction trucks in the survey, minimum statistical requirements regarding representativeness can only be met if a sufficiently large number of truck MACs of different age is measured. The study on methodology proposes as minimum number of MAC equipped trucks to be measured 200 units. Clearly, the selection criteria presented in the second paragraph will be met the better the more vehicles beyond 200 can be evaluated.

5.6 Optional estimation of irregular leakage rate of truck MACs

The EU Measurement Protocol is not qualified for establishing irregular leakage rates. For irregular emissions from PC MACs, in 2003 the EU Commission adopted estimates from elsewhere. If the Commission wants to get own estimates of irregular emissions from truck MACs, the following method based on the analysis of respective workshop records is proposed.

Unlike regular emissions, the time lag between occurrence of irregular leakage and refilling subsequent to repair is very small as irregular leakage mostly results in total refrigerant loss and thus to a standstill of the MAC system. Therefore, in principle records on damage-induced refills are suitable for establishing irregular leakage rates.

Three basic conditions must be given:

- One or more clearly delimited fleets of altogether at least 1,500 trucks[12] in a passably EU representative mix of makes and age-groups,

- garages who exclusively repair MACs from the above fleet (or can separate repaired MACs of its vehicles from other vehicles) and keep records on refrigerant recovered and refilled in conjunction with such repair,

- minimum recording period of one year.

These conditions are not at all complicated or hardly to meet. The problem is that owing to the small charges of the MACs (< 2 kg) vehicle-specific refrigerant recording is not mandatory. The contractor of the upcoming survey on truck MACs is faced with following alternative. Either, he succeeds in finding three or four workshops/fleets with voluntary recording of repair-induced refrigerant consumption over at least one year; or he causes three or four above described workshops/fleets to record such cases for the next 12 months.

[12] According to a German study on passenger car MACs (Schwarz 2001) the annual number of MAC-equipped vehicles with irregular leakage may be expected to range between 1 and 4 per hundred. For statistical significance, the reference sample should be distinctly greater than 1,000.

6. Record-based Empirical Survey on Bus MAC Leakage

For truck MACs service records are hardly available, and if they were, their analysis would not result in useful vehicle-specific individual leakage rates. This is contrary to bus MACs where in turn measurements make no sense for establishing regular leakage rates. This is because bus-MACs usually are so frequently serviced (at least once a year) and refilled that non-topped-up systems, the condition for measurements in line with the EU Measurement Protocol, virtually do not exist after more than two years in use since first registration.

The specifics of bus air conditioning, i.e. high leakage and short maintenance intervals (see 4.2), allow refills to be used as largely adequate indicators for emissions.

6.1 Minimum requirements for data in service records

Condition of making use of refills for leakage determination is that every MAC service, whether on schedule or extraordinary, has been recorded not only in proper details and without gaps in dedicated forms but also over a sufficiently long time of (here suggested) at least the past seven years. The criterion "without gaps", i.e. completeness of recording can be met best with vehicles that have always been serviced in the same workshop[13].

Minimum information to be recorded by a shop are (1) identity of the vehicle, (2) date of service, (3) refrigerant mass recovered from the system, (4) refrigerant charged into the system, (5) nature of service (maintenance/repair), (6) kind of fault in case of repair.

Data items additionally required for representative samples as described under 3.5 which are mostly not recorded in service forms (like pipe and hose length, joint number, body length, norm charge, etc.) must be looked up in documents at operator, service shop, bus maker or MAC maker, on the basis of the recorded vehicle identity (VIN, registration number, etc.).[14] In this context, the meanwhile declared intention of EVOBUS, the EU's largest bus maker, of being involved in the survey is welcome and should be considered in the upcoming study.

This way it is possible to establish for individual bus-MACs in use the age in months from first registration until the date of the latest service as well as the refilled refrigerant quantity over that period. Equating refills with emissions, for each individual bus MAC a specific leakage rate per year can be calculated[15]. Understating the annualised leakage rate because of the time lag of 0 to 12 months between emission and refill has to be taken on board and is the more negligible the longer the bus has been operated before its latest service date.

6.2 Aggregate, regular, and irregular use-phase leakage rate

The individual leakage rates obtained this way are figures reflecting the overall use-phase emissions. The latter comprise all regular as well as all irregular leakages to which a

[13] This may be a problem for coaches that in case of leaky MAC faults are far away from their regular record-keeping workshop. Logbooks kept in the coaches themselves can help compensate such systematic gaps if service carried out abroad is actually entered. This is not always the case, according to sector experts.
[14] It should be mentioned that gathering such additional data is time-consuming and requires at least the same expenditure of working force as collection and computer entering of service record data do.
[15] The calculation is done by dividing the total of refills in grams by the number of months since first registration, and the calculated amount is multiplied by 12.

particular bus MAC has been subject over its entire lifetime since first registration. Such an aggregate use-phase leakage rate may suffice for the objectives of the EU Commission.

If, however, service notes clearly identify the nature of MAC services, i.e. distinguish refills into mere top-ups on maintenance and damage-induced charging upon repair, it is possible to establish for each individual bus MAC both a regular and an irregular leakage rate, based on the same service records. Evidently, such a differentiation would constitute additional knowledge of interest and use.

6.3 Quality and selection of service records

In the mid-1990s, first in Sweden and soon after in the Netherlands, for every stationary and mobile installation with a total charge over 3 kg of halogenated refrigerants (incl. HFCs) mandatory annual inspection and service recording was introduced. Since then, qualified service personnel (accredited at SWEDAC in Sweden, at STEK in the Netherlands) have to fill in dedicated record forms for every regular and extraordinary service on bus MACs.

In both countries, at least the following data are recorded: (1) identity of vehicle, (2) date of service, (3) quantity and type of refrigerant drained from the system, (4) quantity and type of refrigerant charged into the system, (5) nature of the inspection, maintenance, repair and installation activities on the system, (6) faults and alarms related to the system[16]. Such a data set is sufficient to find out on its basis all lifetime refrigerant refill into a clearly defined bus MAC on condition that all records from its first to its latest service are kept on the same place.

In Sweden and in the Netherlands, the data records are kept in the workshop that has done the MAC service, in the Netherlands they must additionally be entered in a logbook that is kept near the air conditioning system, i.e. in the bus itself.

Apart from mandatory service records, in some other EU countries, there are sporadic voluntary service records serving the same purpose as mandatory do. For example, following on their records of recovery and charge quantities of CFC R-12, some garages in Germany continue keeping "Record Sheets" for the R-134a refrigerant. Although the law does not require vehicle-specific recording, workshop entries sometimes meet the above listed minimum criteria that facilitate establishing leakage rates for bus MACs.

To meet the criteria for the sample composition outlined sub 3.5, it is strongly advised to use mandatory records from Sweden or the Netherlands, or better from both countries, when performing the empirical survey on EU bus leakage rate. If, however, in other countries equivalent vehicle-specific recording of bus MAC service is available that goes a least seven years back, it can be used alternatively or additionally.

In this connection, a warning shall be given. When selecting recording shops for the empirical survey on bus MACs it must be ensured the refrigerant quantities are handled there with sufficient accuracy. Recovered and refilled quantity should be both measured and entered in increments of at least 0.1 kg, which demands the use of scales instead of naked eye. General intervals of 1 kg and more are not acceptable. When analysing logbooks, a visit of the

[16] In the 1990s in Denmark, a similar control system was introduced for systems with a minimum refrigerant charge of only 1 kg. As the 1 kg threshold also relates to refills, mandatory service records from Denmark do not fit the purpose of the upcoming survey that needs indications also below that mark.

workshop that has made the entries might be useful to get a picture of the accuracy behind the figures.

6.4 Begin and size of the bus MAC survey

The survey on bus MACs could start in the second half of 2005 when the main season in the calendar year for MAC servicing is over. The bus segment is rather inhomogeneous as to the three sub-segments of city buses, intercity buses, and coaches as well as the disparity of MAC technologies, so that minimum statistical requirements regarding representativeness can only be met if a sufficiently large number of recorded vehicles is analysed. The study on methodology proposes as minimum number of MAC equipped buses subject to detailed lifetime examination a total of 150 units. Clearly, that the selection criteria presented in the third paragraph will be met the better the more vehicles beyond 150 can be evaluated.

7. Conclusions

This study on methodology proposes to the European Commission conducting the survey on MAC leakage rate of commercial vehicles in the form of two empirical studies, one on the leakage rate of truck MACs, and another on the leakage rate of bus MACs.

The first shall essentially be based on measurements of regular leakage with an adjusted Measurement Protocol; the second shall be based on the analysis of existing vehicle-specific service records on recovery and charge of refrigerant that go back long enough in time.

The diversity of the two approaches allows it to conduct the study on bus MACs independently from the study on truck MACs with respect to both time and place.

Annex I: Preliminary Truck MAC Control Measurements

Truck MAC Test Measurements at DC-Mettingen on 17 April 2005

Background/Objectives

Within the framework of the climate protection goals of the EU, a ban on the refrigerant R-134a in mobile air conditioners (MACs) of passenger cars is scheduled from 2011 onwards, and in this context the EU Commission is reviewing the necessity of R-134a in MACs of trucks and buses. Therefore, their leakage rates have to be established. Currently, the methodology is being developed how to determine the existing refrigerant charge in MACs of trucks in order to compare it with the initial fill at the assembly plant.

Performance of Measurements/Operation

The measurements were carried out on 17 April 2005 on the car pool area of the Mettingen department of the DC plant Untertürkheim, from 10.00 a.m. to 1.35 p.m. Over this time, ambient temperature was rising from 14°C to 22°C. The car pool administration had made available ten trucks of the current model ACTROS 1844. They originated from the Wörth plant where their MAC had initially been charged with 1,125 ± 15 g (according to information from Wörth). These vehicles had been used in inter-factory traffic since the time from 25.11.2004 (oldest vehicle) to 22.02.2005 (youngest vehicle). The average mileage of the seven measured trucks amounted to 14,133 km.

The measurements took place on request of the EU study contractor, Mr Schwarz from Öko-Recherche. He was present together with his measuring expert Mr Borgert (M-tec) who did the measurements by means of the below mentioned devices (property of the company Waeco). Mr J.P. Pochic (DC - Truck Product Creation), who had not only made possible the measurements but also provided the necessary vehicle data, represented the DaimlerChrysler Company, apart from Mr Schmid, the person in charge of the cars.

1. Determination of Recovered and Un-Recovered Refrigerant Mass

- Measurement of the current refrigerant charge in an R-134a filled MAC.
- Relation to reference values.

2. Measuring Approach

- Access to refrigeration circuit by joining hoses to both service connections.
- Complete extraction of the refrigerant with the aid of a recovery station.
- Weighing of the recovery station with external scales (calibrated), before and after suction extraction.

3. Used Measuring Equipment

- Recovery Station: Make A`GRAMKOW WAECO RHS 650
- Scales: Make SOEHNLE, electronic, gauged, Resolution 10 Grams

4. Vehicle Pool/Results of Measurements

Vehicle Date of First Registration	Regis-tration Number	Vehicle Identification Number (VIN)	Test Vehicle Pool Mettingen +/ - 10 Grams	Default Wörth +/- 15 Grams	Delta to Default Wörth in Grams	Delta to Minimum Wörth in Grams	Delta to Maximum Wörth in Grams
25.11.2004	S-OF 8130	WDB9340621K967852	1020 g	1125 g	- 105 g	- 80 g	- 130 g
25.11.2004	S-OF 8131	WDB9340621K965995	1040 g	1125 g	- 85 g	- 60 g	- 110 g
13.12.2004	S-OF 8521	WDB9340321K974398	1060 g	1125 g	- 65 g	- 40 g	- 90 g
13.12.2004	S-OF 8524	WDB9340321K968096	1070 g	1125 g	- 55 g	- 30 g	- 80 g
15.12.2004	S-OF 8571	WDB9340321K974043	1120 g	1125 g	- 5 g	+ 20 g	- 30 g
04.01.2005	S-OF 8898	WDB9340621K981017	1080 g	1125 g	- 45 g	- 20 g	- 70 g
22.02.2005	S-OF 4741	WDB9340621K969391	960 g	1125 g	- 165 g	-140 g	- 190 g

*Outlier

5.Average Values and Standard Deviations

n	5	6 *	7
$\overline{X}$	1054 g	1065 g	1050 g
s	24 g	34 g	51 g
s/ $\overline{X}$	2.3 %	3.2%	4.9%

* incl. measured 1120 g

Rating

- Statistically, the measured value 960 g must be categorized as outlier.
- The true average value of the sample is 1065 g.
- The deficiency ranges from 5 g to 105 g. Average deficiency is 60 g.

Interpretation

- Given average 5 months since initial MAC filling (acc. to VINs) and considering refrigerant loss from passenger car MACs of about 8% per year (as established in a recent EU study), a meantime loss of 35 g (calculative 37.5 g) is supposed in case of a standard initial charge of 1,125 g.
- Thus, the remainder in the system is [1125 – (1065 + 35)] = 25 g.
- The converse calculation, i.e. assuming a remainder of 25 g in the system and recalculating the meantime refrigerant loss (five months) correlates likewise with the study on passenger car MACs.

Conclusion

- The method applied at Mettingen is capable of recovering the refrigerant mass remaining in a MAC except for 25 g.

Confirming accuracy of measured data as indicated above

Signed by Jean-Pierre Pochic, DaimlerChrysler (TPC/CFH).

Responsible for interpretation

Signed by Dr. Winfried Schwarz, Öko-Recherche, Frankfurt am Main

Annex II: References

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Annex III: Minutes of the Kick-Off-Meeting, Brussels, 2 February 2005

EUROPEAN COMMISSION
DIRECTORATE-GENERAL
ENVIRONMENT
Directorate C - Air and Chemicals
ENV.C.1 - Clean Air & Transport

Brussels, 2 February, 2005
ENV.C.1/MVa D(2005)

Subject: **Minutes of the Kick-Off Meeting Study on the Methodology to Establish Leakage Rates of Mobile Air Conditioners in Light and Heavy Duty Vehicles**

The kick-off meeting was held in Avenue de Beaulieu 5, Brussels on 2 February 2005. List of participants is attached.

1. Opening

Matti Vainio welcomed the participants and explained the objective of the study (i.e. a methodology to establish the MAC leakage rate of commercial vehicles), as required, i.a. in the draft directive of phasing out HFC-134a from passenger cars (under discussion in the Parliament).

2. Presentation of the study

Dr Schwarz, contractor for the study on methodology, presented two different methods of leakage rate assessment, (1) service record approach and (2) extra measurements based on a uniform measurement protocol. He suggested for Light and Heavy Duty Vehicles special measurements to establish a regular leakage (= gradual refrigerant loss from intact systems) – in the same way as was carried out in the study on measuring the leakage of HFC-134a of MACs of passenger cars. As far as buses and coaches are concerned a different approach could be used. Due to their special MAC design they undergo regular annual maintenance (including check-up on refrigerant level). Thus, it may be possible to use service records of fleet operators or bus-makers to estimate the leakage rate.

3. Discussion

3.a Exclusion of Light Commercial Vehicles from the study

The ACEA experts noted that the MACs of Light Commercial Vehicles (LCV) of category N1, Classes 2 and 3 are essentially the same as for passenger cars. Thus, the leakage rates established in the earlier study can be transposed to N1 Class 2/3. However, some of the N1 Class 2/3 vehicles are not based on the (fixed) passenger vehicle concept and thus need more flexible hoses between the chassis and the body. Thus, the leakage rate of passenger cars is slightly understating the leakage rate of N1 Class 2/3. However, the difference is likely to be so small that it would not be meaningful to repeat the measurements. N2 (3.5t-12t) are a very small class and are either based on N1 or N3 concepts.

Thus, it was agreed that the methodology should be developed only for Heavy Duty Vehicles (mainly N3) and Buses/Coaches (mainly M3).

3.b Issues concerning HDVs and Buses/Coaches

The main reason for focussing on N3 and M3 was that the MAC design was likely to result to a different leakage from passenger cars. In the previous study it was noted that the usage patterns, longer driving time, higher mileage per year or climatic conditions in the EU did not play a major role.

Concerning trucks (mainly N3), tilting cabins, introduced to make engines more accessible, require fairly long refrigerant lines (4-8 metres), with some 30% flexible hoses to connect compressors with chassis-mounted condensers and cabin-integrated evaporators.

Concerning buses (mainly M3), lines are longer[17] than in trucks and the refrigerant charges are much higher (e.g. 17 kg). The volume to be cooled is large, the compressors are usually rear-mounted, and condensers and evaporators are far away. It was concluded that the length of lines (number of connections) and flexible hoses was an important issue to consider when developing the methodology for buses.

3.c Methodology of measuring of leakage of MACs of Heavy Duty Vehicles

It was agreed that the surveying method for leakage rate of HDV-MACs should be based on several HDV fleets. The sample should be large enough (about at least 150) and reflect the EU-wide MAC-equipped HDV-fleet by relevant models and makes. Climatic conditions are unlikely to play a major role in leakage.

It was agreed that ACEA together with its members (DaimlerChrysler, Volvo/Renault, MAN, IVECO, Scania and DAF) would discuss with selected fleet-operators if these would be willing to cooperate in the study. If so, fleet operators shall be asked to let an expert measure the refrigerant at a specific number of vehicles (e.g. 30). The expert and the measurement equipment would need to be the same for all measurements to ensure that there is no measurement bias. In return, the MACs in question will be topped-up to full charge, and the fleet operators will be informed about the leakage rate and the quality of their MACs measured.

Matti Vainio offered to give all measured data to the companies if they so wished. Naturally, information of individual vehicles would be given only to the manufacturer in question.

It was agreed that the final Measurement Protocol would be tested in the premises of some manufacturers to ensure that what is supposed to be measured (refrigerant charge) is actually measured. This same test was carried ex-post in the MAC study for passenger cars. It was agreed that the Measurement Protocol for passenger cars will be sent to participants of the meeting on 3 February 2005.

Follow-up:

- **Send Measurement Protocol to participants by 3 February 2005.**
- **Give comments on the applicability of the Measurement Protocol for N3 by 16 February 2005.**
- **Suggest fleet operators by 4 March 2005.**

[17] As an example, one bus mark has 56 metres long refrigerant lines with 30% flexible hoses.

3.e Methodology of measuring of leakage of MACs of Coaches and Buses

Industrial representatives confirmed that the proposed approach to utilise existing service records of buses is most likely the most appropriate approach. Mr Pochic from DC told that EVOBUS (DaimlerChrysler's bus-company) checks their coaches in use twice a year thoroughly on their main components including MACs. City buses undergo the same service only once a year.

It was agreed that Mr Pochic will inquire the MAC experts about to which extent service records of coaches could be used for establishing annual coach leakage rate. The representatives of Volvo/Renault and MAN, Daniel Foucher and Annerose Zacherl, would do the same, and ACEA would contact the other manufacturers to see if they followed the same practice.

In difference from coaches, buses are mostly operated by companies of the public transport, which often run MAC service shops on their own. Therefore, bus operators themselves (or their association) shall be asked if they keep service records in a way that allows for conclusions on annual MAC leakage rate. Mr Vainio would get in touch with the International Union of Public Transport (UITP) to see if they could help.

The industrial representatives agreed to contact their in-house experts for buses and coach MACs not only concerning MAC service records of coaches but also of buses. It was further agreed that all participants would give suggestions on city bus operators to Winfried Schwarz.

Follow-up:

- **Suggest city bus companies to be included in the study by 25 February 2005.**
- **Inform to what extent companies' MAC service records of coaches and buses could be used by 4 March 2005.**

4. Follow-up

A draft final report is foreseen to be sent to all the participants by end of March. The participants are requested to give their comments on the draft final report bilaterally to Matti Vainio with a copy to Winfried Schwarz. A second meeting will be held if necessary, but it was envisaged that the next meeting would take place once the contractor has been selected to carry out the measurements.

Matti Vainio

Encl. Participants

Participants

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Annex IV: Rough Cost Estimate of the MAC studies

Study on Trucks

1. Preparation of the measurements

(Compilation of sample, adjustment of questionnaire,
contacting fleet operators, etc.)

13-15 person-days

Person-day means a full working day of a senior researcher

2. Implementation of measurements **15,000 €**

("Measurement" includes all collection of vehicle-specific data acc.
to on-site questionnaire).

Costs of measuring by MAC experts (Basis: 200 measurements)	11,000 €
Travel costs connected with measurements	4,000 €

3. Evaluation of measurements

(Analysis of results and of additional data, reporting, etc.)

17-20 person-days

Person-day means a full working day of a senior researcher

Supplementary cost notes on truck MACs

1. Possible additional cost for fleet staff

The cost of measurements will rise if the truck fleet operators allow access to their vehicles only on Saturdays and/or on condition that a member of their staff takes care of the vehicles the all the measuring time. Assuming 50 Euro per hour compensation on Saturdays, additional cost of up to 3,500 Euros might arise.

It should be added that the question of compensation was brought on the table several times by the ACEA representatives.

2. Additional cost for establishing irregular leakage rate.

If the EU Commission decides to exercise the option of establishing the irregular leakage rate of trucks, too, additional work must be done by the contractor of the upcoming study.

Between 2 and 3 days of a Senior Researcher should be considered necessary to collect the data as described under 5.6 (this study).

Study on Buses

1. Preparation of the analysis of service records

(Selection of representative sample, contacting properly recording MAC workshops covering the sample variety, etc.)

Senior researcher	**8-10 person-days**

2. Copying and entering paper-based MAC data on site

Senior researcher	**4 person-days**
Assistant	**4 person-days**
Travel costs connected with data entering	**4,500 €**

3. Evaluation of entered data

(Analysis of entered and additional data, reporting, etc.)

16-19 person-days