ÇUKUROVA UNIVERSITY
INSTITUTE OF NATURAL AND APPLIED SCIENCES

MSc THESIS

Erkin Efehan AYAN

FAULT ELIMINATION PROCESS FOR COMMERCIAL VEHICLES BY ELIMINATING OF THE OVER HEATING PROBLEM IN THE BUSES

DEPARTMENT OF MECHANICAL ENGINEERING

ADANA-2016

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ABSTRACT

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This study focuses on the fault elimination method by eliminating the overheating problems in the commercial vehicles. Fault elimination which is the main occupation in all engineering systems is a difficult process and should be handled properly. In order to maintain the operation of engineering products, systems or services and improving quality progressively, fault elimination processes should be done by applying science, psychics, mathematics, and engineering knowledge. In the study, the problems such as bad inside climate which affect the passenger comfort and customer satisfaction, discoloration of exterior engine lids, heat transfer through the floor from the engine compartment into interior without absorption of heat and noise, temperature differences, excessive heat in the engine compartment, excessive heat over the seat rails, insufficient ventilation of the interior air, have been studied according to fault elimination method. The most feasible solutions were discussed and proposed in the study such as air flow optimizing, better insulation of engine compartment, additional air ducts, and waste heat recovery. The study showed that managing the excessive heat properly improves efficiency, decreases cost and improves customer satisfaction.

Key Words: Fault Elimination, Commercial Vehicles, Excessive Heat, Solution

ÖZ

YÜKSEK LİSANS TEZİ

OTOBÜSLERDE AŞIRI ISINMA PROBLEMİNİN TİCARİ ARAÇLAR İÇİN HATA ELİMİNASYON SÜRECİYLE GİDERİLMESİ

Erkin Efehan AYAN

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Bu çalışma, ticari araçlarda aşırı ısınma problemlerini giderme ile hata eliminasyonu üzerine odaklanmıştır. Bütün mühendislik sistemlerinin temel uğraşı olan hata eliminasyonu uygun bir şekilde işletilmesi gereken zor bir süreçtir. Mühendislik ürün, sistem veya servislerinin devamını sağlamak ve sürekli olarak kaliteyi geliştirmek için, hata eliminasyon süreci bilim, fizik, matematik ve mühendislik bilgisi uygulanarak yapılmalıdır. Bu çalışmada, yolcu konforu ve müşteri memnuniyetini etkileyen kötü iç hava, motor dış kapaklarının renk atması, motor kabininden zemine ısı ve ses absorbsiyonu olmadan ısı transferi, sıcaklık farklılıkları, motor kabininde aşırı ısı, koltuk rayları üzerinde aşırı ısı, yetersiz iç havalandırma, gibi problemler hata eliminasyon yöntemine göre çalışılmıştır. Hava akış optimizasyonu, motor kabininin daha uygun izolasyonu, ek hava kanalları, ve atık ısı geri kazanımı gibi en uygun çözümler tartışılmış ve çalışmada sunulmuştur. Çalışma aşırı ısının doğru şekilde yönetildiğinde verimliliği arttırdığını, maliyetleri düşürdüğünü ve müşteri memnuniyetini arttırdığını göstermiştir.

Anahtar Kelimeler: Hata Eliminasyon, Ticari Araçlar, Aşırı Isı, Çözüm

EXTENDED SUMMARY

Bu çalışma, ticari araçlarda aşırı ısınma problemlerini giderme ile hata eliminasyonu üzerine odaklanmıştır. Bütün mühendislik sistemlerinin temel uğraşı olan hata eliminasyonu uygun bir şekilde işletilmesi gereken zor bir süreçtir. Mühendislik ürün, sistem veya servislerinin devamını sağlamak ve sürekli olarak kaliteyi geliştirmek için, hata eliminasyon süreci bilim, fizik, matematik ve mühendislik bilgisi uygulanarak yapılmalıdır. Bu çalışmada, yolcu konforu ve müşteri memnuniyetini etkileyen kötü iç hava, motor dış kapaklarının renk atması, motor kabininden zemine ısı ve ses absorbsiyonu olmadan ısı transferi, sıcaklık farklılıkları, motor kabininde aşırı ısı, koltuk rayları üzerinde aşırı ısı, yetersiz iç havalandırma, gibi problemler hata eliminasyon yöntemine göre çalışılmıştır. Hava akış optimizasyonu, motor kabininin daha uygun izolasyonu, ek hava kanalları, ve atık ısı geri kazanımı gibi en uygun çözümler tartışılmış ve çalışmada sunulmuştur. Çalışma aşırı ısının doğru şekilde yönetildiğinde verimliliği arttırdığını, maliyetleri düşürdüğünü ve müşteri memnuniyetini arttırdığını göstermiştir.

Dizel (sıkıştırma patlamalı) motorlar yüksek tork üretme kabiliyeti ve benzinli motorlara göre daha yüksek verimlilik ve daha az özgül yakıt tüketiminden dolayı özellikle taşımacılık ve ağır iş makinelerinde en çok kullanılan termik makinelerdir. Dizel motorlar dizel çevrimi prensibine göre çalışırlar. Teorik olarak incelendiğinde dizel motorların termik verimliliği benzinli motorlardan yüksektir. Buınun temel sebebi, dizel motorlar benzinli motorlardan daha yüksek sıkıştırma oranı ile çalışmalarıdır. Bu yüksek oran beraberinde motor periferinde yüksek sıcaklıkları da beraberinde getirmektedir.

Bir çok Avrupa ülkesinde ve özellikle Türkiye`de insan ve malzeme taşımacılığı, bu alanda hizmet veren ticari araçlar bünyesindeki kamyon ve otobüslerle yapılmaktadır. Ticari araçlar lojistik zincirinin en önemli halkasını teşkil etmektedir. Toplu taşımacılık özellikle büyük şehirlerde olmazsa olmaz bir gelişmişlik göstergesidir. Bir şehirin alt yapısının gelismisligini o şehirin ulaşım

ağı öne çıkarır. Aynı şekilde büyük sehirlerler arasında insanları taşıyan otobüs seferleri de günümüzün vazgecilmezlerindendir. Büyüklü küçüklü yüzlerce firma, modern ve konforlu, klimalı, kapalı devre eğlence sistemli ve televizyonlu, hosteslerin çay,kahve, kek vb. gibi servis yaptığı seyahati keyife dönüştüren otobüsleri hizmete sunmaktadır. Sefer sayısının çok olması ve uçak seyahatlarina göre maliyetinin daha düşük olması sebebiyle otobüs yolculuğu tercih sebebidir. Iyi bir lojistik,insan ya da malzemeden bağımsız, başarının anahtarıdır. Malzemelerin üretime gecikmesi kadar çalışanların iş gücü olarak fabrikaya gecikmesi de verimliliği düşürecektir. Malzeme ve insan gücü olmadan üretim yapılamaz. Bu iki önemli öge ticari araç taşımacılığını çok önemli kılmaktadır. Sadece iki şehir arasındaki seyahatlerde değil, şehir içi otobüsleri de bizi okula, eve, şehir merkezine taşımakta ve hayatımızın önemli bir parçasını oluşturmaktadır.

Konforlu seyahatin bir parçası olan araç içi iklimlendirme sistemleri yolculuğunuzun konforlu geçmesine çok büyük bir etki etmektedir. Araca konulan iyi bir iklimlendirme sisteminin düzgün ve etkin çalışabilmesi için aracın aerodinamik yapısı da çok önemlidir.

Günümüzde bir çok ticari araç üreticisi profesyonel mühendislik araştırma geliştirme faaliyetleri yaparak yeni teknolojileri araçlarına entegre etmeye çalışmakta ve satış sonrasında da müşterilerini servis ağlarıyla desteklemeye devam etmek zorundadırlar. Çünkü müşteri memnuniyeti, müşterinin tekrar araç alması ve ticari döngünün devamı anlamına gelir. Kısaca, müşteriyi memnun ettiğiniz sürece üretmeye devam edebilirsiniz. Uygulanan yeni teknolojilerin çeşitli çıkış noktaları bulunmaktadır. Inovasyon öncülüğü (piyasada ilklerden olabilmek), maliyet düşürme (verimlilik) ve yasal gereklilikler gibi bu tetikleyici sebepler, yeni teknolojilerin araştırılmasına on ayak olmaktadır.

İşte bu gereksinimler bazı çevresel etkileri de beraberinde getirmektedir. Dizel motorlu araçların emisyon değerleri, devletlerin kontrolü altındadır ve bu sebepten yıllar bazında emisyon degerlerinn azlatilmasina yönelik Euro değerleri tanımlanmıştır. Bu yasal gerekliginin araçta uygulanması özellikle yeni nesil dizel motor gelistirmelerinde çeşitli teknolojik zorlukları da beraberinde getirmektedir. Kısaca, ozona zarar veren nitrojen oksit ve hidrokarbonlar ve partiküllerin daha düşük ve daha zararsız egsoz emisyon limitlerine çekilmesi zorunluluğu getirilmiştir.

Yeni emisyon limitleri, Avrupa ve Türkiye´de Euro Emisyon oranı olarak tanımlanmıştır. "Euro IV" değerleri Kasım 2006 ve "Euro V" değerleri de Ekim 2008 de Avrupa da devreye alınmıştır. Euro 6 regülasyonu ise 2014 başı itibariyle Avrupa da devreye girmiş olup, 2.610 kg üzerindeki tüm araçlarda yeni tıp onayı gerektirmiştir. Özellikle bu alanda öncü olmak isteyen üretici firmalarda büyük araştırma-geliştirme faaliyetlerine bütçe ayirilmasina sebep olmuştur. Tüm bu bahsi geçen teknik değişiklikler, dizel motorlarda gerekli bazı modifikasyonlari beraberinde getirmiştir. Bu değişiklikler motorun yeni destek ekipmanları sebebiyle daha ağır olmasına ve egsoz geri dönüşüm sistemi ve seçici katalitik azaltma sisteminin yüksek sıcaklıklarda çalışma zorunluluğu sebebiyle motor odasındaki sıcaklıkların da artmasına sebep olmuştur. Yani kısaca, Euro Normundaki sayısal her artış, motor odasında daha yüksek sıcaklık anlamına gelmektedir.

Yeni motor jenerasyonunun mevcut araca adaptasyonu ciddi paketleme sıkıntılarına yol açmaktadır. Yeni parçaların montajı, zaten sıkışık durumdaki motor odasının daha da sıkışmasına ve üretimde montaj problemlerini de baraberinde getirmektedir. Araçların büyüklüğünden dolayı, ticari araçlarda tolerans değerleri binek araçlara göre daha fazladır, bu da üretimde hep ekşi ya da hep artı toleranslarda çalışıldığında montaj bölgesinde sikismalara yol açmaktadır.

Yeni teknolojiler araç yapısını daha karmaşık hale getirmektedir. Bu sebepten dizaynda farkedilemeyen veya öngörülemeyen hatalar testler sırasında ortaya çıkabildiği gibi, test kriterlerinin eksik olması ya da tüm saha şartlarını kapsayamasi gibi nedenlerle müşteri araçlarında da oluşabilir. Bu sebepten ticari araç üreticilerinin sağlam ve etkin bir Hata Giderme Sistemine sahip olması gereklidir. Bir taraftan, seri üretimde belirlenen hatayı bir an önce çözerek, sahada bu hatadan etkilenen araç sayısını sınırlamaya çalışmak önceliklendirilir, diğer taraftan da sahadaki hatalar için reaktif veya proaktif olmak üzere çözüm ya da çözümler üretilmesi gerekmektedir.

Bu çalışmanın amacı, profesyonel bir ticari araç üreticisinin kullandığı hata yönetim sistemi ile, otobüslerde özellikle homojen olmayan iklimlendirme konforunun ve aracın arka bölgesinde motor odasından kaynaklı aşırı ısınma probleminin "Hata Eliminasyon Süreci" ile sistematik olarak giderilerek, çeşitli ölçümler eşliğinde validasyonu ve çözümlerin bulunmasına yönelik yapılan çalışmaları anlatmaktır.

Bu çalışmadaki bazı sonuçlar, özellikle fazladan havalandırma boşluklarının açılmasının her zaman ise yaramadığıdır. Örneğin bazı coğrafi bölgelerdeki çok yüksek yaz sıcaklıklarında çalışma koşullarını iyileştirmeden ziyade daha kötü sonuçlar ortaya çıkmasına sebep olabilmektedir. Bazı değerler ek kriterler olmadan fazla anlam ifade etmeyebilir, örneğin sıcağı izole etmek için kullanılan alimünyum yüzey,iskelet yüzeyinde ısı transferini düşürdüğü gibi refleksiyon etkisiyle motor odası sıcaklığının daha da artmasına sebep olabilmektedir. Yani iskeletteki ısı düşüşü, motor odası üzerinden geri dönmekte ve toplamda etkin olmayabilmektedir. Kapağa açılan havalandırma boşlukları akustik emisyon değerlerini etkileyebilir. Hava sirkülasyonunu iyileştirmek için takılmayan bir yağmur oluğu, motor odasının daha fazla kirlenmesine ve farklı şikayetler oluşmasına sebep olabilmektedir. Yapılan izolasyon değişiklikleri aracın montaj şartlarını, toplam maliyetini ve ağırlığını etkileyebilir.

Doğalgaz ile çalışan motorların karmaşık egsoz gazı iyileştirmesi sistemine ihtiyaçları yoktur, otto çevrimiyle çalışan bu tip motorların verimliliği dizel motorlara oranla daha düşüktür, ancak dizel motorlara oranla daha yüksek sıcaklıklarda çalışırlar.

Motor odasında kullanılan izolasyonların doğu seçilmesi ve özellikle yapışma süreçlerinin detaylı validasyonu çok önemlidir. Kullanılan iklimlendirme sisteminin yerleşimi ve homojen bir hava sirkülasyonunu sağlaması önemli bir gerekliliktir. Hava sirkülasyonunun motor odasına yığılması ve izolasyonun yetersiz olması, iklimlendirme sisteminin daha çok çalışmasına sebep olacaktır. Bu durum iklimlendirme sisteminin havayı düzgün sirküle edememesiyle birleştiğinde, aracın bir bölümünde çok soğuk, bir bölümünde ise çok sıcak olmasına yol açabilmektedir. Ayrıca iklimlendirme sisteminin fazla çalışması yakıt tüketiminin artmasına ve ayrıca bakım ve tamirat maliyetlerinin de yükselmesine neden olabilmektedir.

Isının kök kaynağına inerek uygulanacak doğru yöntemler, üretimde oluasabilecek montaj hatalarının önüne geçebilir, doğru malzeme seçimi maliyetleri düşürebilir. Sonuç olarak, deneysel ve teorik çalışmaların değerlendirilmesiyle bulunan ve uygulanan bu çözümler, yapılan öncesi ve sonrası ölçümler neticesinde %20 lik bir iyileşme getirmiştir. Uygulanacak öngörülü tasarım ve hatalardan öğrenme metodu ile yeni projelerde, doğru validasyon süreçleriyle müşteri problemi oluşmadan doğru teknolojik çözümler üretilebilir.

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ABBREVIATIONS

FMP : Failure Management Process
PEMS : Portable Emission Measurement System
FLIR : Forward Looking InfraRed
CO : Carbon Monoxide
HCI : Hydro Carbon Injection
NOx : Nitrogen Oxide
EGR : Exhaust Gas Recirculation
SCR : Selective Catalytic Reduction
Ke : Kettle
TEG : Thermo Electric Generators
HVAC : Heating Ventilation Air Conditioning
COP : Conformity of Production
DPF : Diesel Particle Filter
TI : Technical Information

1. INTRODUCTION

In many European countries and especially in Turkey, Bus travel is the easiest, cheapest, most popular way to travel. The buses, operated by dozens of companies large and small, are modern and comfortable, with air conditioning, entertainment, a steward to bring you snacks and drinks, and departures are frequent, and fares are low to moderate. Not only the coaches which brings you from city A to city B, also the city buses which you should take from school to home or to the city center are a very important part of our lives. Today’s buses and coaches rely increasingly on effective air conditioning systems to meet growing passenger demand for a higher level of comfort. But simply installing a good air conditioning system is not enough to guarantee efficient operation; equally important is a perfect match between the A/C system and the vehicle. Although many bus producers adopt a total approach, from professional engineering development and support for customers, through to quality service contracts for European bus and coach operators, there are always some technical difficulties due to the continuous change of new engine technologies. That means, tougher limits on harmful exhaust emissions from trucks, lorries and buses, including ozone precursors such as nitrogen oxides and hydrocarbons as well as particles.

Internal combustion engines are basically heat sources due to their operating principle. Internal combustion engines combust the fuel inside the cylinders and a high pressure occurs during the combustion. Also, this combustion causes a high amount of heat release and thus the temperature of the engine and components tremendously increases. Furthermore, the exhaust gases pushed out the cylinders have significantly high temperatures. The high temperatures caused by the operation of the engine are a difficult engineering problem to deal with. The engine must be kept around an optimum operating temperature for the best efficiency and to prevent the possible damages caused by high temperatures on components of the engine and moreover, the warming effects of the engine around the engine cabin and passenger compartments must be managed properly.

The new tougher emission limits (on harmful exhaust emissions, including ozone precursors such as nitrogen oxides and hydrocarbons as well as particles) are to replace both the "Euro IV" limits (which have applied since November 2006), and the "Euro V" emission limits, which will apply from October 2008. The proposal concerns the so-called Euro VI regulation, laying down harmonized technical rules for trucks, lorries and buses (heavy vehicles over 2,610 kg), which all new vehicles will have to comply with in order to get the necessary type approval. The result is of course new technologies and innovations to reach these emission values. Buses fuelled by compressed natural gas (CNG) have been around in Europe and in Turkey for many years. At one time they held a very significant advantage over diesel buses because of their lower emissions which made these CNG buses very popular. That gap has almost closed but CNG buses remain popular in some countries, usually for political reasons. There are drawbacks, not least the weight of the gas tanks on the roof of the vehicle. They increase its unloaded weight, and therefore can restrict the total number of passengers. Although the consumption of gas is about 1.6 times that of diesel per km, its normal tax rate is much lower. From the technical point of view the CNG engines have a higher running temperature as diesel engines. But due to these above mentioned new emission values, also by diesel engines the necessary modifications must be adapted. That makes the engines heavier and warmer due to the exhaust gas recirculation and selective catalytic reduction systems. That makes the engine room isolation and air ventilation a very important expertise area.

Detecting the problems and bringing out feasible solutions are the main occupation of the engineers. In any engineering system, the problems which occurred and the problems which are possible to arise must be examined carefully, and the easiest, most economical and safest solutions should be applied. There are many different methods used in engineering in order to detect the problem, finding out the solutions, and eliminate the faults. In order to eliminate a fault, to define the problem clearly and finding out the source of the fault is the key point for all engineering systems.

The aim of this study is to eliminate the isolation and ventilation problematic by two types of buses according to the fault elimination method with detailed temperature analysis and air flow measurements with different try-outs.

2. PRELIMINARY WORK

2.1. Fault Detection and Solutions

Excessive heat has negative drawbacks in all engineering systems. Excessive heating problems significantly affect the workers, production levels, quality of products and operations, ergonomics and comfort of the systems. Many corporations and researchers work to find out feasible solutions for excessive heat problems. In literature, there are few studies on the excessive heat problems in many different disciplines. But, also many researcher studied on the subject of fault detection, diagnosis and different possible solutions to problems. Fault detection, diagnosis, and elimination of faults are the main study subjects in all engineering disciplines.

Wanh et al., (2010) published a study which focuses on the solution to excessive heat supply in a city primary heating network using gas-fired boilers for peak-load compensation. The authors calculated the excessive heat supply rates of five substations and studied on the feasibility of proposed scheme providing energy savings from both energetic and exergetic points of view. The study revealed that the combined heating scheme with coal as the basic heat-source and gas-fired boilers as peak-load heat sources is energy-efficient to some extent, although requires the use of natural gas. And also the exergy decreased by 10.97%, which indicates that the combined heating scheme effectively reduces the primary energy consumption and pollutant emission of the heating systems. (Wang, 2010).

Zarbov et al., (2006) published a study which focuses on applied electrophoretic deposition (EPD) performance, problems and solutions. The authors emphasized that the design of the EPD is related with geometry of the final product and dimensional tolerances. The microstructure and freedom of the products from process defects are in relationship with deposition parameters and the dispersion chemistry. The authors revealed that, (EPD) has the potential for improving the dimensional and engineering tolerances of many components in a micro-electronic circuit. Design of the EPD cell and choice of EPD parameters and their control, can be solved with pre-treatment, choise of dispersion media, selection of steric and electro-steric additives and also with focusing on the requirements for the EPD substrate and post-EPD treatment of the product.

Trebuna et al., (2016) published an article that deals with applications of applied mechanics to problems which are related with transportation and storage of spent nuclear fuel. The authors studied on the solutions of problems such as cask reliability, safety of transport complex, cooling of casks in a storage system. The investigation was of the solutions was performed with numerical and experimental methods of mechanics. In the study, investigation was made by performing some numerical and experimental techniques such as modal analysis of the container, residual stresses in the container body, experimental verification of the container fixture, drop and penetration test of the container model, thermal and stress analysis of the container. The study revealed that, experimental and numerical methods gave the same results.

Das and Parouha, (2014) developed two hybrid metaheuristic Differential Evolution (DE) and Particle Swarm Optimization algorithm (PSO) in order to solve engineering problems. The authors aimed more efficiency of DE and PSO and removing drawbacks of which cause to reduce capability of algorithms. The investigations were performed on three engineering problems. The study revealed that DPD is an effective optimizer for optimizing the problems.

Yin et al., (2014) investigated the online fault diagnosis method which based on incremental support vector data description (ISVDD) and extreme learning machine with incremental output structure. The authors outlined that an online fault diagnosis system should detect faults, recognize and categorize the fault types. The authors proposed ISVDD to solve problems.

Yongzhi and Zhangming, (2012) presented a study that investigates an early fault detection method for marine diesel engines. The authors developed an early fault detection method based on thermal parameters and a fault predication system for marine diesel engines. The method was developed based on data mining technology.

Simani et al., (2011), presented a study that investigates a hybrid model based on fault detection of wind turbine systems. The authors focused to detect faults in early stage of occurrence and handle the faults properly to be able to improve the reliability of wind turbines. The study performed on the pitch sensors which are used to control the turbine blades which maximize the power production. The process was assumed to be nonlinear due to uncertain input-output data and uncertain nature of wind speed. The authors tested the effectiveness the strategies collected from wind turbine simulated model and they proposed that this method can be used for fault detection of wind turbine pitch angle sensor.

Wong et al., (2014) published a study that represents real time fault diagnosis for gas turbine generator systems using extreme learning machine. The authors underlined that a real time fault diagnostic system is a critical component of gas turbine systems which are used in many power plants in order to maintain the operation of the power plant and prevent the interruption of electricity supply in any kind of abnormal situation. To maintain the electricity supplement extreme learning machine (ELM) was proposed by the authors in order to identify faults quickly. The experimental results showed that diagnostic framework can detect component faults faster than support vector machine which is traditional identification technique.

Venkatasubramanian et al., (2003) reviewed fault detection and diagnosis processes based on quantitative model methods. Fault detection and diagnosis is an important problem in process engineering. It is the central component of abnormal event management (AEM) which has attracted a lot of attention recently. AEM deals with the timely detection, diagnosis and correction of abnormal conditions of faults in a process. Early detection and diagnosis of process faults while the plant is still operating in a controllable region can help avoid abnormal event progression and reduce productivity loss. Since the petrochemical industries lose an estimated

20 billion dollars every year, they have rated AEM as their number one problem that needs to be solved. Hence, there is considerable interest in this field now from industrial practitioners as well as academic researchers, as opposed to a decade or so ago. There is an abundance of literature on process fault diagnosis ranging from analytical methods to artificial intelligence and statistical approaches. From a modelling perspective, there are methods that require accurate process models, semi-quantitative models, or qualitative models. At the other end of the spectrum, there are methods that do not assume any form of model information and rely only on historic process data. In addition, given the process knowledge, there are different search techniques that can be applied to perform diagnosis. Such a collection of bewildering array of methodologies and alternatives often poses a difficult challenge to any aspirant who is not a specialist in these techniques. Some of these ideas seem so far apart from one another that a non-expert researcher or practitioner is often left wondering about the suitability of a method for his or her diagnostic situation. While there have been some excellent reviews in this field in the past, they often focused on a particular branch, such as analytical models, of this broad discipline. The basic aim of this three part series of papers is to provide a systematic and comparative study of various diagnostic methods from different perspectives. We broadly classify fault diagnosis methods into three general categories and review them in three parts. They are quantitative model-based methods, qualitative model-based methods, and process history based methods. In the first part of the series, the problem of fault diagnosis is introduced and approaches based on quantitative models are reviewed. In the remaining two parts, methods based on qualitative models and process history data are reviewed. Furthermore, these disparate methods will be compared and evaluated based on a common set of criteria introduced in the first part of the series. We conclude the series with a discussion on the relationship of fault diagnosis to other process operations and on emerging trends such as hybrid blackboard-based frameworks for fault diagnosis.

Varga, (2011) published an article that discuss the solution of the fault detection problem in presence of parametric uncertainties. The basic approach is an extension of the nullspace method for constant systems to the case of linear parameter varying (LPV) models. In a general setting, we consider the case when parts of the unknown parameters are non-measurable and parts of them are measurable. The resulting LPV-gain scheduled fault detection filter provides robustness with respect to both types of parametric uncertainties. Symbolic and numerical computational procedures which underlie the proposed synthesis approach are discussed.

Akhmetzyanov and Salnikov, (2015) presented a study that investigates the methods and algorithms for the solution of inverse problems of modelling and control in reservoir engineering. The authors summarized that statement and solution of the problems of modelling and control of hydrodynamic parameters in reservoir engineering are usually associated with insufficiency and/or inaccuracy of the original input data (initial and boundary conditions) and the parameters of filtration equations in porous medium of reservoirs. In such conditions it is necessary to solve the identification problem (machinery monitoring) of the rough specified initial data (initial and boundary conditions), as well as parameters (permeability coefficients) of hydrodynamic models of reservoirs by historical data. This means that the traditional hydrodinamic models, which are formulated as direct initial boundary value problems for the equations of fluid filtration are improperly posed, i.e. small changes in the input data can lead to an arbitrarily large changes in the output. Therefore the models for the control of the field development are formulated as inverse problems and the iterative regularization methods are offered for their solutions. Problem of high dimensionality naturally arises under these statements of the problems of modelling and control, to solve which the multilevel parallel computing technologies based on the hierarchical decomposition combined with the multigrid versions of the methods of splitting by physical processes, spatial and temporal coordinates are offered. Dimension of the problem is even greater increases under development of offshore fields and coastal areas (e.g. in the Arctic) in real-time when it is required to create the integrated simulation models of the complex technological system (reservoir - well - oil and gas collecting network) as a whole. To solve the problems of identification and adaptation of initial and boundary conditions and filtration parameters the iterative regularization methods for direct and inverse problems for the original model equations by historical data are offered. To create the integrated model of the complex technological system as a whole the innovative parallel computing technologies with optimal hierarchical (multilevel) embedding of parallel algorithms into the architecture of multiprocessor computer systems using MPI/OpenMP or OpenCL/CUDA are offered.

Laouti et al., (2011) studied support vector machines for fault detection in wind turbines. The authors summarized the study ; support vector machines (SVM) are used for fault detection and isolation in a variable speed horizontal-axis wind turbine composed of three blades and a full converter. The SVM approach is data based and is therefore robust to process knowledge. Moreover, it is based on structural risk minimization which enhances generalization and it allows accounting for process non linearity by using flexible Kernels. In this work, a radial basis function was used as Kernel. Different parts of the process were investigated including actuators, sensors and process faults. With duplicated sensors, we could detect sensor faults in blade pitch positions, generator and rotor speeds rapidly. Fixed value fault were detected in 2 sample periods and offset faults could be detected for Db ³ 0.5° with a detection time that depends on the offset level. The converter torque fault (an actuator) could be detected within two sample periods. Faults in the actuators of the pitch systems could not be detected. Faults in the process concerning friction in the drive train could be detected only for very high offset.

Puncochar et al., (2015) represented a study that investigates adaptive generalized policy iteration in active fault detection and control. The authors summarized that the design of an active fault detector and controller is formulated as a dynamic optimization problem that is solved using the generalized policy iteration algorithm. A key parameter of this algorithm that influences computational demands and the speed of convergence is the number of successive approximations used in a policy evaluation step. Although general guidelines are known, no exact algorithm for choosing this parameter exists. The paper proposes an adaptive algorithm for determining this key parameter to speed up convergence given a specified accuracy of the solution. The adaptive algorithm is demonstrated and compared with non-adaptive generalized policy iteration algorithms in a numerical example.

3. MATERIAL AND METHOD

The experimental study was conducted in Development and Research Laboratories of MAN Truck and Bus AG in Munich/Germany and also by sub-company Manas in Ankara/Turkey.

3.1. Material

3.1.1. City Buses and Coaches

Excessive heat problems of buses and coaches have been defined due to technical inspections, test drives, customer feedbacks and all records of the products in the company. Table 3.1 shows the general problems caused by excessive heat in the buses and coaches.

Table 3.1. General problems caused by excessive heat in the buses and coaches

Problem	Problem Level
Excessive Heat Transfer Through Gaps	High
Heat Transfer via Structure (beams, rails, and other)	High
Too High Temperature Differences	Moderate
Heat Radiation From Heat Sources (Engine, heat from battery and baggage compartment)	Too High

In the study, the occurred problems during manufacturing, testing and the data collected from customer feedbacks were analyzed and problem and the possible solutions have been defined. Figure 3.1 and 3.2, and illustrates the general view of city buses and coaches focused in this study, respectively.

Figure 3.1. General view of city buses

Figure 3.2. General view of coaches

3.2. Methods

3.2.1. Fault Elimination Method

Fault elimination can be defined as the processes of defining, diagnosing and solving the occurred problem in order to maintain the operation of products or services in any engineering system. Figure 3.3 shows the basic mechanism of fault elimination method.

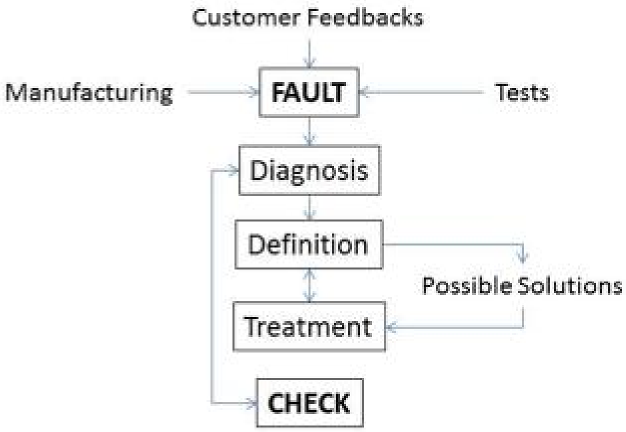


Figure 3.3. Basic mechanism of fault elimination

Fault elimination is a difficult process which should be handled carefully. The key point of the fault elimination is correctly defining the origin of fault or defect. Fault elimination is a continuous process which is progressively proceeds. The main reason of this phenomenon, in most cases the defects or faults do not appear immediately. The faults become distinct under different conditions and engineers may always not able to consider these situations.

Another crucial point is finding out the most feasible solution to problem. An engineer should apply the science, mathematics, physics, logic, economics and appropriate experience in order to find suitable solutions to problems. A problematic has solutions more than one in most cases. But, the most feasible one should be chosen and the solution should be considered from side of view of different disciplines.

The first point of fault elimination is defining the problematic correctly with its all possible causes. One of the most effective ways of defining the problem correctly is using fishbone diagrams. Figure 3.4 illustrate a basic of defining the problem with the aid of a fishbone diagram.

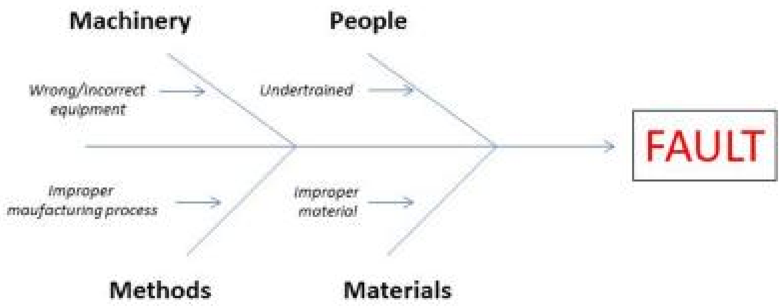


Figure 3.4. Fishbone diagram

3.2.2. Excessive Heat Problems

Since engine's itself is heat source due to its operating principle, the heat produced should be managed correctly. The following problems have been detected in the city buses and coaches and studied through this study.

General Problems : In some cases the customers want their money back because the passengers are complaining about bad inside climate (too hot, e. g. FMP A9118x, too cold, differences between front and rear part of the coach, e. g. FMP A2799x). Installation of additional air condition systems in a fleet of around 150 low floor (articulated) busses for one customer was very problematical, because gas tanks have to be moved. One case, where additional heating of the engine cooling system is necessary to fulfill exhaust gas (PEMS-Portable Emission Measurement System) limits at low outside temperatures, FMP A0976x is solved. Many measures and some guidelines (limits, benchmark to competitor vehicles), some for special types of busses, some for individual chassis numbers), much experience (practical and theoretical, e. g. air flow simulations), but no "global" heat management approach for current and future series production. In DIN EN

ISO 13731-1 temperature limits are standardized (Ergonomics of the thermal environment-Methods for the assessment of human responses to contact with surfaces. Part 1: Hot surfaces (ISO 13732-1:2006)): surfaces of heaters below 60 °C, other surfaces below 43 ° C. (Fault 1)

Fault (2) : Current thermal comfort issues at city busses;

- At high outside temperatures interior surface temperatures exceed limits (FMP A1122x) (1)
- Interior temperatures are too high (2)
- Paint on exterior engine lids discolours (3)
- Interior temperature differences front – rear are too high (4)
- At low outside temperatures it takes too long to achieve PEMS exhaust gas limits for hybrid busses (5)

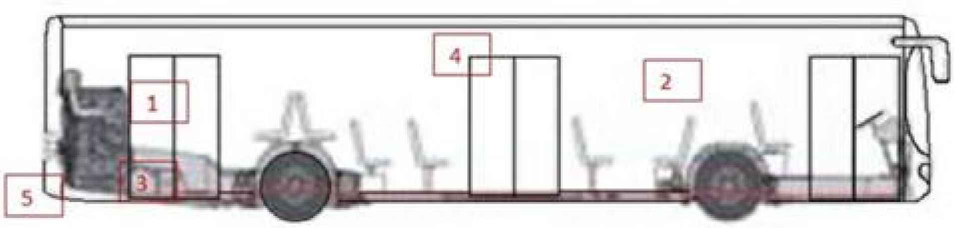


Figure 3.5. Zones/locations of heat issues at city busses

Fault (3) : Current thermal comfort issues at coaches;

- Customer still complaints about surface temperature of the seat rails (1)
- Heat is conducted from heated chassis beams to connected parts and surfaces (e. g. seat rails) (2)
- Connections between chassis beams and some interior surfaces are (still) not insulated (3)

- Chassis beams beneath baggage compartment without insulation heat will be conducted into passenger compartment (4)
- Aisle seat rails connection is not insulated in the baggage compartment (5)
- Hot air in the passenger compartment is not vented (to the outside) (6)
- Intercity bus overheating (7)

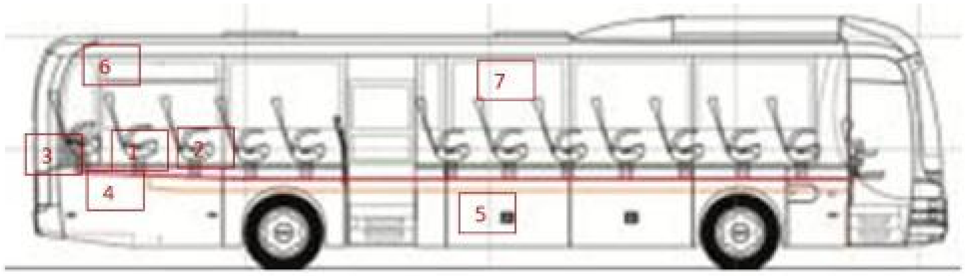


Figure 3.6. Zones/locations of heat issues at coaches

Fault (4) : Heat transfer through the gap between floor and lid is visible in this picture, but not easy to seal. Figure 3.6 illustrates the infrared picture of a closed lid.

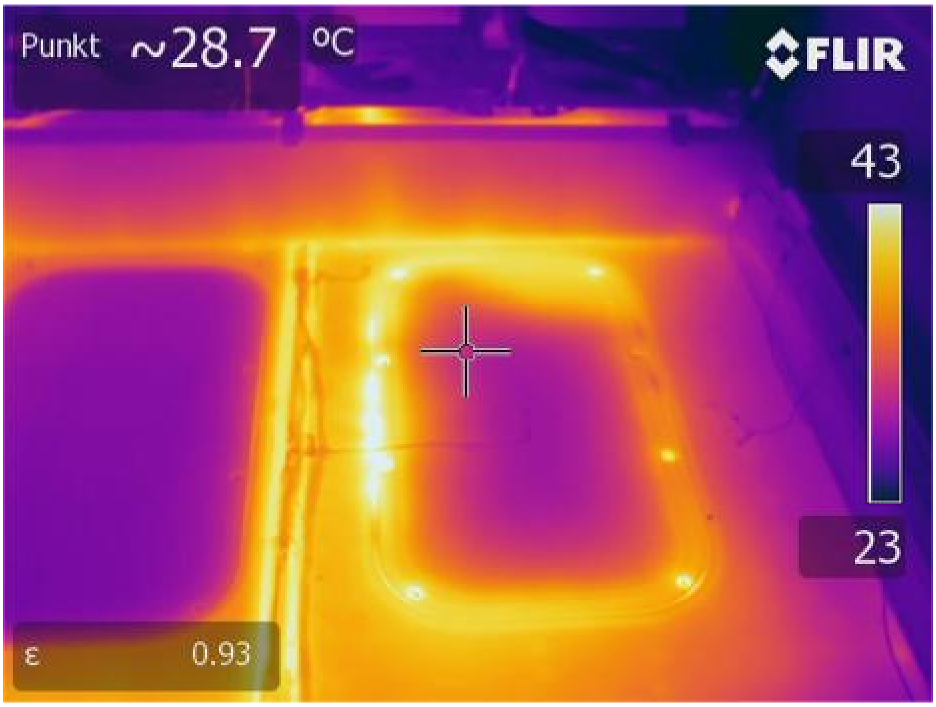


Figure 3.7. Infrared Picture of a closed lid in the floor

Fault (5) : The edges of the insulation material are sensitive to wear (chafing) which will affect the sealing and therefore heat) (and noise) can enter the passenger compartment.

Fault (6) : Discoloration of exterior engine lids.

Fault (7) : Heat transfer through the floor from in the engine compartment into the interior. Without absorption heat (and noise) can be transferred through the floor and especially through gaps. Figure 3.7 shows the infrared and real photo of the floor of a P11, FMP A9090x.

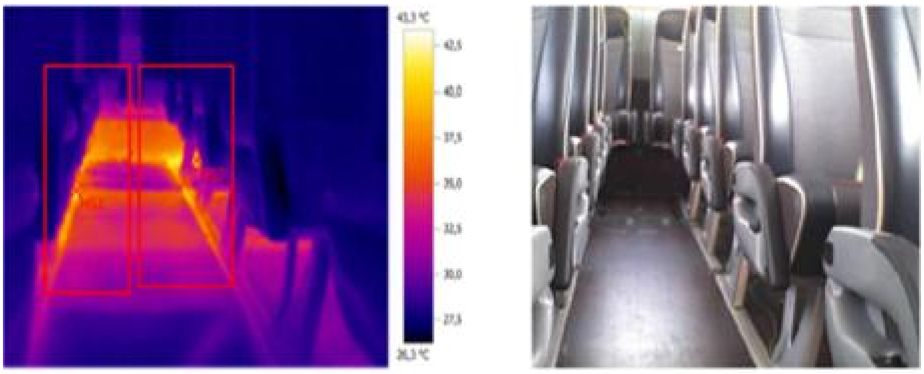


Figure 3.8. Infrared and real photo of the floor of a premium bus, FMP A9090x

Fault (8) : Heat transfer through gaps.

Fault (9) : Insulation material absorbs heat and noise, but water, diesel and oil as well. Oil soaked insulation material is dangerous, especially when parts of it are lying on hot surfaces (marten, Marder). Chassis rails without insulation will heat up while driving and transfer the heat into the passenger compartment (e. g. via the seat rails).

Fault (10) : Heat from the engine compartment is radiated through the rear corners.

Fault (11) : Unnecessary heat transfer from engine (and baggage) compartment into the interior.

Fault (12) : Temperature differences between seats exceed limits.

Fault (13) : Excessive heat in the engine compartment is not vented to the outside.

Fault (14) : Seat mounting is safety relevant (seat belts are mounted at the seats, not at the chassis) . Good mechanical contact to chassis is necessary. Therefore heat (and structure born noise) is transferred from the chassis to the seat rail. Plastic cover helps against heat radiation and keeps dirt outside of the seat rail.

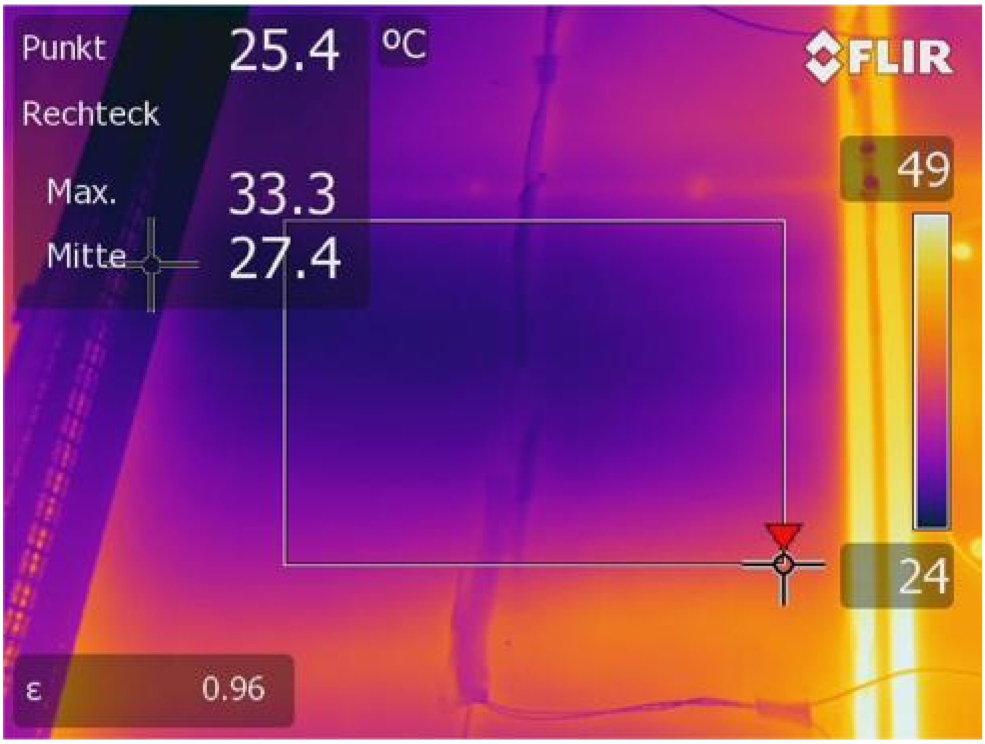


Figure 3.9. Infrared picture of seat rail

Fault (15) : Excessive heat is transferred via battery and baggage compartment into the passenger compartment.

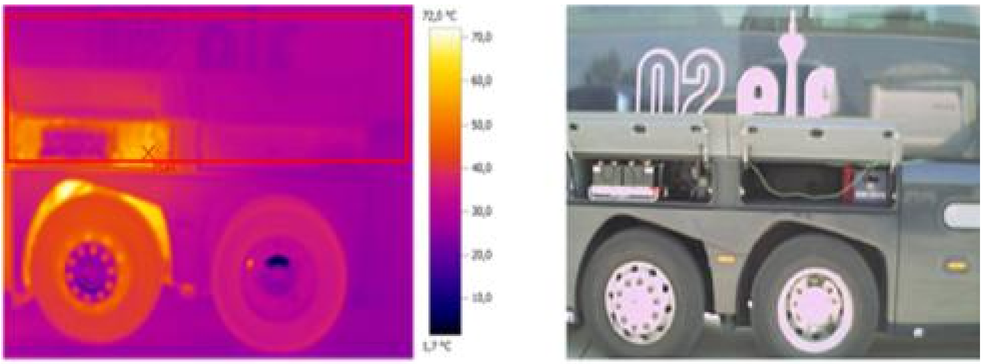


Figure 3.10. Infrared and real photo of battery and baggage compartment

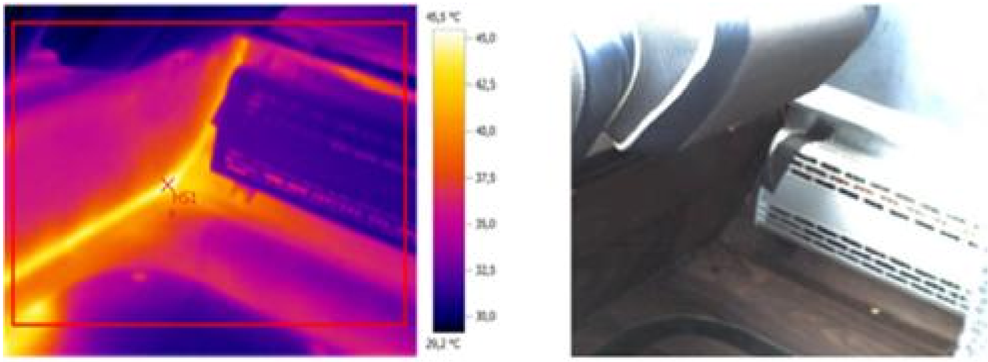
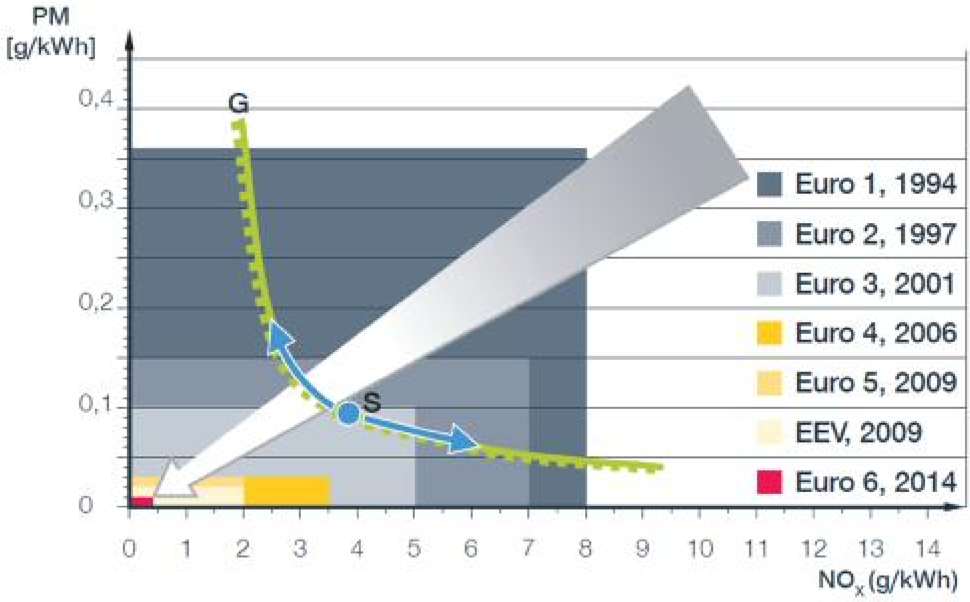


Figure 3.11. Infrared and real photo of battery and baggage compartment

3.2.3. Solution Techniques

Exhaust Gas After Treatment: Over the recent years, the exhaust gas limits were reduced. The last steps from Euro 2 to Euro 6 are shown in figure 3.11 below.



G – Limit for exhaust gas reduction without after treatment
S – Optimized ratio of NOx/PM emissions without exhaust gas after treatment
Figure 3.12. Emission limits over the recent years

To achieve Euro 6 exhaust gas limits (figure 3.11), some manufacturers (Mercedes, Scania,DAF etc.) use a combination of exhaust gas recirculation (EGR), filter(s) and selective catalytic reduction (SCR) with Ad blue (urea in water).

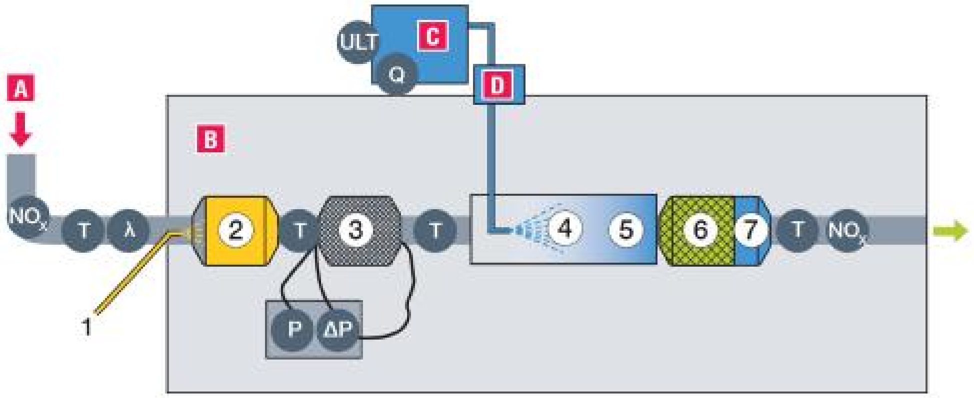


Figure 3.13. Schematic drawing of the exhaust gas after treatment for Euro 6

Table 3.2. Exhaust gas after treatment system for Euro 6

A	Exhaust pipe (from engine/turbocharger)		Sensors, values for exhaust gas reduction
B	Silencer with HCI (Hydro Carbon Injection)	□	Lambda-ratio of air in exhaust gas
C	Ad blue tank	NO_x	Nitrogen-oxygene
D	Ad blue dosing unit	T	Temperature
1	Hydro Carbon Injection	P	Pressure
2	Diesel oxidation catalytic converter (DOC)	ΔP	Pressure diffrence
3	Diesel particle Filter (DPF)	UL	Urea Level
4	Ad blue injection	Q	Ad blue quality (urea percentage in water)
5	Mixing and chemical reaction		
6	SCR reduction catalytic converter		
7	Ammonium barrier catalytic converter		

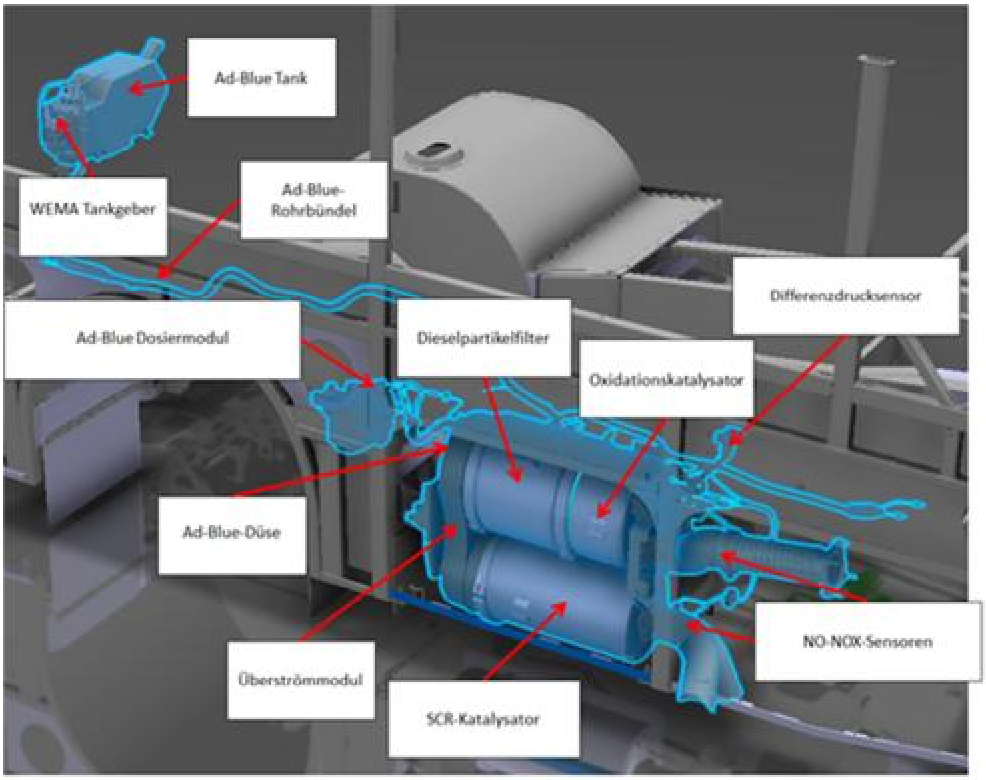


Figure 3.14. Installation of the exhaust gas after treatment components in a bus

Figure 3.13 gives an idea, where additional insulation between the heat sources filter and catalytic converters and heat sink passenger compartment is necessary – try to find some space for insulation material. To prevent the diesel particle filter from clogging, the soot has to be burnt from time to time. If engine loads (which lead to high exhaust gas temperatures) are not high enough, additional diesel is used to burn the soot from the diesel particle filter – hydro carbon injection (HCI), which increases the fuel consumption and heats up (not only) the filter. Good insulation keeps the heat inside of the exhaust gas after treatment system. The SCR system needs a certain temperature level to prevent the ad blue from crystallization. In Euro 6 busses, an exhaust brake after the exhaust system is used to keep the heat inside without engine load. Heat is necessary for exhaust gas after treatment, insulation will help for each type of bus. Gas engines don't need complicated exhaust gas after treatment but radiate more heat than diesel engines because the Otto combustion process is less effective than the Diesel process. Insulation at the heat source(s) saves space, material and costs.

Waste Heat Recovery: The heat contained in the exhaust gas is necessary for exhaust gas after treatment. The chemical reactions need certain temperature level to burn soot and reduce NOx. The rest of the thermal power can be used for waste heat recovery. Two ways of waste heat recovery are under examination at the ERP research department: Clausius Rankine process and Thermo electric generators.

Clausius Rankine process: The Clausius Rankine process is used in each conventional power plant: boil water to steam (e. g. via burning gas, oil or coal) in a kettle (Ke), use the steam in steam turbine(s) (T) which drives a generator (G) to get electrical power from thermal power (waste heat) to electrical power, (Figure 3.14). To close the circle, a condenser (Ko) and pump(s) are used no loss of the medium (water, ammoniac, some alcohols).

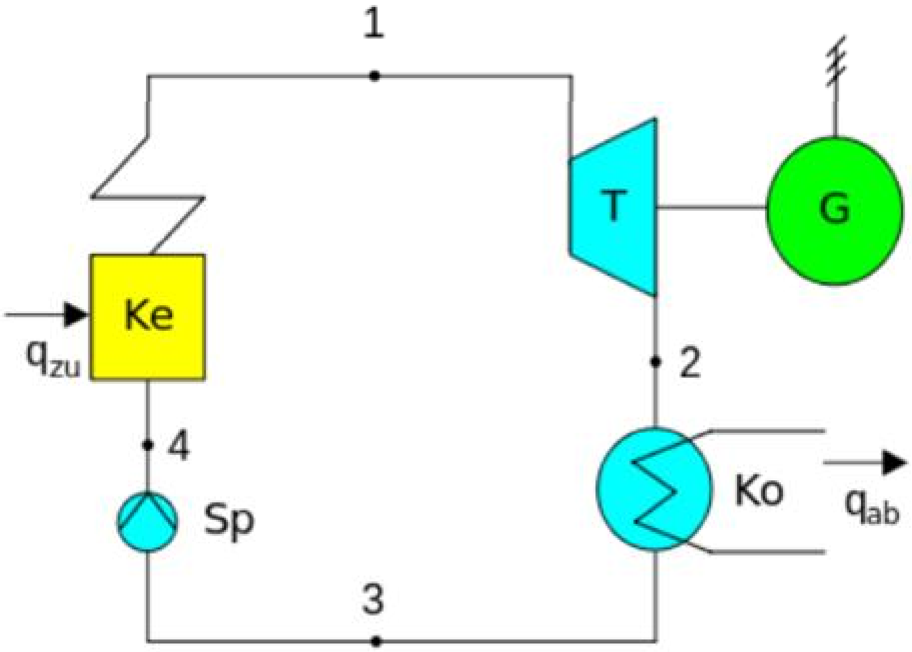


Figure 3.15. Schematic drawing of the Clausius Rankine process

First tests at the ERP test bench (figure 3.15) showed up to 10 kW additional power from waste heat.

Figure 3.16. Schematic drawing of the Clausius Rankine process

Approximately, 1 to 1.5 % fuel consumption can be reduced with this method. An additional mass of ~ 30 kg is necessary. At the Austrian plant the whole equipment for the Clausius Rankine process is mounted into a semitractor unit to prove the feasibility. Steam was heated up to 400 °C in a special designed exhaust gas recirculation (EGR) heat exchanger (no coolant but pure water to get steam). Unfortunately a suitable turbine (good resistance against water drops) was not available during the test period. From the steam properties (temperature, pressure, mass flow) before and after the throttle valve used instead of the turbine nearly 10 kW of additional power are calculated – from waste heat. Because the efficiency of the turbine is determined by the pressure ratio – not the difference - between entrance and outlet, a small exhaust pump (~50 Watts) can increase the efficiency of the system. A water pump is used to fill the EGR heat exchanger with pure water and close the circuit. One disadvantage of the Clausius Rankine process in vehicles is the medium itself: water can freeze and it need to be pure (free of air and chalk). Other media are still in the research phase at chemical companies. This thermal power can be converted to electrical power and is not available to heat up the passenger compartment. Especially at high engine loads energy is generated instead of heat. The Robert Bosch Company showed a steam piston engine with double sealing (steam and oil) at the commercial vehicle show (IAA commercial vehicles) 2012. All questions were answered with “still in concept phase”.

Thermo electric generators (TEG): Some semiconductor structures (Peltier element) can convert temperature differences direct into electrical power. This is the Seebeck effect (figure 3.16). Typical Seebeck coefficients are 10 µV/K, so nearly 0.5 Volt can be achieved between exhaust gas (up to 600 °C after turbo charger) and coolant (80 to 100 °C). TEGs deliver high currents at low voltages, so nearly 1000 Watts of electrical power are estimated from the first tests at the ERP research department – without moving parts. Ford USA used these elements in a field trial for SUV’s. To get 24 Volts or more, TEGs need to be connected in series.

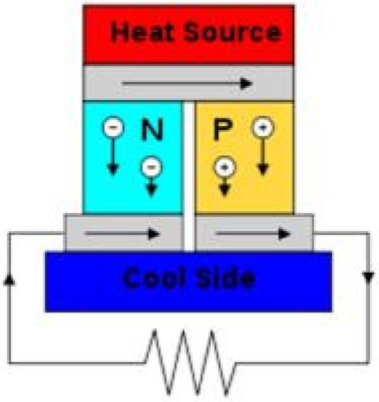


Figure 3.17. Seebeck effect

This is one single exception, where good insulation between hot and cold side won‘t help but a good example for

Insulation/shielding of hot surfaces: Don‘t let the heat radiate, shield it at the source. To keep high temperatures inside the (exhaust gas) system some insulation/shielding can be necessary. This measure also decreases the engine compartment temperatures and can reduce noise radiation of the insulated housing. FMP A0976x is one example where insulation would help to keep the exhaust gas after treatment working, even at low outside temperatures.

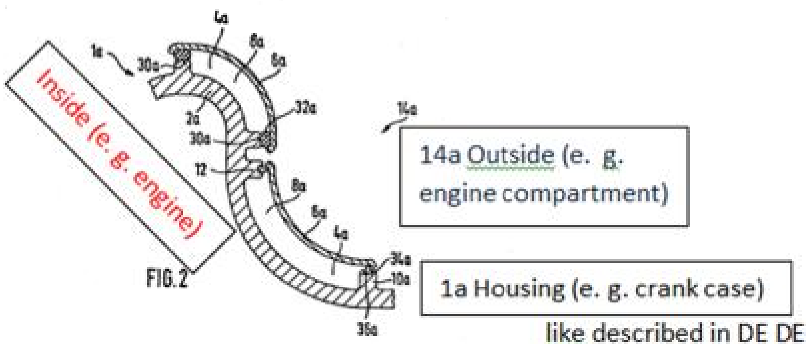


FIG.2

like described in DE DE000019914934A1

Figure 3.18. Drawing/cross section for thermal (and acoustical) shielding of a machine housing

1a Machine housing with insulation

2a Original machine housing (structure, e. g. crank case of a diesel engine)

4a, 8a cavity between structure and shielding, filled with air, insulation material or evacuated

6a shielding, preverably made from sandwich sheet metal (metal-damping material – metal)

10a, 12 rib, beam, reinforcement of the structure

30a, 32a, 34a, 36a different methods for bonding the shielding 6a with the structure 2a at the ribs 10a or 12: bonding, gluing, snapped in special grooves.

4. RESULTS AND DISCUSSIONS

4.1. Solutions According to Fault Elimination Method

Fault (1)

Solution(1) : Future thermal management Measures: Lead the heat (only where it’s needed), don’t let it out, reduce excessive temperatures at the source.

- From exhaust gas via heat exchangers (e. g. for waste heat recovery -> Clausius Rankine Process or TEG – thermo electric generator create electrical power from temperature differences (Peltier-element) into exhaust gas after treatment (Euro 6 without HCI, additional heating or Diesel injection to achieve the necessary conversion temperatures)
- Shieldings/insulation of hot surfaces (e.g. like described in DE000019914934A1_1)
- Air flow optimization(!) through engine compartment (if necessary with additional fans)
- Optimized/larger radiators and/or intercoolers for engine, gear box and retarder (can be cheaper than heat management, HVAC –heating, ventilation, air condition in the passenger
- Use the heat (e. g. for waste heat recovery and exhaust gas after treatment), don’t let it go where it’s not necessary or reduces comfort. This avoids expensive, difficult to plan and (nearly) not documented conversions for specific vehicle types or single vehicles. Some measures can be used in all types of buses, some only in specific types (e. g. double deck)
- Check the conformity of the product not only against legal limits (e. g. emissions and noise “instruction AA BFS 533, wb533.pdf”) but also heat (DIN EN ISO 13732-1) limits. This helps to know and improve properties and behavior of the products. COP (Conformity of Production).

Fault (2) : Current thermal comfort issues at city busses;

Solution(2) :

- Better insulation between engine and passenger compartment
  Insulation with enhanced thickness above Diesel particle filter (DPF)
  Optimized encapsulation beneath Diesel particle filter (DPF)
  Insulation behind interior covers, rear seats and engine compartment
  Extended heat cover at DPF (Diesel particle filter) (1)
- More powerful air condition (2)
- Better heat insulation for exterior engine lids (TI T4006x) (3)
- Additional air vents, better air condition (4)
- Night heater to heat up the engine cooling system (TI T7040xx) (5)

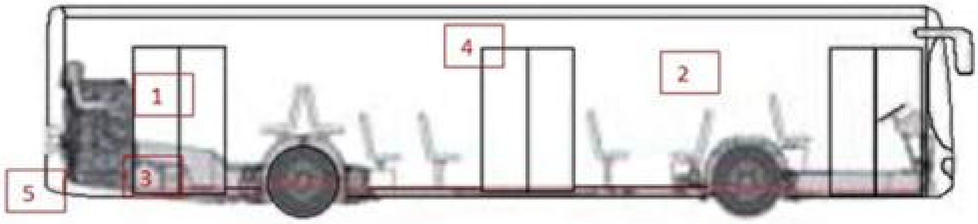


Figure 4.1. Zones/locations of heat issues at city busses

Fault (3) : Current thermal comfort issues at coaches;

Solution(3) :

- Insulation of chassis beams and seat rails. (1,4,5)
- Insulation of piping and heaters for the heating system to prevent them from heating when switched off. (2,3)
- Reflecting and insulation materials in the engine compartment. (FMP A118x) Sheet metal shieldings of hot surfaces (e. g. silencer, exhaust gas after treatment). (6,7)

- Air flow optimization through engine compartment (has caused some dirt and corrosion problems, see FMP A0804x). (6)
- Air management in passenger compartment, e. g. additional air ducts (FMP A7993x BUS-P, Claim of cold air ventilation). (6,7)
- Sealed and insulated lids between engine and passenger compartment. (7)

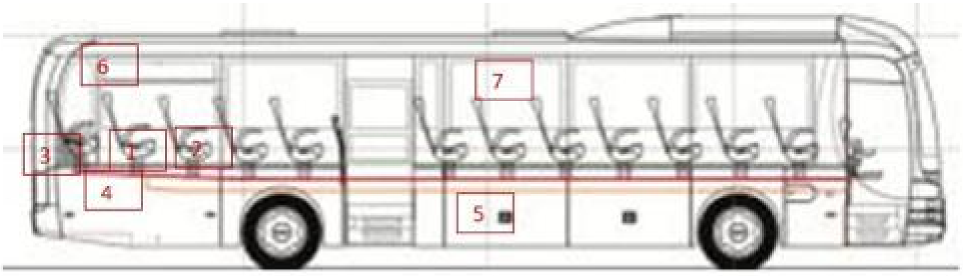


Figure 4.2. Zones/locations of heat issues at coaches

Fault (4) : Heat transfer through the gap between floor and lid is visible in this picture, but not easy to seal. Figure 3.6 illustrates the infrared picture of a closed lid.

Solution(4) : Basically, there are two ways to solve this kind of insulation problem: reflecting and/or absorbing surfaces and optimized sealing of the gap(s). Both solutions can be combined for enhanced effects. Attaching insulation/reflecting material to the lid to reduce heat transfer.

Figure 4.3. Lid in the floor with reflecting surface to the engine compartment and insulation

Fault (5) : The edges of the insulation material are sensitive to wear (chafing) which will affect the sealing and therefore heat) (and noise) can enter the passenger compartment.

Solution(5) : Seal open sharp edges on the insulating mats all round. Either with Terostat 935 sealing paste, or with ALU Cellofoam 40 mm x 33,000 mm adhesive tape. The illustration shows the seal with adhesive tape.

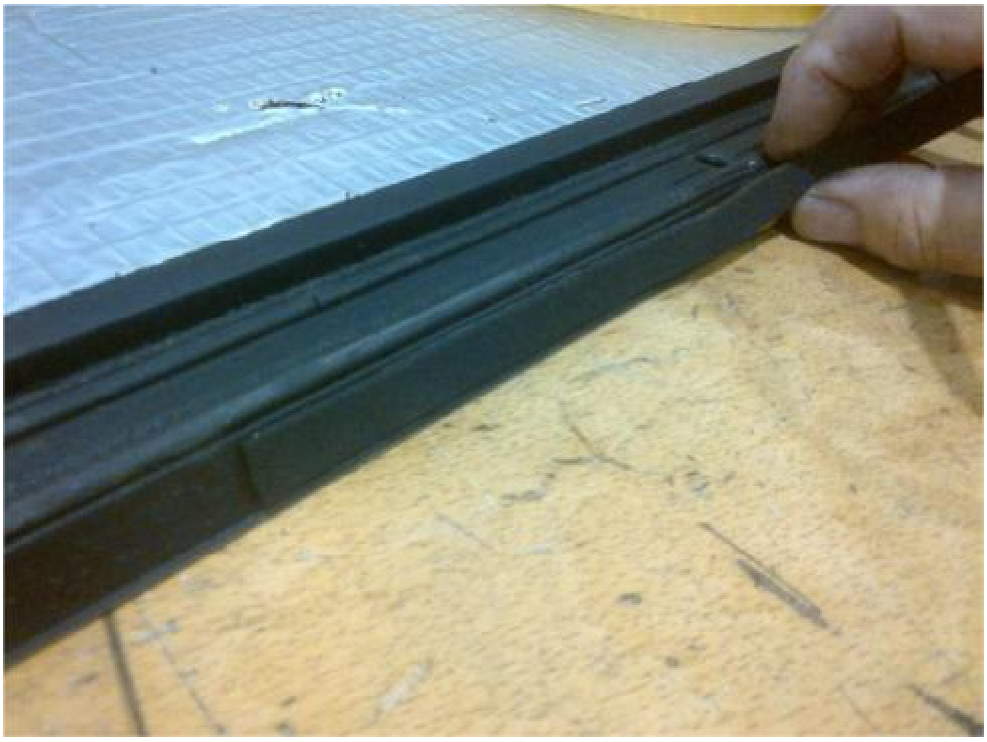


Figure 4.4. Sealing tape 9010 all around the conical outline of the four floor panels in the rear

Fault (6) : Discoloration of exterior engine lids.

Solution(6) : Better insulation with reflecting surface for affected engine lids. Will help for each type of bus, but could lead to more heat inside the engine compartment.

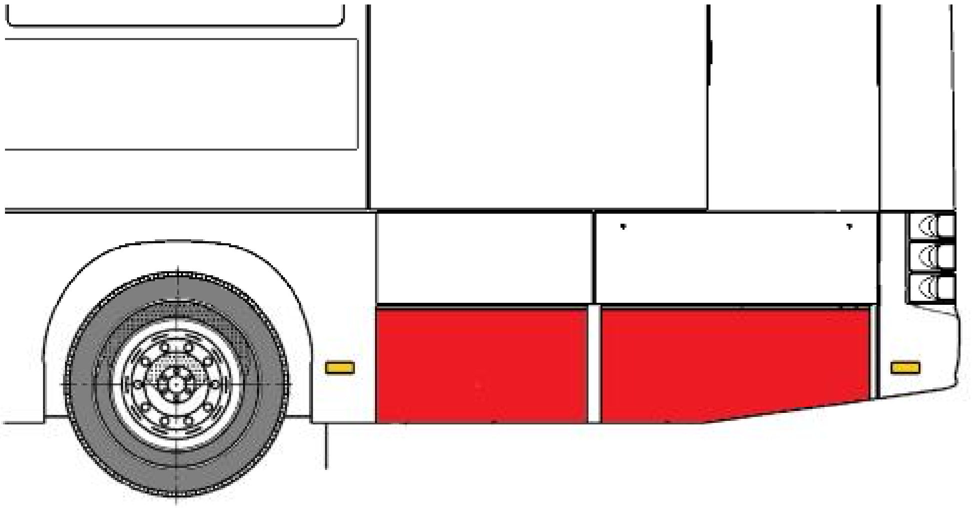


Figure 4.5. Affected discoloured maintenance flaps

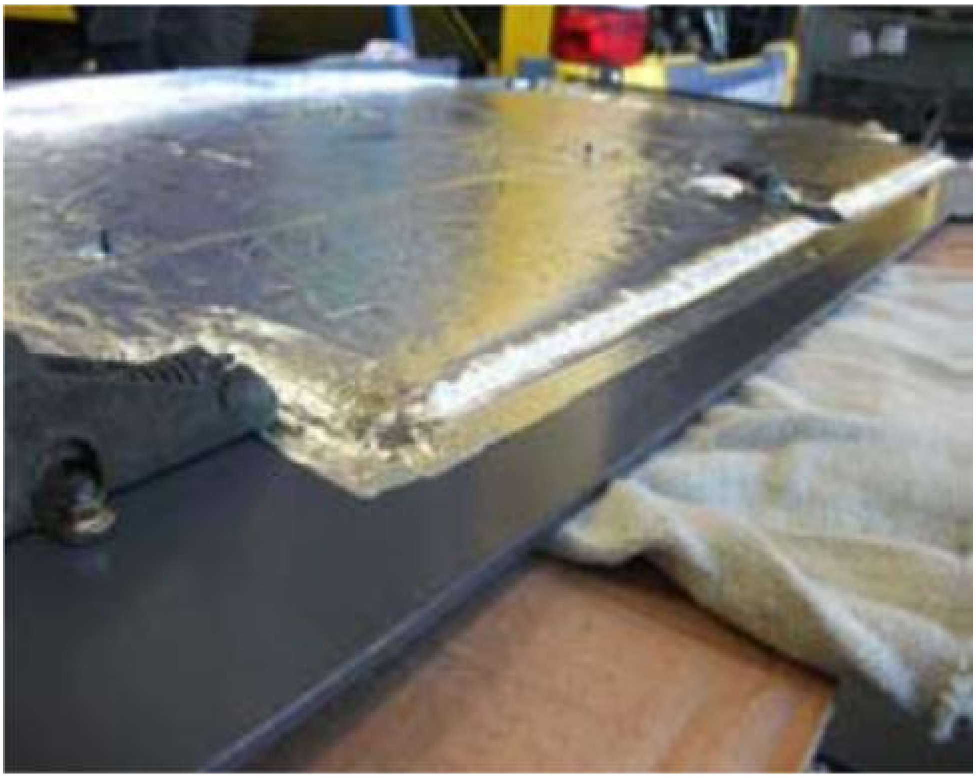


Figure 4.6. Example for a maintenance flap in a city bus after application of insulation mat

Figure 4.7. Maintenance flap with heat reflecting surface and insulation to the engine compartment

Fault (7) : Heat transfer through the floor from in the engine compartment into the interior. Without absorption heat (and noise) can be transferred through the floor and especially through gaps.

Solution(7) : Better insulation with reflecting surface for the engine compartment. Will help for each type of bus, but could lead to more heat inside the engine compartment.

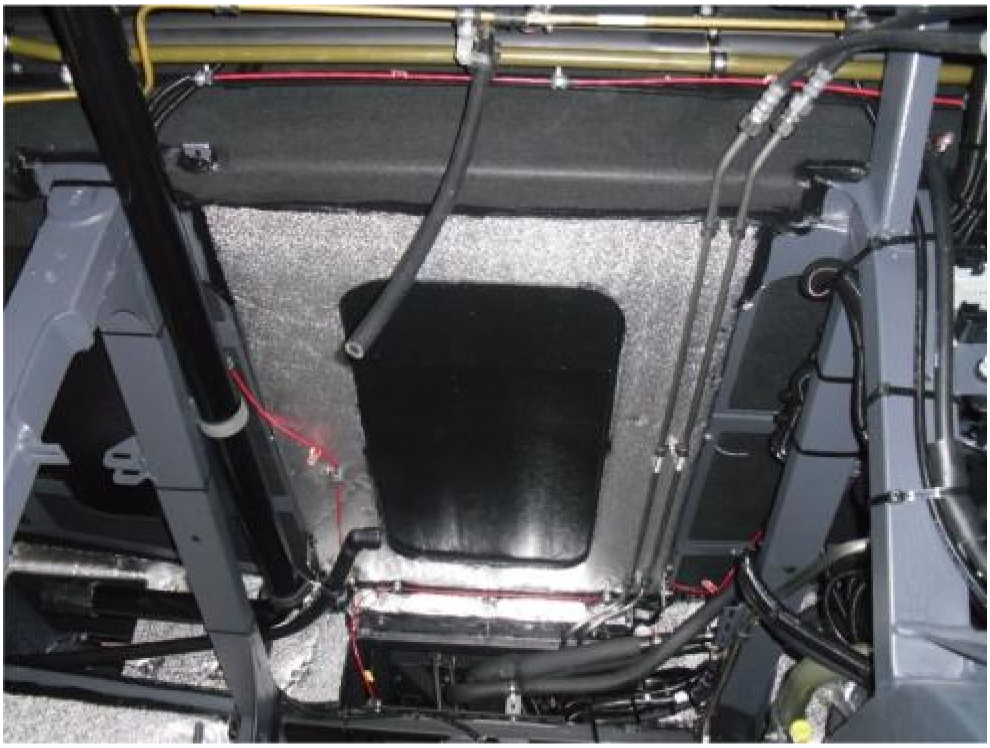


Figure 4.8. Reflecting surface to engine compartment. Beams are not insulated, will heat up and conduct the heat into the interior

Reflecting surfaces are easy to clean (steam cleaner), but reflect heat (and noise) and can cause temperature problems in the engine compartment (hoses, plastic parts of electric equipment, e. g. sockets,)

Fault (8) : Heat transfer through gaps.

Solution(8) : Absorption material between engine compartment and interior. Will help for each type of bus, but could lead to other problems if soaked with (inflammable) fluids.

Figure 4.9. Insulation in the engine compartment for large surfaces to the passenger compartment, but not for chassis beams

Fault (9) : Insulation material absorbs heat and noise, but water, diesel and oil as well. Oil soaked insulation material is dangerous, especially when parts of it are lying on hot surfaces (marten, Marder). Chassis rails without insulation will heat up while driving and transfer the heat into the passenger compartment (e. g. via the seat rails). A new problem is insulation material absorbs heat and noise, but water, diesel and oil as well. Oil soaked insulation material is dangerous, especially when parts of it are lying on hot surfaces (marten, Marder). Chassis rails without insulation will heat up while driving and transfer the heat into the passenger compartment (e. g. via the seat rails).

Solution(9) : Reflective coating at the surfaces of absorption material (for all types of busses) or insulation of the heat sources can be used.

Figure 4.10. Heat reflecting surface in the engine compartment

Fault (10) : Heat from the engine compartment is radiated through the rear corners.
Solution(10) : Fill corners with foam, Will help for all types (apart from some city busses which don’t have these corners)

Figure 4.11. Filling of the corners of travel busses with PU foam

Possible new problem: Foam is difficult to remove if repairs need to be done at the piping. Absorption material is easy to remove but can cause corrosion problems when it stays wet (FMP A43216x corrosion of case brackets).

Fault (11) : Unnecessary heat transfer from engine (and baggage) compartment into the interior.

Solution(11) : Insulation of piping where possible

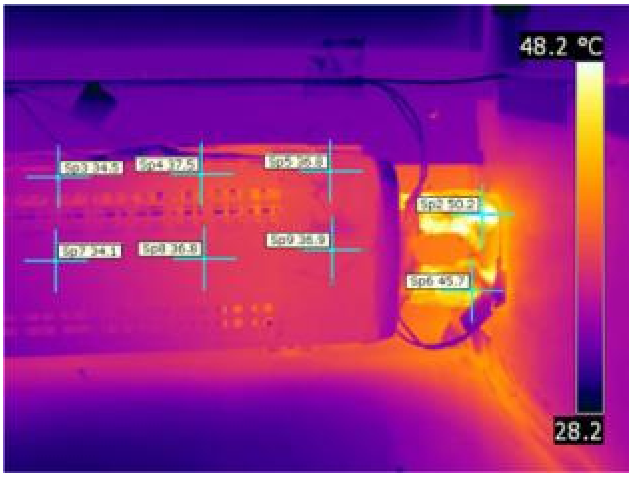


Figure 4.12. Infrared picture of a heater (switched off) and piping

Figure 4.13. Insulation for the piping to the heaters, the bracket ist made of plastic

Mounting brackets need to be strong and flexible (temperature differences), but must not transfer heat (or structure borne noise) into the chassis. Insulation of the piping prevents from unnecessary heat transfer in all types of busses.

Fault (12) : Temperature differences between seats exceed limits.

Solution(12) : Additional air ducts reduce temperature differences between different seats. Will help in each type of bus (in city busses frequently opened doors limited effect).

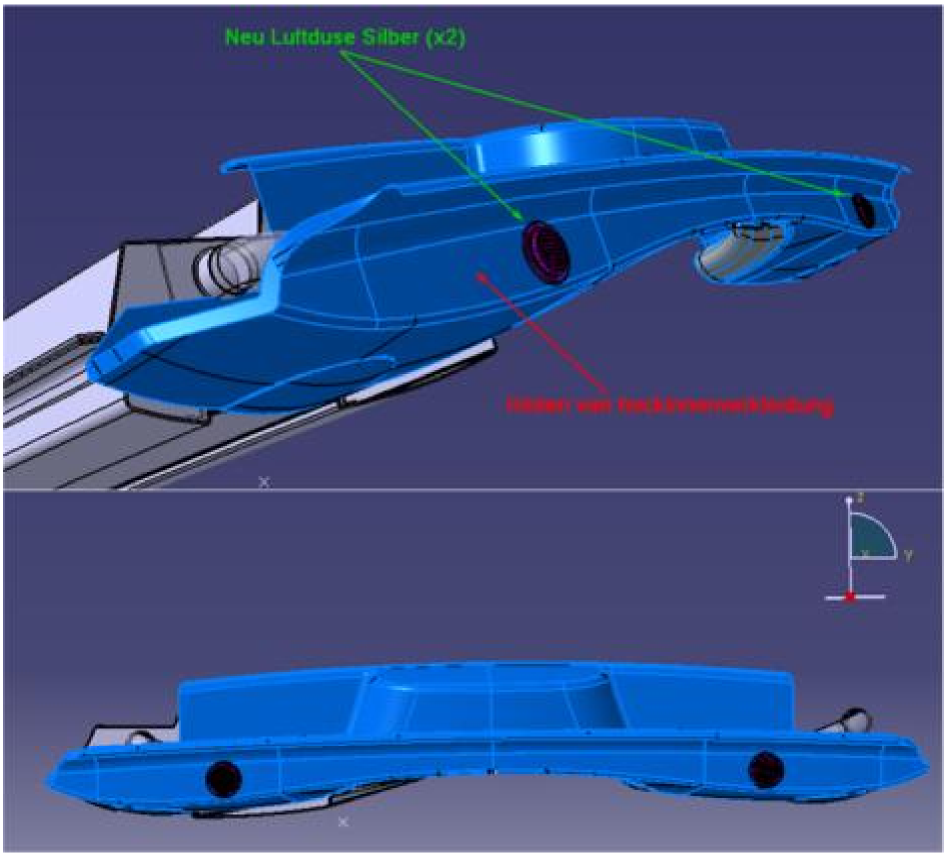


Figure 4.14. Additional air ducts in the rear part of the passenger compartment

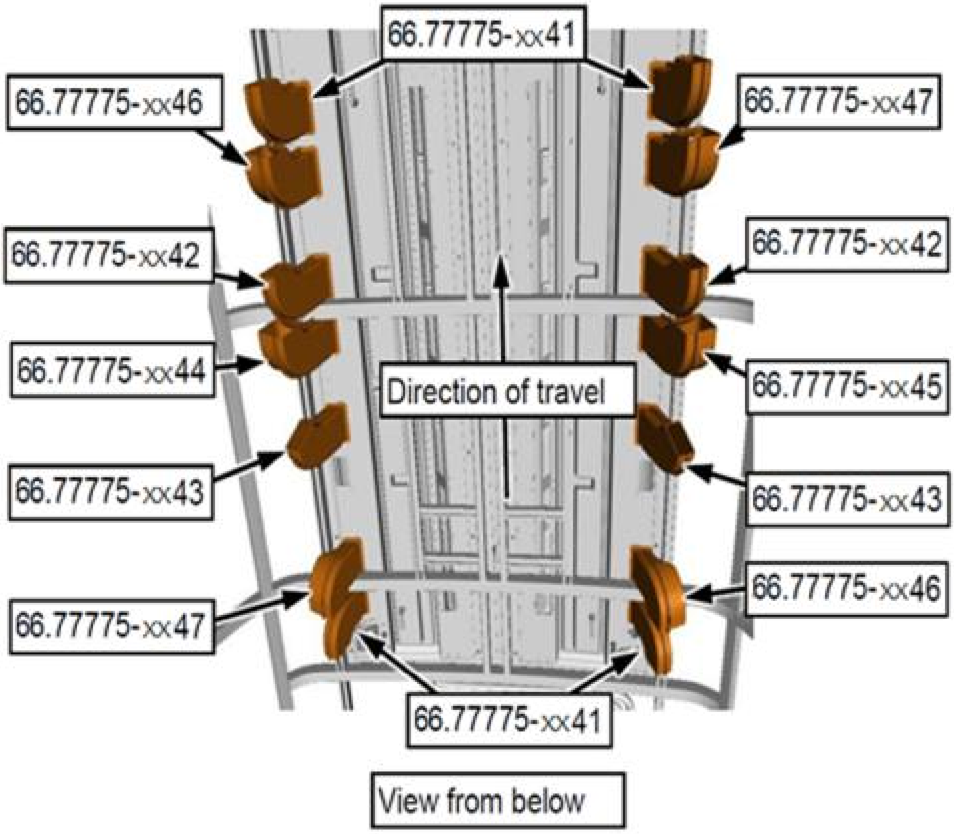


Figure 4.15. Additional air ducts in the passenger compartment (TI 667XX1)

Fault (13) : Excessive heat in the engine compartment is not vented to the outside.
Solution(13) : Better ventilation for engine compartment will help in each type of bus (low floor, intercity, travel busses and coaches).

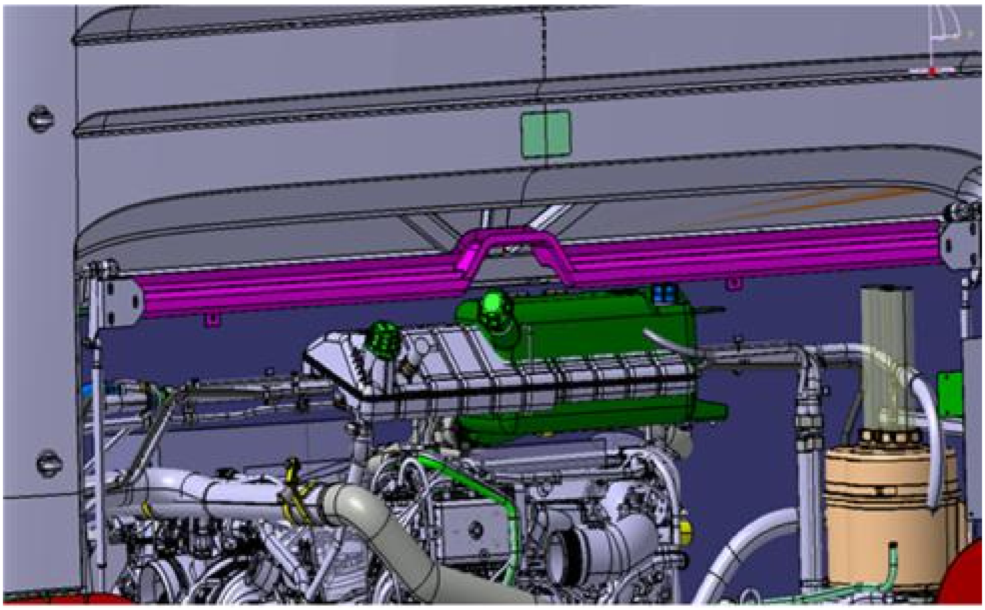


Figure 4.16. 3D drawing of the rain channel to guide rain and dirt away from the engine

Figure 4.17. Photo of the rain channel

This measure will help at least for coaches and regional traffic, sometimes for city busses, depending on the average speed (drag, air flow) of the affected vehicle. For better air flow through the engine compartment the rain channel was left, which led to a new problem FMP A20804x (Water, salt and dirt enter the engine compartment and were sprayed around by pulleyes dirt and corrosion while driving the vehicle from the factory to the customer).

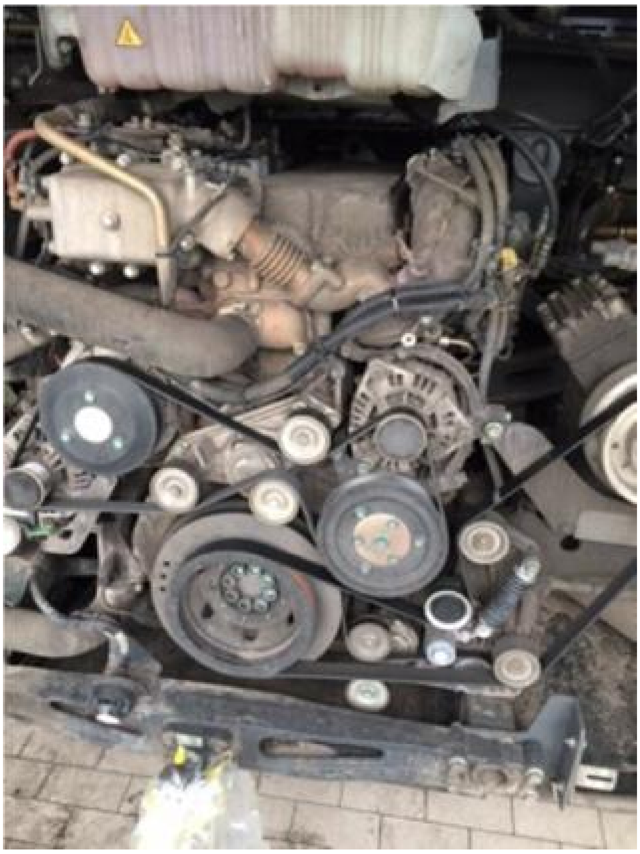


Figure 4.18. Dirt and corrosion at engine and auxiliaries

New solution: Optimized rain channel with gaps, picture 2.21. Ventilation of engine compartment without water ingress.

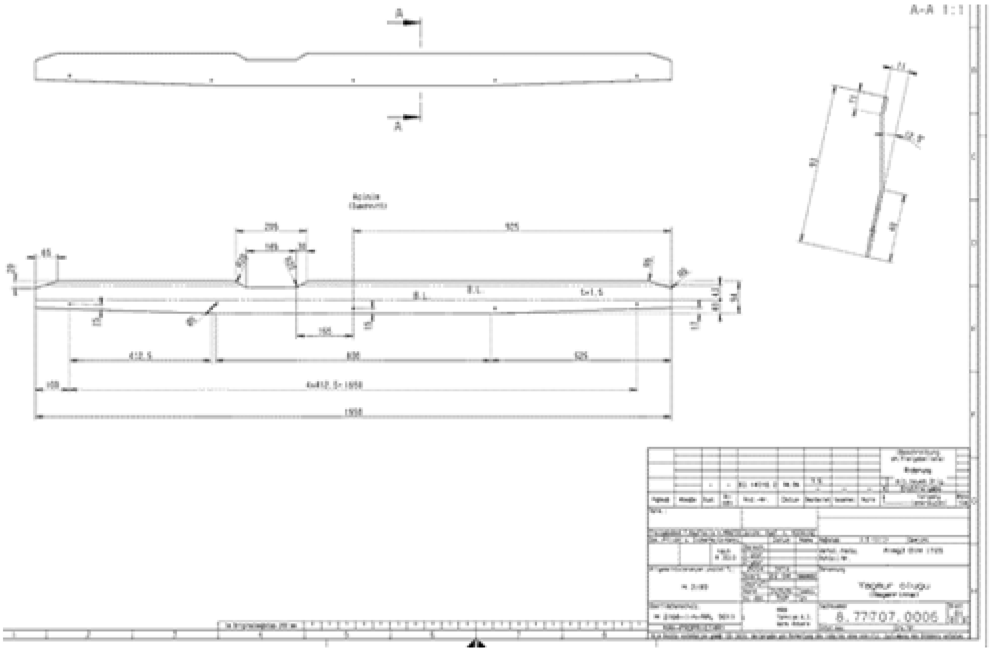


Figure 4.19. Rain channel 8.77770-006 with ventilation gaps

Figure 4.20. Engine lid with vents

Fault (14) : Seat mounting is safety relevant (seat belts are mounted at the seats, not at the chassis) . Good mechanical contact to chassis is necessary. Therefore heat (and structure born noise) is transferred from the chassis to the seat rail. Plastic cover helps against heat radiation and keeps dirt outside of the seat rail.
Solution(14) : Plastic cover for seat rail.

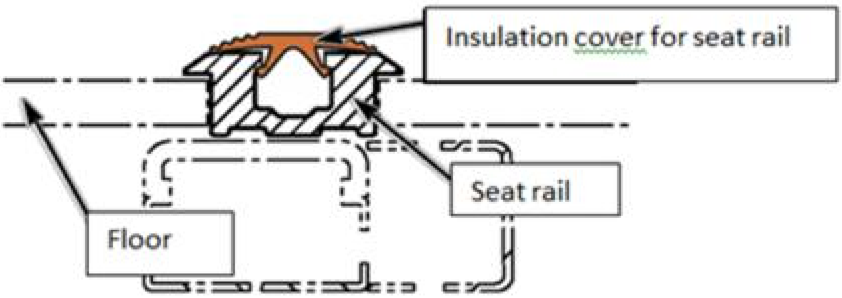


Figure 4.21. Cross section drawing for mounting the seat rail cover

This measure will help in bus types with seat rails, not in city busses.
Fault (15) : Excessive heat is transferred via battery and baggage compartment into the passenger compartment.
Solution(15) : Add insulation material to chassis beams (also in documentation), increase the thickness of insulation material from 8 mm to 16 – 20 mm where possible. Will help for coaches and busses for regional traffic (city busses don’t have baggage compartments).

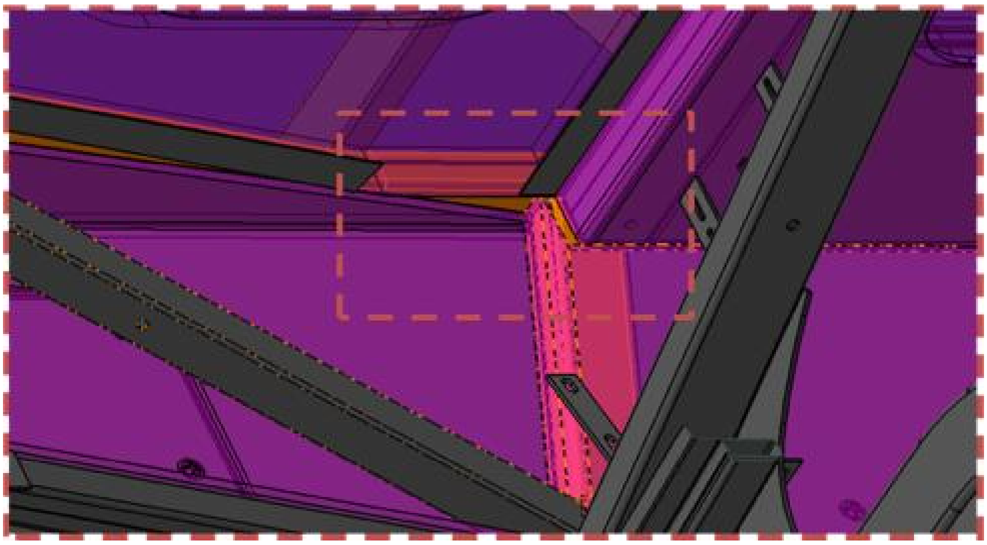


Figure 4.22. Draft for better insulation of chassis beams

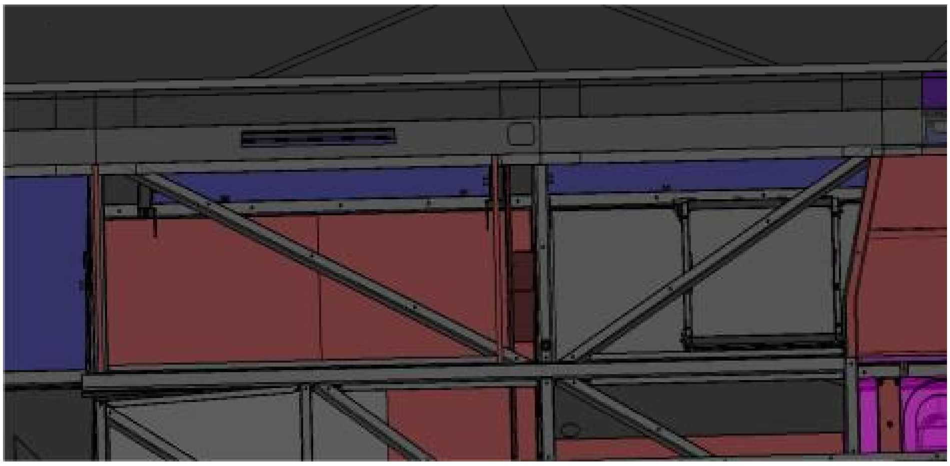


Figure 4.23. Drawing for better air ventilation in battery and baggage compartment

Figure 4.24. Photo for better air ventilation in battery and baggage compartment

Some of the above described measures will help at each bus type (e. g. better insulated and sealed lids), some are only applicable for specific bus types. The effect of some ventilation measures depends on the speed (drag, air flow around the vehicle) of the affected vehicle which need to be validated through tests or simulations.

After application some of these modifications signs to a app. 20% effectiveness at these areas

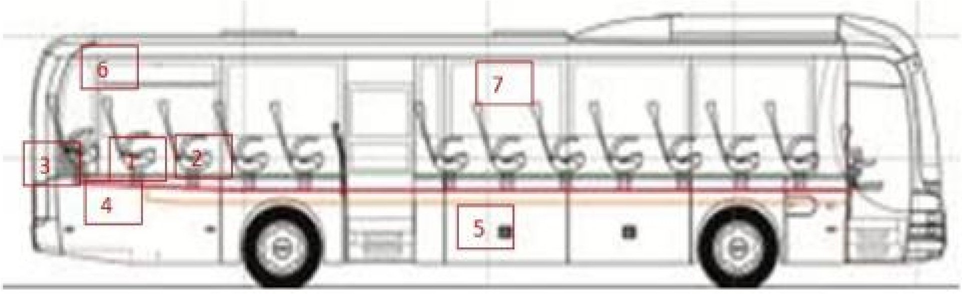
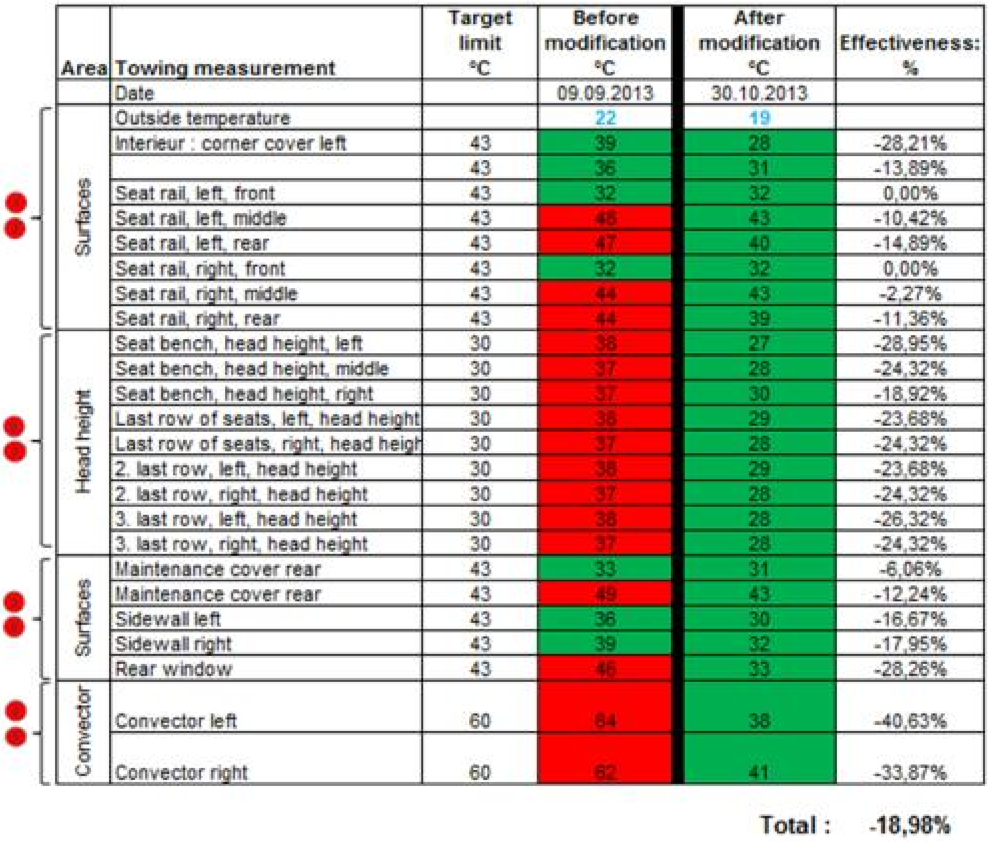


Figure 4.25. Measurement points on the bus

Table 4.1. Test results before and after modification



Area	Towing measurement	Target limit °C	Before modification °C	After modification °C	Effectiveness: %
	Date		09.09.2013	30.10.2013	
Surfaces	Outside temperature		22	19	
	Interieur : corner cover left	43	39	28	-28,21%
		43	36	31	-13,89%
	Seat rail, left, front	43	32	32	0,00%
	Seat rail, left, middle	43	48	43	-10,42%
	Seat rail, left, rear	43	47	40	-14,89%
	Seat rail, right, front	43	32	32	0,00%
	Seat rail, right, middle	43	44	43	-2,27%
	Seat rail, right, rear	43	44	39	-11,36%
Head height	Seat bench, head height, left	30	38	27	-28,95%
	Seat bench, head height, middle	30	37	28	-24,32%
	Seat bench, head height, right	30	37	30	-18,92%
	Last row of seats, left, head height	30	38	29	-23,68%
	Last row of seats, right, head heigh	30	37	28	-24,32%
	2. last row, left, head height	30	38	29	-23,68%
	2. last row, right, head height	30	37	28	-24,32%
	3. last row, left, head height	30	38	28	-26,32%
	3. last row, right, head height	30	37	28	-24,32%
Surfaces	Maintenance cover rear	43	33	31	-6,06%
	Maintenance cover rear	43	49	43	-12,24%
	Sidewall left	43	36	30	-16,67%
	Sidewall right	43	39	32	-17,95%
	Rear window	43	46	33	-28,26%
Convector	Convector left	60	64	38	-40,63%
	Convector right	60	62	41	-33,87%
				Total :	-18,98%

5. CONCLUSIONS

Some of the solutions described in this study – especially the venting solutions - are based on the assumption, that the inside of the bus (from engine to passenger compartment) has higher temperatures than the outside. These remedies won’t help in some hot regions at some hot times. Some measures won’t help without additional measures, e. g. reflecting material reduces heat transfer, but increases engine compartment temperatures ventilation necessary could lead to noise emissions and dirt ingress into the engine compartment. All insulation measures are limited by available space (thickness), costs and weight.

Gas engines don’t need complicated exhaust gas after treatment but radiate more heat than diesel engines because the Otto combustion process is less effective than the Diesel process.

Sometimes, minimum temperature levels are not achieved (1st trip in the morning in scandinavian countries), especially at the driver´s seat. In these cases some more “heat” is necessary to fulfill customer requirements (e. g. FMP A0799x).

Don’t let the heat out, use it for exhaust gas after treatment (without hydro carbon injection - HCI) and waste heat recovery, which means leading the heat.

Some insulation at the engine housing and exhaust gas manifold is needed to use the heat for exhaust gas after treatment and/or waste heat recovery. Imagine exhaust gas after treatment with HCI (hydro carbon injection = burning diesel to increase the temperature which) causes higher temperatures in the engine compartment which need higher AC power to cool down the passenger compartment. You can save fuel three times: exhaust gas after treatment (nearly) without HCI, waste heat recovery which converts waste heat to electrical power and is not available to heat up the environment and don’t need to cool down by powerful air condition systems.

Insulation at the heat source(s) saves space, material and costs and is a good example for leading the heat saves space, material and therefore costs. In technical acoustics primary measures (e. g. balancing shafts reduce vibration ant the source) and secondary measures (reduction of noise transfer and/or reception, e. g. softer engine mounts) in this special field of thermal comfort it is very difficult to develop primary measures (diesel engines generate less heat than gas engines). But as a rule of thumb for insulation measures: The closer to the source, the better the efficiency.

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