

本田財団レポート 102
第23回本田賞授与式 記念講演（2002年11月15日）

自動車排気の触媒による浄化

ジョンソン・マッセイ社
カタリティック・システムズ部門 副社長
バリー J. クーパー博士

The Catalytic Control of Motor Vehicle Emissions

Commemorative Lecture at the Twenty-Third Honda Prize Awarding
Ceremony on the 15th November 2002 in Tokyo

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Barry John Cooper

Vice President, Catalytic Systems Division
Johnson Matthey



略歴

1942 年	英国 ベッドフォードシャー州ルートンで生まれる
1964 年	ルートン・カレッジ・オブ・テクノロジーで B S 学士号を取得
1966 年	インペリアル・カレッジ化学技術工学部で修士号取得
1976 年	ロンドン大学で博士号取得
1964 ~ 77 年	ジョンソン・マッセイ P L C テクノロジー・センター（英国）に勤務
1977 ~ 79 年	トロンドハイム大学応用化学部附属 SINTEF 研究所（ノルウェー）に勤務
1979 年 ~ 現在	ジョンソン・マッセイ INC（米国）に勤務 主任サイエンティスト、開発マネジャー、技術部長、技術担当副社長を経て、現在、Diesel Emission Control System 担当副社長

受賞歴：

1980 年	自動車排気制御用 3 元触媒の開発により、Fellowship of Engineering(現王立工学アカデミー)の MacRobert Award を受賞（英）
1990 年	SAE(Society of Automotive Engineering)技術文献への顕著な貢献を認められ、同会の Arch T. Colwell 功労賞を受賞（米）
1992 年	SAE フェローに選出（米）
1994 年	先進の自動車排気制御用 3 元触媒の開発により、Honda Supplier Award for Technology Development を開発チームリーダーとして受賞
2000 年	貴金属科学への顕著な貢献により、International Precious Metals Institute から Henry J. Albert メダルを受賞（米）
2000 年	CRT（連続再生式トラップ）方式のディーゼル有害微粒子除去システムの発明・開発に対して、二度目の MacRobert Award を受賞（英）
2000 年	自動車排気制御の先進技術に対して、Manufacturers of Emission Control Association から特別功労賞を受賞（米）
2001 年	ガソリンエンジン排気制御委員会議長としての功績に対して、特別功労賞を受賞（米）

Personal History

1942	Born in Luton, Bedfordshire, England
1964	B.Sc. in Luton College of Technology, England
1966	Diploma of Imperial College in Chemical Engineering at Imperial College, London
1976	Ph.D. at London University
1964-77	Employed in Johnson Matthey Plc., Technology Center, England
1977-79	Employed in SINTEF, Department of Applied Chemistry at University of Trondheim, Norway
1979-	Employed in Johnson Matthey Inc., U.S.A. as Principal Scientist, Development Manager, Technical Director, Vice President (Technology), now Vice President of Diesel Emission Control Systems

Awards:

1980	The MacRobert Award for the development of Three-Way Catalysts for Automotive Emission Control from the Fellowship of Engineering, now the Royal Academy of Engineering, UK The Arch T. Colwell Merit Award from the Society of Automotive Engineers, USA for outstanding contribution to SAE technical literature
1992	Elected to SAE Fellow from the Society of Automotive Engineers
1994	Team Leader for the Honda Supplier Award for Technology Development for advanced Three-Way Emission Control Catalysts
2000	The Henry J. Albert Award for significant contribution to research advancing the use of Precious Metals from the International Precious Metal Institute, USA
2000	The MacRobert Award from the Royal Academy of Engineering, UK. for the development of the Continuously Regenerating Trap for control of Diesel Particulate Emissions
2000	The Manufacturers of Emission Control Association Award for Outstanding Contributions in the development of Advanced Motor Vehicle Emission Control Technology
2001	The Special Achievement Award from the Manufacturers of Emission Control Association in recognition of Leadership as Chairman of the Gasoline Engine Emission Control Committee

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Johnson Matthey

Good Evening ladies and gentlemen.

Minasama Konnichiwa

I am here this evening as the proud recipient of the Honda Prize to tell you about the contributions I have made to the development of Catalytic Convertors - those magic boxes in the exhaust pipe of your car that have done so much to make the air cleaner for us all. But first I would like to start by acknowledging key people who have brought me here this evening

My sincere thanks go of course to the Honda Foundation for electing me as this year's prizewinner and to Mr. Kawashima for his kind welcome to my wife and I.

I would also like to personally thank staves for their kind support in preparing me for the prize ceremony.

I would like to thank the Directors of Johnson Matthey and I would also like to recognize particular colleagues at Johnson Matthey with who I have worked with in my 30 years of developing catalytic emission control systems.

They are Gary Acres, Brian Cooper, David Evans and Dennis Webster who started Johnson Matthey's first program in catalytic emission control for motor vehicles in 1970. I would also like to acknowledge Jim Thoss, Pelham Hawker and Par Jones They were my colleagues in the development and commercialization of our Continuously Regenerating Trap system for control of diesel particulate emissions in the 1990's.

I indebted to Sir Alec Broers and Britain's Royal Academy of Engineering for nominating me for this prize.

Particular thanks go to Mr. Tadayoshi Hayashi of Honda and Dr. Hideaki Muraki of Johnson Matthey who solicited independent letters of support for my nomination from Professor Misono and Professor Daisho.

Thanks also to my old friend Professor Trimm who is here all the way from Australia. He welcomed me as a fresh PhD student and taught me what a catalyst is when I was very very young.



Figure 1

My talk today is all about cleaning up the air by removing exhaust emissions from motor vehicles using catalytic convertors. This is a device that converts harmful gases in the exhaust of your car to clean nitrogen water and carbon dioxide.

If you drive a car ---- you have one of these highly effective devices which are so beneficial to our environment in the exhaust pipe of your car.

The Honda Company truly follows the advocacy of the Honda Foundation, and its founder, Mr. Soichiro Honda in developing products that are of benefit to human civilization. These products are geared towards harmony with both the environment and surrounding human activities.

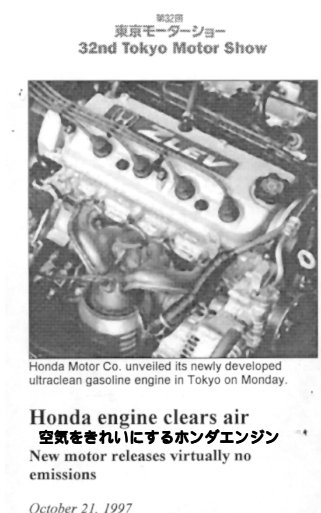


Figure 2

The Honda organization is synonymous with the production of very high quality, environmentally friendly vehicles. Indeed, the latest vehicles produced by Honda are powered by engines that are the lowest emitters of pollutant gases in the world. They meet or exceed the most stringent emission legislation in the world.

The ability of motor vehicles today to produce virtually zero exhaust emissions is due to the development of sophisticated catalysts and engine control systems. This enables over 98% of exhaust pollutants emitted from the engine to be removed by catalytic means.

But first lets turn the clock back to the 1960s.....

In the 1960's a vehicle without any emission control devices would emit over 100 grams of pollutant for every mile driven.

This meant that all the motor vehicles in America would emit over over 120 million tonnes of exhaust pollutants every year. That is equal to 14 tonnes of pollution over every square kilometer of land area.

Fortunately, today exhaust emissions are much lower as a result of technological advances and government enforced regulations. Today's emission levels are 98% lower at just over 2 million tonnes or 0.3 tonnes per square kilometer.

Emission Standards						
United States (g/mile)			排気規制値			
Year	HC	CO	NOx			
Pre-Control	9	90	3.1			
1975	1.50	15	3.1			
1977	1.5	15	2			
1980	0.41	7	2			
1981-U.S.	0.41	3.4	1			
1994-U.S.	0.25	3.4	0.4			
1993-Calif	0.25	3.4	0.4			
1994-TLEV	0.125	3.4	0.4			
1997-TLEV	0.075	3.4	0.2			
1997-2003 ULEV	0.04	1.7	0.2			
2004 ULEV2	0.04	1.7	0.5			
2004 SULEV2	0.01	1.0	0.02			

Japan (g/Km)						
Year	CO		HC		NOx	
	max	mean	max	mean	max	mean
1976	2.7	2.1	0.39	0.25	0.84	0.6
1991	2.7	2.1	0.39	0.25	0.48	0.25
2002	1.27	0.67	0.17	0.08	0.17	0.08

Figure 3

This slide shows how emission legislation has moved from 1975 through to today for the United States and Japan.

Vehicles are now capable of meeting these stringent standards. And Catalytic Convertors are the reason they do.

My purpose here tonight you how I was involved in making this happen.

My role in this story started in the Johnson Matthey Laboratories in 1970.

So welcome to my story.....



Figure 4

Actually the tale begins in the 1950's when Photo-chemical smog - the brown haze we see in the air - was becoming a persistent problem in the Los Angeles basin. It was also later seen in Tokyo *and other large cities*.

Research by Professor Haagen-Smit in California showed that the smog was due to a reaction between nitrogen oxides and hydrocarbons *in the air*.

Measurements showed that cars were responsible for 70% of the hydrocarbon emissions and 60% of the nitrogen oxide emissions in the air.

These observations were responsible for the strict legislation to control emissions from motor vehicles. Legislation to control these emissions occurred at almost the same time in the United States in 1975, and in Japan in 1976.

The severity of this new legislation required a new approach to the control of emissions. Catalytic devices were shown to have great promise in the race to lower emissions. The challenges to make catalytic convertors work were formidable. My presentation aims to show you how some of the key challenges were overcome. And how work in the Johnson Matthey laboratories has made a significant contribution to this challenge.

So how do Catalytic Convertors work?

To understand this lets look at what a catalyst is,

Lets look inside the convertor

and lets look at the chemical reactions that occur over a catalyst....

The classic definition of a catalyst is a substance that can speed up a chemical reaction without itself being used up.

In exhaust emission control, we remove pollutants by a chemical reaction on a solid catalyst surface.

The path of the reaction is altered by the presence of the catalytic surface. This happens by the formation of surface chemical compounds - the pollutants stick to the surface and react.

Now let us look inside the catalytic convertor and find out more about this catalyst.....

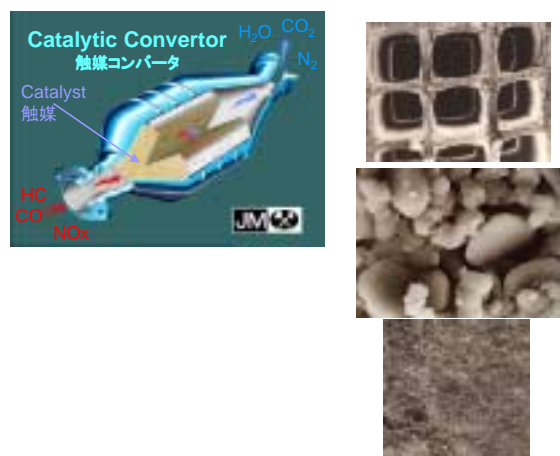


Figure 5

Here we see a picture of a catalytic convertor in the upper left of the slide. You can clearly see how the catalyst is contained inside the steel can of the catalytic convertor.

Microscope pictures inside the catalyst are shown on the right.

The top right picture shows the channels through which the exhaust gas flows.

The middle picture shows the particles of catalyst coated on the channel walls.

The bottom right picture shows a high magnification picture of the crystallites inside these particles.

The catalytic coating contains platinum group metals. These are typically platinum, palladium or rhodium. These metals drive the catalytic process, and the reactions take place on the surface of tiny metal crystals in the catalyst coating.

Later we will explore this micro structural world and look at catalyst design.

But first what are the catalytic reactions??? *Let us look at some chemistry.....*

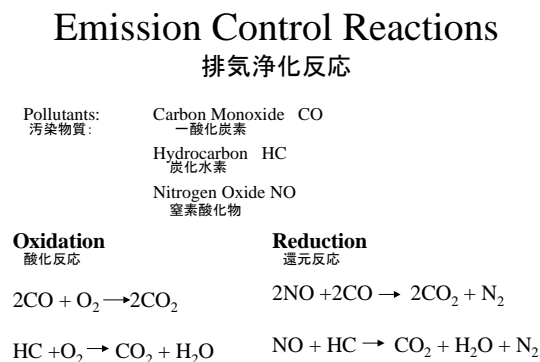


Figure 6

Emission control reactions are really quite simple. They can be divided into oxidation reactions and reduction reactions.

The pollutants from a gasoline engine are the poisonous gas carbon monoxide together with hydrocarbons from unburnt fuel. These are formed by incomplete combustion of gasoline.

In addition a third pollutant nitrogen oxide is also formed from nitrogen and oxygen at high temperature in the combustion chamber of the engine.

The reactions that occur under oxidizing conditions are the reaction of carbon monoxide with oxygen to produce carbon dioxide, and the reaction of hydrocarbon with oxygen to produce carbon dioxide and water.

Nitrogen Oxide is removed by a reduction reaction with carbon monoxide and hydrocarbon to produce nitrogen.

Having looked at what a catalytic converter is, and how it works, let's go back to the 1970s and the first experiments

In 1970 the big problem for a catalytic converter was the high emissions that occur when a car is started from cold. The catalyst needs to reach its operating temperature or so-called light-off temperature before it starts to work.

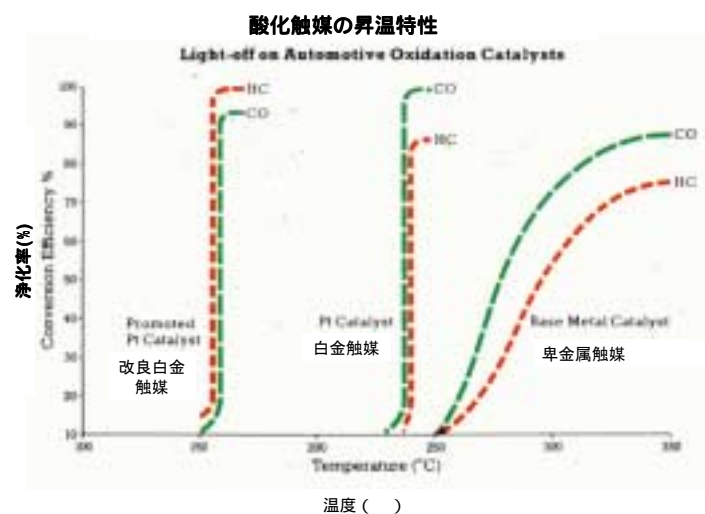


Figure 7

Our first experiments focused on lowering the light-off temperature of the catalyst so that the catalyst would work better under cold conditions.

This slide duplicates some of the early test results reported in our first research report on design of catalysts for exhaust emission control. The vertical axis shows conversion, and the horizontal axis is temperature.

The results show that a platinum catalyst has a lower light-off temperature than a base metal catalyst.

However, we discovered that we could lower the platinum catalyst light-off temperature further by promoting the platinum catalyst by other platinum group metals,

The promoted catalyst was also found to be very effective for controlling nitrogen oxide emissions.

The promoted catalyst used rhodium in addition to platinum.

米国特許			
United States Patent [19]		[11]	3,951,860
Acres et al.		[45]	Apr. 20, 1976
<hr/>			
[54]	CATALYST	3,397,154	8/1968 Tatem..... 252/463
[75]	Inventors: Gary James Keith Acres; Barry John Cooper, both of London, England	3,476,508 11/1969 3,565,574 2/1971 3,565,830 2/1971 3,615,166 10/1971 3,741,725 6/1973	Kearby et al. 423/213 Kearby et al. 423/213 Keith et al. 252/466 PT Hindin et al. 252/466 PT Graham 252/466 PT
[73]	Assignee: Johnson, Matthey & Co., Limited, London, England	FOREIGN PATENTS OR APPLICATIONS	
[22]	Filed: Nov. 20, 1972	413,967 7/1934	United Kingdom..... 423/214
[21]	Appl. No.: 307,823	623,256 7/1961	Canada 423/239
		662,460 12/1951	United Kingdom..... 423/213.2
[30] Foreign Application Priority Data		Primary Examiner—W. J. Shine	
	Nov. 22, 1971 United Kingdom..... 54038/71	Attorney, Agent, or Firm—Cushman, Darby & Cushman	
	Nov. 22, 1971 United Kingdom..... 54039/71		
[52]	U.S. Cl. 252/432; 252/455 R; 252/462; 252/466 PT; 423/213.5	[57] ABSTRACT	
[51]	Int. Cl. ² B01J 21/02; B01J 23/56	This invention relates to a catalyst comprising an inert material impregnated or coated with a mixture or alloy of platinum and rhodium in which rhodium is present in an amount up to 20 wt.%. The catalyst is particularly suitable for use in 1) catalytically reducing an oxide of nitrogen in a gaseous stream, 2) the oxidation of an organic compound in a gas also containing oxygen and 3) the preparation of methane by the steam reforming of naphtha or naphtha distillates.	
[58]	Field of Search..... 252/462, 466 PT, 432, 252/455 R, 455 Z, 460; 423/213, 214		
[56] References Cited		5 Claims, 7 Drawing Figures	
	UNITED STATES PATENTS		
	3,065,395 11/1962 Gary 423/213 X		
	3,118,727 1/1964 Cohn 423/239		
	3,259,453 7/1966 Stiles 423/214		
	3,346,328 10/1967 Sergeys et al. 423/213		

Figure 8

The discovery was filed as a patent in November 1971, and the patent was granted in April 1976 as US Patent number 3,951,860

The catalyst was subsequently tested on a vehicle according to the new **1970** US Test procedure. This test was difficult to pass as it incorporated a cold start, and so it was a real challenge for the new catalyst system.

So what is this test.....

The US vehicle emission test was developed in the early 1970's based on driving in the Los Angeles area.

Transient test cycles were developed to get realistic vehicle emission measurements based on driving patterns around Los Angeles

**US Test Procedure (FTP)
(Phases 1 and 2)**

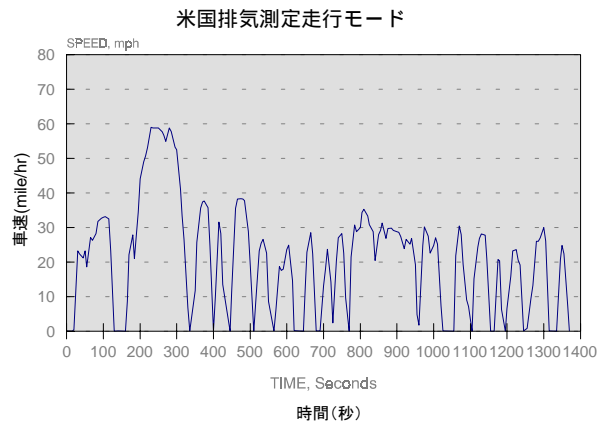


Figure 9

The US test procedure is shown in this slide, where vehicle speed is plotted against time of the test. A vehicle must be driven following this speed trace while emissions are collected from the exhaust of the car.

Similar, but not identical, tests are now in place in Japan and in Europe.

The test is carried out by placing a vehicle on a dynamometer. The vehicle is driven while following the speed trace on a monitor placed alongside the vehicle.

**First Johnson Matthey Test Car
最初のジョンソン・マッセイの実験車両**



Figure 10

This historic slide from the 1970's shows Johnson Matthey's first test car undergoing tests with the new platinum/rhodium catalyst in our laboratory in Royston, England.

After developing the platinum/rhodium catalyst Johnson Matthey contracted Ricardo Engineering in England to carry out a 25,000 mile (40,000km) durability trial.

Johnson Matthey's First Durability Test Vehicle
ジョンソン・マッセイの最初の耐久実験車両

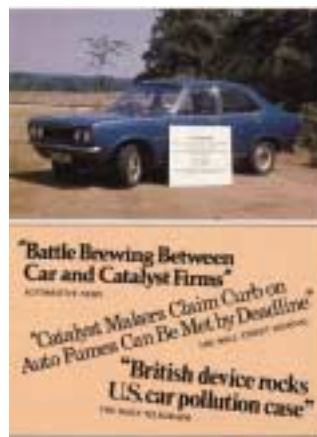


Figure 11

The car we used was a Chrysler Avenger and is shown in this slide.

Johnson Matthey's successful 25,000-mile demonstration of the platinum/rhodium catalytic converter in 1972 was highly acclaimed. It proved it was possible pass the level of emissions in the new US 1970 Clean Air Act.

The results were presented at a hearing held by the United States Environmental Protection Agency. The landmark results were widely reported as shown by the headlines from British newspapers at that time.

At the same time our attention was focussing on high volume manufacture of monolith catalysts for catalytic convertors. This, in itself, proved to be a substantial technical challenge.

The task was to coat ceramic monoliths containing a hundreds of small parallel channels with high surface area catalytic materials efficiently and reproducibly.

Washcoating Monolith Supports モノリス担体への触媒担持



Figure 12

The technique adopted by Johnson Matthey was to washcoat the catalytic materials onto monoliths using a waterfall technique. Here we see a ceramic monolith passing through the waterfall of catalyst material. Some really clever chemistry was required control the properties of the coating during the process - but we will not go into that here.

The manufacturing process was successfully developed and entered into production in 1974 at Royston in the United Kingdom and Wayne, Pennsylvania in the United States.

Today Johnson Matthey has 9 production plants around the world producing emission control catalysts.

Catalytic convertor systems continued to develop rapidly over the next five years.....

Conventional Oxidation Catalyst (COC) Ca. 1975 酸化触媒システム

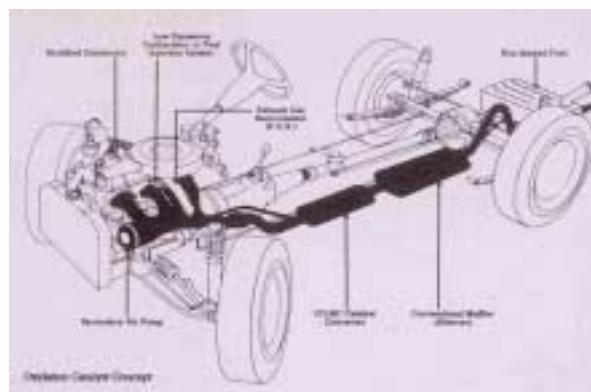


Figure 13

In 1975, the car companies adopted the conventional oxidation catalyst.

A single catalyst was used to control carbon monoxide and hydrocarbon emission. An Air Pump was used to provide air in front of the catalytic converter for the oxidation process.

Dual Bed Converter (DBC)
Ca. 1978 2段触媒システム

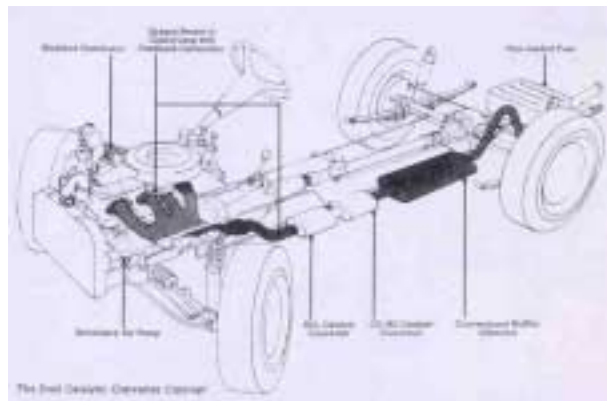


Figure 14

In 1978, the dual-bed converter was introduced to obtain NO_x control in addition to carbon monoxide and hydrocarbon control. In this case, the engine was tuned rich and a converter capable of reducing nitrogen oxides was placed in the exhaust stream. This was followed by an air pump and conventional oxidation catalyst.

Three Way Catalyst (TWC)
Ca. 1981 三元触媒システム

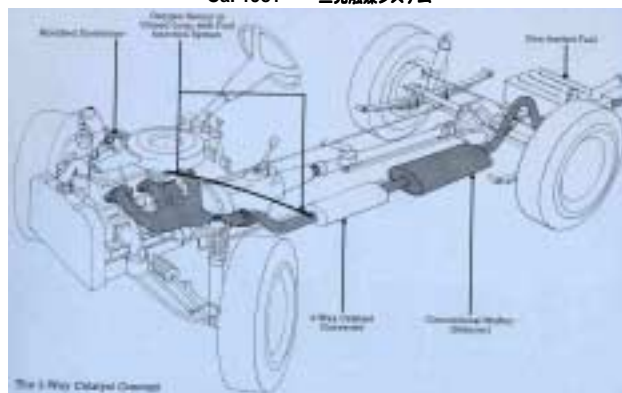


Figure 15

In 1981, the modern three-way catalyst came into effective use due to the development a new technology - the oxygen sensor..... This sensor allowed the engineer to control the engine air fuel ratio very precisely.....

To understand the importance of air fuel ratio control we need to look at how the three-way catalyst efficiency changes as air fuel ratio changes.

**CATALYST EFFICIENCY vs.
ENGINE AIR-FUEL RATIO**
触媒の浄化率とエンジンの空燃比

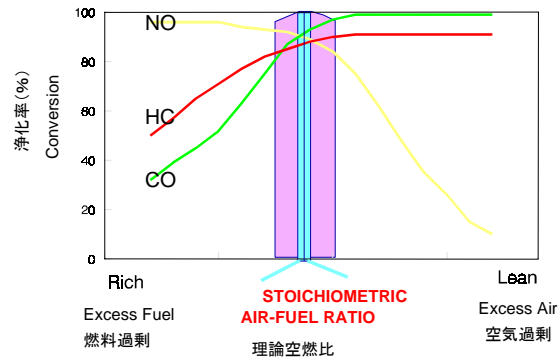


Figure 16

This slide shows how the efficiency of three-way catalysts depends on control of air fuel ratio into the engine. The vertical axis is conversion and the horizontal axis is air fuel ratio. Optimum efficiency occurs where air and fuel into the engine are chemically balanced -the so called stoichiometric air fuel ratio. You can see at this point the catalyst efficiency is very high for conversion of all three pollutants.

So if you control Air/Fuel into the engine the catalytic convertor works a lot better.....

Early Oxygen sensor
初期の酸素センサー



Figure 17

The device that made Air/Fuel control possible was the oxygen sensor. An early oxygen sensor is shown in this slide.

The oxygen sensor is capable of detecting oxygen in the exhaust.....

When the Air Fuel ratio is rich oxygen in the exhaust is low. When it is lean oxygen is high.

The oxygen sensor is placed in the exhaust stream ahead of the three-way converter. It detects the change in oxygen concentration across the stoichiometric by a change in electrical potential from the oxygen sensor. Therefore the perfect point for operation of a three way catalyst can be found.

Now the race was on to improve performance at this critical air fuel ratio.....

In the late 1970's and early 1980's, three-way catalysts advanced substantially in performance capability.

Advances were made due to the advent of oxygen storage materials. Under rich conditions these materials release oxygen to promote Carbon Monoxide oxidation. Under lean conditions they promote nitrogen oxide reduction by storing oxygen.

One such oxygen storage material that is cerium dioxide, CeO_2 . This can be reduced to the lower valent oxide Ce_2O_3

Cooper et al. SAE 850128
"Operational Criteria Affecting the Design of Three-Way Catalysts"

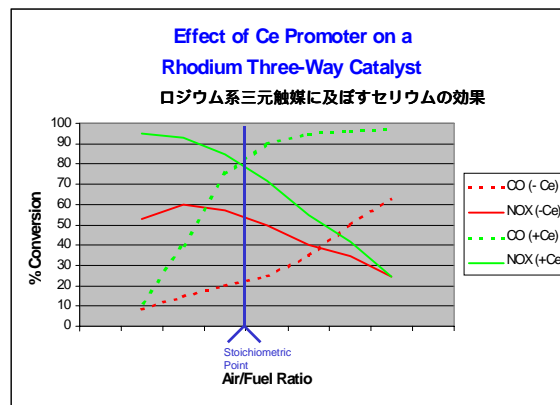


Figure 18

The effect of cerium promoters was clearly identified in our SAE paper 850128 titled "Operational Criteria Effecting the Design of Three-Way Catalysts". A graph from this paper is reproduced here in this slide. It shows the effect of cerium promoter on a three-way catalyst. ***Again we see a plot of conversion against air/fuel ratio.***

The simple message here is that the Cerium Dioxide promoted catalyst in green has much higher activity for Carbon Monoxide and Nitrogen Oxide conversion than the unpromoted catalyst in red.

The design of modern three-way catalysts is substantially more complex than catalyst systems that were tested in the early 1970's.

These new designs emerged after pioneering work in the Johnson Matthey laboratories led to a deeper understanding of what happened to multi-metal catalysts such as platinum and rhodium in use.

An excellent example is given in our SAE Paper in 1977. In that paper we reported the analysis of a severely sintered rhodium/platinum catalyst. ***Sintering is bad for catalyst performance as it causes loss of catalyst activity.***

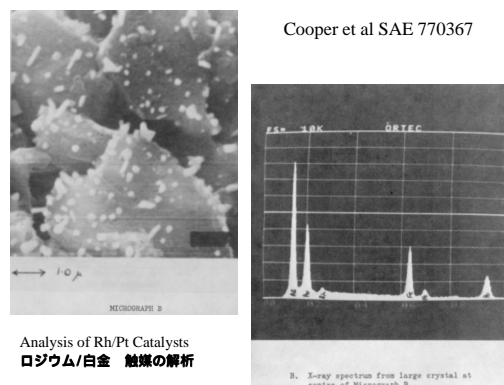


Figure 19

In the micrograph on the left you can clearly see the ***sintered*** platinum crystallites. But Energy Dispersive X-ray Analysis on the right revealed that the large sintered crystallites of metal contained both platinum and rhodium

Application of a surface analysis technique called X-Ray Photo Electron Spectroscopy ***also revealed that the rhodium was concentrated at the surface of the platinum crystallite.*** Also the rhodium on the surface was oxidized.

It raised the question of whether physical separation of platinum and rhodium would improve catalyst performance.

Trials showed that catalysts where the two metals had been deliberately separated from each resulted in lower emissions.

THIS LED TO A WHOLE NEW CONCEPT - STRUCURAL DESIGN OF CATALYSTS.....

Catalyst structural design consisted of making multiple layers of catalysts with platinum and rhodium in different layers.

Catalyst Structural Design
Combining Optimum Components
触媒構造の設計
最適成分の組み合わせ

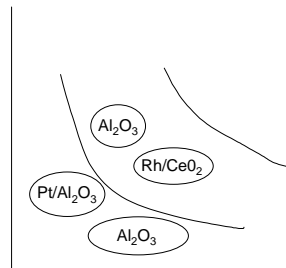


Figure 20

A schematic of such a catalyst is shown in this slide. It represents the corner of a monolith catalyst cell in which the lower layer of catalytic materials contains platinum and alumina, and the upper layer contains rhodium on cerium dioxide.

Lets see a microscope picture of this catalyst.....

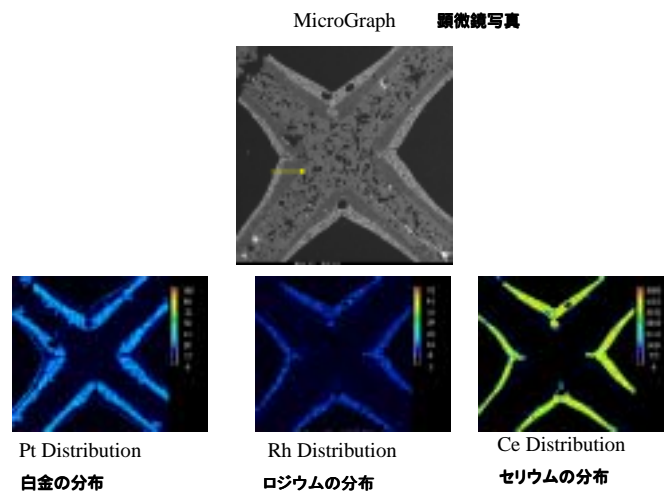


Figure 21

A electron microscope image of such a catalyst is shown in this slide.

The first picture at the top is the electron image showing an intersection of the monolith substrate walls coated first with a **dark** coating layer followed by a light-coating layer.

The picture at the bottom left shows the platinum distribution and the bottom middle picture shows the rhodium distribution. The platinum is clearly distributed in the lower catalyst layer and the rhodium is distributed in the upper catalyst layer.

The picture at the bottom right shows the cerium dioxide distribution within the catalyst. The cerium dioxide is associated with the rhodium in the upper layer of the catalyst.

The structural design target had been achieved! ***These catalysts came into use in the early 1990's***

An **even more complex** example of sophisticated structural design for a tri-metal platinum, palladium, rhodium catalyst was **developed and patented** in US Patent number 5,753,580. This was patented by T. Hayashi and S. Kikuchi of Honda who are with us in the audience tonight.



Figure 22

This Patent was based on joint work with Johnson Matthey and Honda was gracious enough to award Johnson Matthey the technology award shown in this slide in 1994.

Similar structural designs were used in the early 1990's in palladium-only catalysts to overcome the limitations of using a single catalytic metal.

Structural Design of Pd only Catalysts パラジウムだけの触媒設計

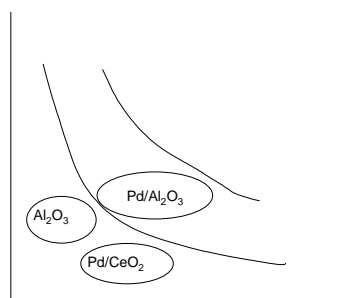


Figure 23

A Schematic of such a catalyst is shown here where the lower layer contains Palladium on cerium dioxide, and the upper layer contains Palladium on alumina.

The use of Palladium was driven by more stringent emission legislation coming from California with the advent of the Low Emission Vehicle (LEV) regulations.

These regulations placed even more emphasis on cold-start performance and palladium was found to be uniquely suited to control hydrocarbon emissions under cold-start conditions. So how did structural design help??

By use of structural design techniques we were able to obtain better performance of the palladium catalyst under cold start conditions by lowering the catalyst light off temperature.

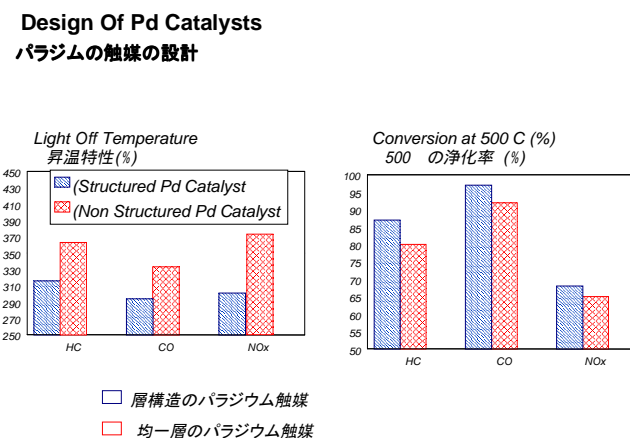


Figure 24

The improvements in light-off temperature are shown in the left graph.

Also we were able to get higher conversion when the catalyst is hot, as shown in the right graph.

But these catalysts used a lot of palladium.....



Figure 25

The use of palladium catalysts at high metal loadings became very common in the mid to late 1990's causing a large escalation in palladium price, peaking at the end of 2000.

This resulted in a significant increase in price of the catalytic converter. This was obviously undesirable to the car manufacturer and to the vehicle buying public.

Significant pressures were placed on reducing the palladium use in catalytic converters to achieve cost-effective performance by substituting *part of the palladium with* low levels of platinum and rhodium.

But this had to be achieved against even tighter emission standards.....

Johnson Matthey has responded to this challenge with new catalyst designs containing ultra-low levels of platinum group metals.

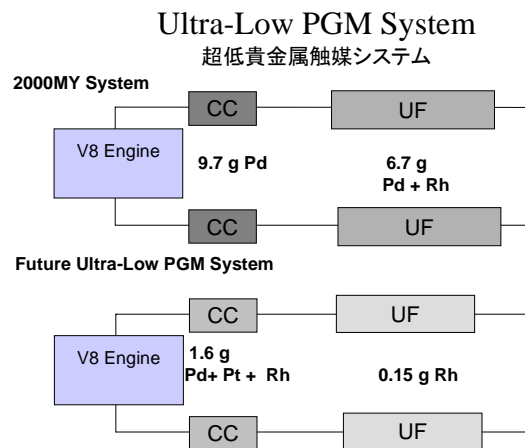


Figure 26

An example of such a design is shown in this slide.

This system is designed for a V-8 engine and consists of two close-coupled converters labeled CC, followed by two under-floor converters labeled UF. This is a typical convertor configuration for a V8 engine.

Here a 2000 model year system is compared to a future system containing catalysts at ultra low levels of platinum group metals.

The new system represents an 84% reduction in platinum group metals in the close-coupled converter and 98% reduction of platinum group metals in the under-floor convertor. This of course results in substantial price reductions available to the customer.

The under floor converters contain less than 100 parts per million Rhodium – a virtually undetectable amount.

BUT DO THEY WORK???? YES THEY DO!!!!

Ultra-Low PGM System beats LEV II after 50,000 mile aging
 超低貴金属触媒システムは5万マイル耐久後、LEV-II規制値を凌駕する

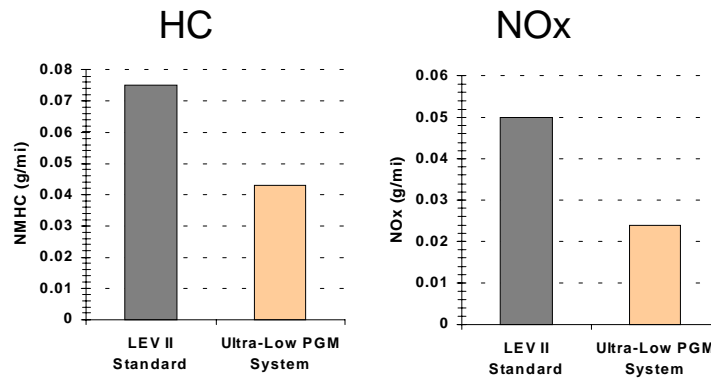


Figure 27

You can see in the yellow bars that tests of the ultra-low platinum group metal system have shown that it beats the new California LEV2 standard.

It gives less than half the emissions that are allowed even after 50,000 miles aging



Figure 28

I would now like to conclude this part of the presentation on gasoline vehicle catalysts before moving on to talk about diesel catalysts. Technology advances ***such as these*** have enabled Johnson Matthey to remain a leader in the market place.

Today all the major motor vehicle corporations around the world employ Johnson Matthey catalysts in their convertor systems.

The new challenge is to develop convertor systems for diesel engines.....



Figure 29

We are all aware of the smoky exhaust of diesel engines and the annoyance it creates in our city environments

Diesel engine manufacturers have made substantial strides in reducing the smoke or particulate emission from the engine through combustion system improvements.

But growing health concerns over diesel particulates have led to strict new legislation. In the United States both the California Air Resources Board, and the Environmental Protection Agency have declared Diesel Particulate a toxic substance.

But what is diesel particulate - often also called soot or smoke.....???

Schematic of Diesel Particles

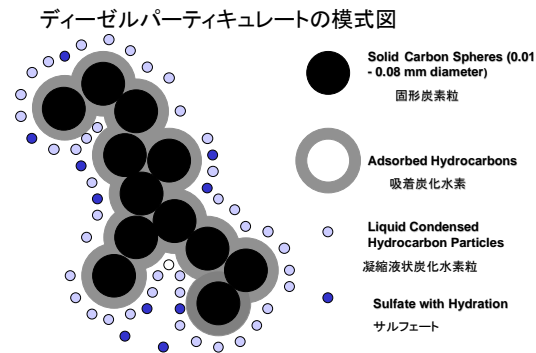


Figure 30

Diesel particulate consists of a carbon core comprising solid carbon spheres which agglomerate together to form a particle. These particles contain adsorbed hydrocarbons, many of which are cancer causing and toxic.

The particulates are small enough to be breathed deep into the lungs where they cause most damage.

For the past two decades, intense research has been conducted on filter systems, which are capable of removing these particles from diesel exhaust

High efficiency filters capable of eliminating 98% of the particulate have been developed.



Figure 31

The most well known of these is the wall flow filter manufactured by NGK in Japan and Corning in the United States.

The filter consists of a ceramic monolith with, alternate cells plugged, forcing the exhaust flow through the wall. The particulate is trapped on the wall of the filter.

The major problem with filter materials is that they rapidly fill with diesel particulate and become clogged. This increases the back pressure across the filter and leads to poor engine performance and ultimately engine failure.

Therefore, no diesel particulate filtration device can operate without the use of a regeneration system to remove the particulate from the filter.

Prior to 1989 various complicated regeneration methods had been used. These included such approaches as electrical heaters or diesel fuel burners. Their purpose was to heat the filter to high temperature and oxidize the carbon particulate.

Think of it like setting light to your charcoal barbecue grill!!

Johnson Matthey's challenge was to develop a catalytic process for burning diesel particulate that would operate under the low temperatures found in diesel exhaust.

Cooper-Thoss SAE 890404

TABLE 4
Effect of Exhaust Components
On Particulate Combustion Rate
排気組成の煤燃焼温度に及ぼす効果

TEST	N ₂ Balance	NO 400 ppm	O ₂ 12%	H ₂ O 4.5%	RATE °H ₂ O/hr
1	✓				0
2	✓	✓			10
3	✓	✓	✓		32
4	✓	✓	✓		0
5	✓	✓	✓		30
6	✓	✓	✓	✓	64
7	✓	✓	✓	✓	28
8	✓			✓	4
9	✓	✓		✓	0
10	✓		✓	✓	0

NO₂ BURNS SOOT

✓ Indicates component present

Figure 32

In 1989 we reported a breakthrough in SAE paper 890404.

In that paper, my co-author, Jim Thoss, and I reported that the combustion of diesel particulate could be reduced to from 600°C to 250° C by using Nitrogen Dioxide NO₂ in the exhaust.

The key results are shown in this slide in red. When NO and oxygen were passed over a platinum catalyst NO₂ was formed and the rate of particulate (Soot) burning substantially increased.

The next challenge was to develop a catalytic convertor to produce NO₂ together with a filter system to collect the particulate.

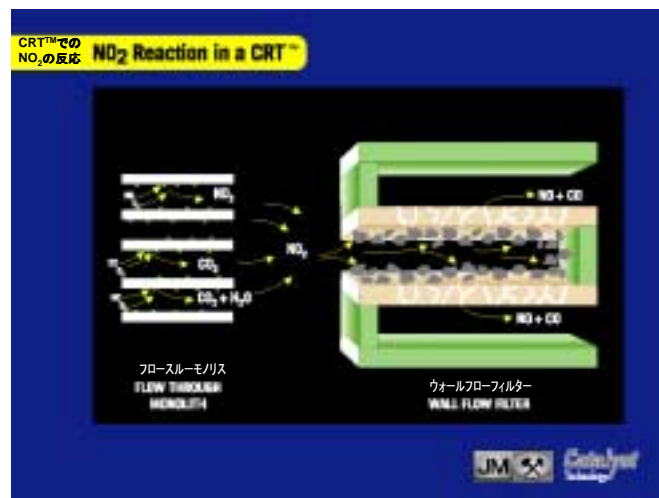


Figure 33

It was found by experiment that it was more effective to place the platinum NO₂ generating catalyst, shown in the left on this slide, in front of the filter shown on the right.

By placing the catalyst in front of the filter, the NO₂ is forced to flow through the particulate bed creating a higher rate of reaction to burn the particulate.

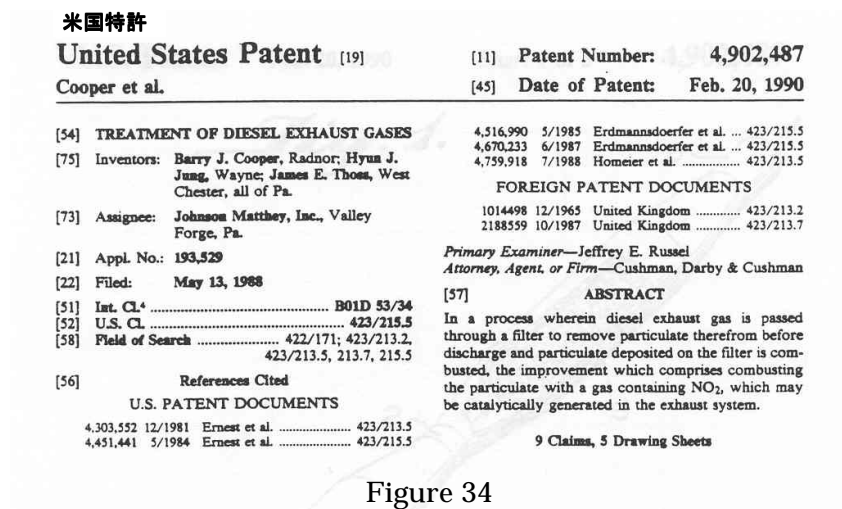


Figure 34

This famous design was patented in February 1990 as US patent 4,902,487.

CRT® Layout Diagram

CRT® の構造



Figure 35

The convertor design that introduced into commercial use is shown in this slide. It was introduced 1995 and named the Continuously Regenerating Trap or CRT system.

The picture shows the convertor design for a heavy duty diesel engine.

The catalyst to generate NO₂ is shown in the front section. The wall flow filter is shown in the rear section.



Figure 36

The first use occurred in Gothenburg, Sweden. Subsequently, other major cities have opted for the use of CRT system on public utility vehicles.

You can see the CRT installed on a tanker truck in the picture on the left. This truck has traveled over 300,000 miles with no filter blockage.



Figure 37

Today, some 35,000 CRT systems are in operation in major cities throughout the world ranging from Los Angeles in the West to Tokyo in the East

We at Johnson Matthey are now working on the development of a combined catalytic filter system and catalytic nitrogen oxide reduction system to simultaneously remove diesel particulate and nitrogen oxides from diesel engines -----But that is another story.....

We are now up to date and it is time to conclude this presentation.....

I hope you have enjoyed my historical review. I have tried provide an insight into the technical challenges that have been overcome on the way to clean air.

The past 30 years in emission control have been exciting and I have been proud to play a role in this industry which has done so much to benefit our environment.

I could of course have not done it without the help and support of my colleagues at Johnson Matthey.

Many others throughout the world have also significantly contributed. Many are good friends, some of who are with us in the audience today.

To those who I have worked with, I would like to say thank you.

To my competitors I would like to say thank you. You have stimulated us at Johnson Matthey to make better more cost-effective products for the automotive industry.

To my customers, I am eternally grateful for your support over the years.

To my wife Ann I am even more grateful for your support over the years.....

But before I go let me show you one more slide.....

I would like to show you a cumulative plot of Johnson Matthey's catalyst production from 1975 through to today.

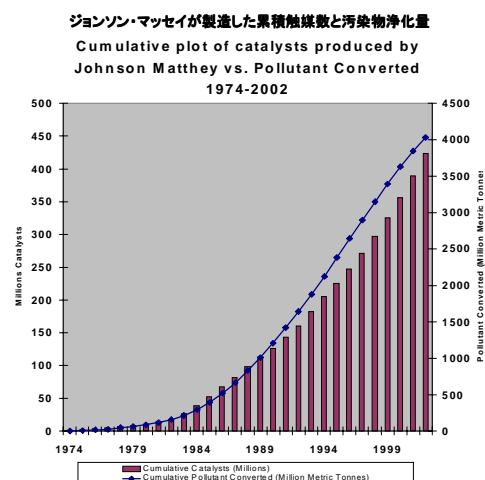


Figure 38

If you look at the bars in this plot you will see we are close to reaching the production of half a billion catalysts for catalytic converters.

The line is an estimation of how many tons of pollution those catalysts have removed from the world's atmosphere.

Amazingly, those catalysts have removed **4 Billion Tons** of pollution from the atmosphere since the inception of our business.

Now, that is ECO Technology!

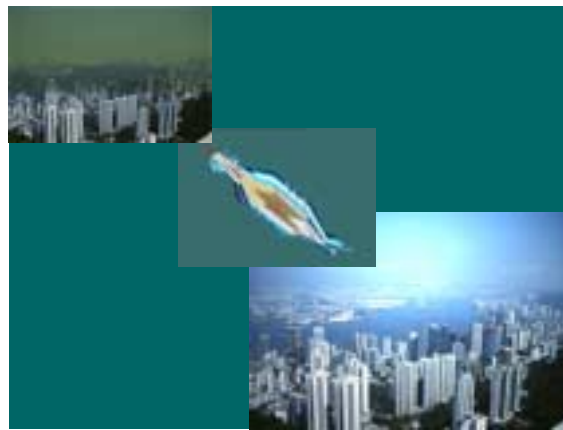


Figure 39

I am proud to be part of an Industry, which has so substantially benefited our environment and has made the world healthier for us, our children and our grandchildren

Thank you very much, indeed, ladies and gentlemen for listening to my story this evening.

And thank you once again to the Honda Foundation for honoring me with this award. I am truly most grateful.

*Minasama Honto-ni Arigatou Gozaimashta,
mata,*

*Kono Yoh-na May-I-yo Aru Show Wo Itadaki,
Honda Foundation Ni Kansha Itashimass.*