

The Reduction of Nitric Oxide in Automobile Emissions

STABILISATION OF CATALYSTS CONTAINING RUTHENIUM

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Catalysts containing ruthenium are used to reduce nitric oxide in automobile exhaust emissions but volatile oxides formed under transient oxidising conditions during operation can severely affect them. However, basic oxides such as alkaline earths or rare earths can stabilise the ruthenium by forming ruthenates, which have little tendency to volatilise. The ruthenates are synthesised either before the catalyst is made or in position on the catalyst support, which may be monolithic or pelleted.

In the development of catalysts for the reduction of nitric oxide in the purification of automotive exhaust emissions one of the desired attributes of a catalyst is its ability to promote selectively the reduction of nitric oxide NO to molecular nitrogen (and not to ammonia as happens over a large majority of catalysts), in the presence of hydrogen-containing compounds in the gas stream (1, 2, 3). Ruthenium-containing catalysts have been found to have a pronounced selectivity for reduction to molecular nitrogen (4, 5, 6), and several laboratories have pursued recently the development of practical ruthenium-containing catalysts.

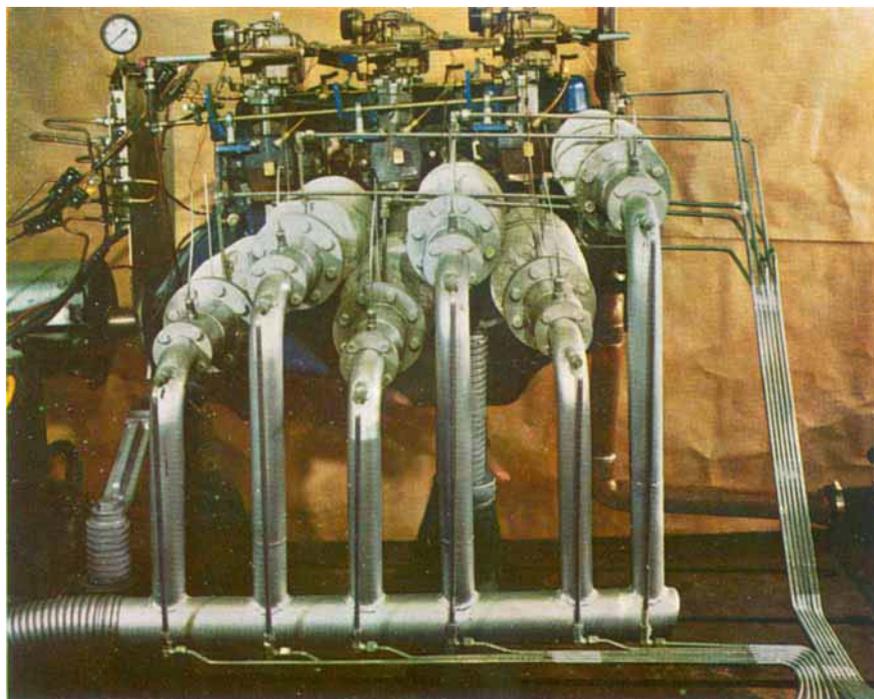
The NO_x-reduction catalysts are intended to operate in an overall reducing atmosphere in an automobile exhaust which is, on the average, a product of the carburetion of a combustible mixture richer than the stoichiometric mixture. However, relatively frequent excursions occur in the operation of the vehicle into conditions where the exhaust contains, for certain time intervals, a net excess of oxygen. Further, in some embodiments of the so-called dual catalyst system it is desirable to use the NO_x-reduction catalyst as a carbon monoxide and hydrocarbon oxidation catalyst during the warm-up period,

deliberately admitting an excess of oxygen during that time.

With the use of ruthenium-containing catalysts it soon became apparent that their stability under oxidising conditions is poor. Analysis of spent catalysts revealed severe losses of the active component, readily explained by the formation and removal of the volatile tetroxide (7).

Various ways were explored to minimise the tendency of the ruthenium to volatilise under oxidising conditions while still preserving the high activity and selectivity of the catalysts.

We have attempted the stabilisation of the ruthenium (or its oxide) on the catalyst by the incorporation of the basic oxide of barium. The reasoning leading to this suggestion was couched in the following chemical terms: since the highly oxidised states of ruthenium (Ru³⁺ and higher) give rise to acidic oxides, their interaction with basic oxides such as barium oxide will lead to the formation of double mixed oxides which should be more stable with respect to volatilisation in the presence of oxygen. Indeed, the higher oxidation states of Ru do form an extensive series of ruthenates, many of the latter well characterised in the literature (8). In parti-



Simultaneous testing of six honeycomb catalysts on an engine dynamometer at the Research Laboratories of the Ford Motor Company. The exhausts from each one of the six engine cylinders are fed to separate catalyst chambers. Pelleted ruthenium catalysts were also tested

cular, the ruthenates of the alkaline-earth metals have been investigated by Ward and co-workers (9). They tend to crystallise mainly with the perovskite structure.

Barium ruthenate BaRuO_3 , in particular, has been well characterised (9a). It has a close-packed stacking of close-packed BaO_3 layers with the Ru ions in octahedral sites. There is metal-metal bonding between the ruthenium ions with an interatomic Ru-Ru distance of 2.55 Å. This is a closer approach than in ruthenium metal (2.65 Å). This structural property may have a bearing on the remarkable catalytic activity of the barium ruthenate which will be discussed later.

Another class of basic metal oxides useful for the stabilisation of ruthenium in an oxidising atmosphere is that of the rare-earth metals. With all the lanthanides, except lanthanum itself, one obtains compounds of the type $(\text{RE})_2\text{Ru}_2\text{O}_7$ which crystallise as cubic pyrochlores (10). The interaction between La_2O_3

and RuO_2 leads to a perovskite phase (11) which has recently been well characterised by Bouchard and Weiher (12). It is worth noting that La_2O_3 is the most basic among the rare-earth oxides and therefore is most suitable for stabilisation. The perovskite LaRuO_3 is considered to be unusual, as it is the only example of an oxide lattice where all the ruthenium is in the formally trivalent state. It is well known that the valence state of the B metal ion in the perovskite formula ABO_3 can be varied in wide limits by substituting mono-, di- or trivalent atoms in the A position. On the other hand, different atoms can be also substituted into the B position. This gives a very wide range of possible ruthenium-containing 'stabilised' catalysts.

The work referred to in the present article is limited specifically to the stabilisation by BaO or La_2O_3 . The subject-matter is the basis for several U.S. patent applications.

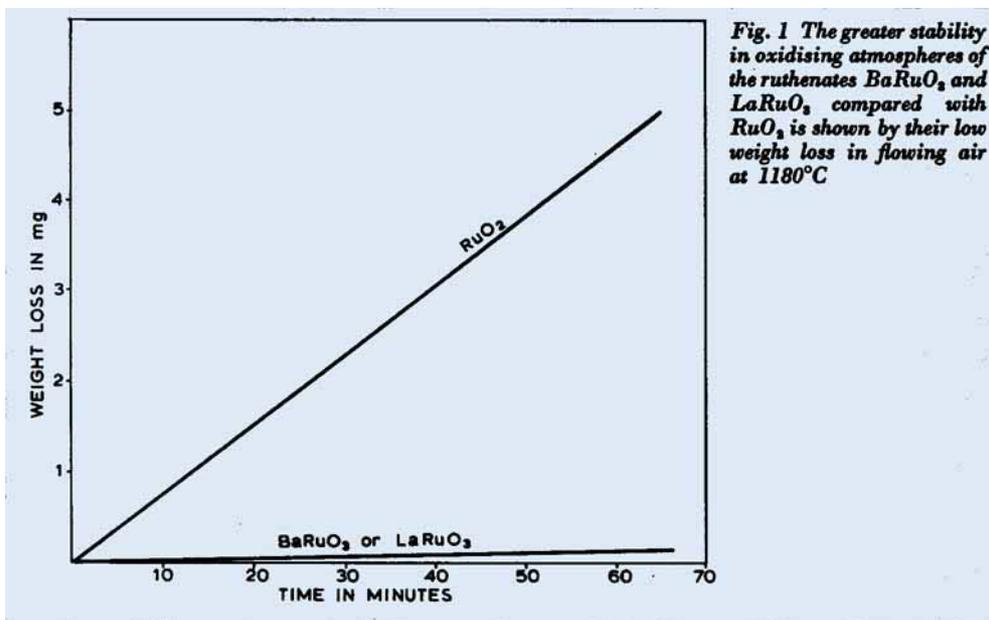


Fig. 1 The greater stability in oxidising atmospheres of the ruthenates BaRuO₃ and LaRuO₃ compared with RuO₂ is shown by their low weight loss in flowing air at 1180°C

Preparation of Catalysts

We have followed essentially two routes in the preparation of the stabilised catalysts. In one technique BaRuO₃ or LaRuO₃ is pre-synthesised. The pre-synthesised ruthenates were finely ground and incorporated on to monolithic supports either from American Lava Corp. or from Corning Glass Works using very dilute (2 wt. per cent) suspensions of colloidal 'Dispal' alumina as the binding agent. There is an obvious disadvantage to the technique, and this is the limit on the particle size achievable by the grinding. At best, the particle diameter is of the order of a few microns (or a few 10⁴ Å), which leaves the major part of the valuable ruthenium atoms in the bulk and inaccessible to the reacting molecules on the surface. On the other hand, there is the obvious advantage that every ruthenium atom has been stabilised as the ruthenate.

The second technique consists of the impregnation of either a pelleted or monolithic support, first by a solution of the nitrate of the stabilising metal barium or lanthanum, followed by calcination to convert the nitrate to oxide, secondly by the solution of ruthenium

trichloride, RuCl₃, which is then dried at 110°C and reduced in hydrogen at ~450°C. The very small particles of the ruthenium metal (<10 Å diameter) are then 'fixed' by rapid heating in air at 900°C. The fast fixation process assures very good dispersion of the resulting ruthenate. There is no direct evidence, however, that every ruthenium atom has been deposited in the vicinity of the stabilising oxide so as to assure the formation of the ruthenate.

Catalysts containing from 200 to 2000 p.p.m. ruthenium by weight were prepared by both methods.

Stability of Ruthenates in Oxidising Atmospheres

To check the stability of the BaRuO₃ and LaRuO₃ and compare it to that of RuO₂, thermogravimetric experiments were performed using the DuPont automatic balance. Figure 1 indicates the vast difference in the weight loss between the ruthenates and RuO₂ at 1180°C in flowing air.

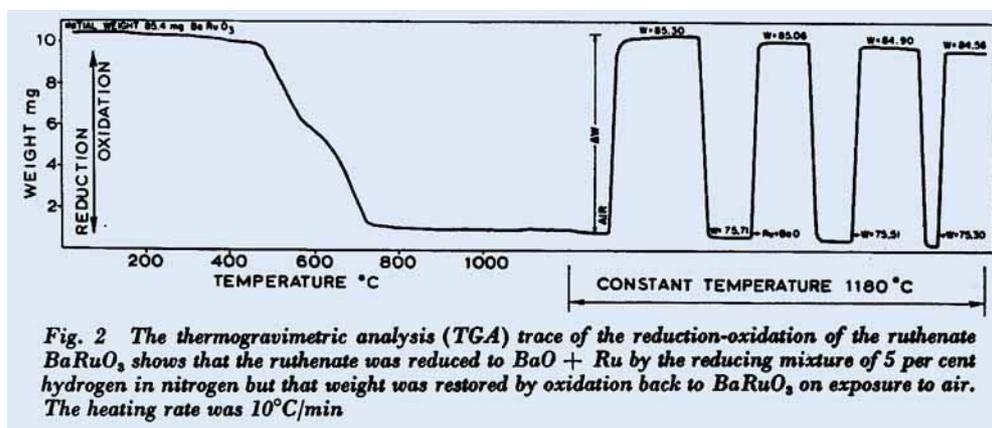
Table I shows the percentage loss of ruthenium in a fast-flowing blend of nitrogen-oxygen from supported pelleted catalysts

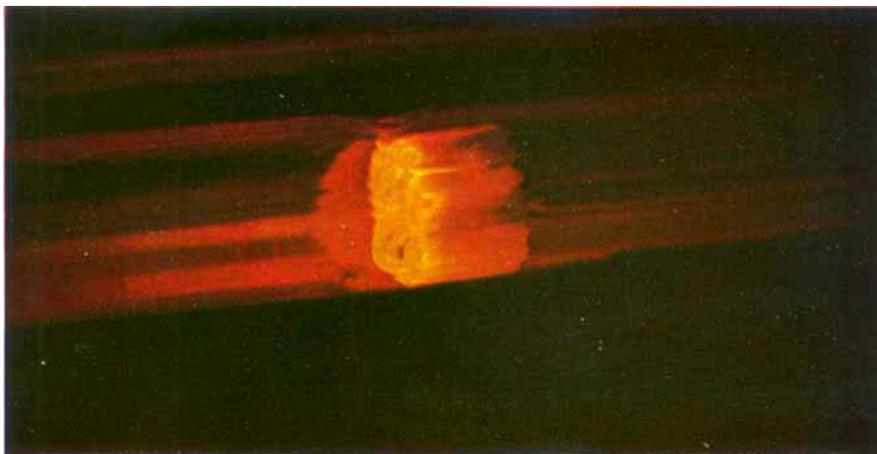
Temperature		Exposure Time in hours	Ruthenium Loss per cent		
°F	°C		Ru Catalyst	Ru-BaO Catalyst	Ru-La ₂ O ₃ Catalyst
950	510	16	0	0	0
1350	730	4	13	0	0
1450	785	4	45	0	0
1530	830	4	90	25	5
1630	885	4	—	25	25
1750	955	4	—	—	25
1820	995	4	—	75	—

Conditions: Space velocity : 38,000/h
O₂ concentration in nitrogen: 2.5-3 per cent
Ru content : 2000 p.p.m.
La or Ba (as metal) content : 3 per cent by weight
Support : UOP Al₂O₃ pellets

containing ruthenium alone or with BaO or La₂O₃. It should be pointed out that, this being one of the earliest preparations, the ruthenium was not prefixed by prereduction and subsequent rapid oxidation and therefore was relatively poorly dispersed (4.6 per cent of the ruthenium atoms are surface atoms). None the less, the vast improvement in stability due to the presence of BaO and La₂O₃ is quite obvious.

The cycling conditions and the possibility of switching from oxidising to reducing exhaust in the operation of an engine requires the knowledge of the changes that the stabilised catalyst undergoes under such treatment. For this purpose presynthesised ruthenates were subjected in the TGA balance to alternate oxidising and reducing conditions. The reducing agents were hydrogen or carbon monoxide (in nitrogen). Since the use of





A honeycomb catalyst glowing during the oxidation of automobile exhaust pollutants generated in a pulse-flame exhaust simulator at the Ford Motor Co. Research Laboratories

carbon monoxide leads under certain conditions to the formation of barium or lanthanum carbonates, we give only the data for reduction by hydrogen, and only the results for BaRuO_3 are presented. The results for LaRuO_3 are analogous. Figure 2 indicates that the BaRuO_3 is reduced to $\text{BaO} + \text{Ru}$ and that the weight is restored upon exposure to air. X-ray diffraction patterns after the four cycles indicate the restoration of the ruthenate, BaRuO_3 . It is possible that frequently repeated oxidation-reduction cycling engenders the migration of the ruthenium to form gradually a separate oxide phase. To prevent this, the stabilisation of very small particles as achieved by the fixation is very important. Another possible stratagem is to dilute the perovskite ABO_3 in the B position by nonvolatile ions such as Mn^{4+} (9a) or others. In lanthanum ruthenate, where ruthenium is trivalent, dilution by trivalent ions such as Ni^{3+} and others should be feasible.

Activity and Selectivity of Ruthenates and Stabilised Ruthenium Catalysts

Under reducing conditions at relatively elevated temperatures the barium (or lanthanum) ruthenate reverts, as shown in the

previous section, to the ruthenium metal and the stabilising oxide. Hence, its activity and selectivity under these conditions might be expected to be the same as in unstabilised Ru catalysts.

At lower temperatures and under a redox potential not quite sufficient to reduce the ruthenates, the catalyst might be required to catalytically reduce nitric oxide while the ruthenium is still coordinated in the ruthenate structure.

The available literature indicated that from simple considerations the ruthenates could be expected to be active catalysts. Thus, first, the perovskite-type ruthenates have been shown to have metallic conductivity, for which convincing explanations have been proffered (12, 13). Secondly, the Ru-Ru distances in some of the structures were shown to be actually shorter than in the metal (9a).

The metallic character should satisfy one of the important conditions required for the redox catalytic activity, the ability to chemisorb both electron-donor and electron-acceptor adsorbents. The close proximity of the ruthenium atoms should provide the dual sites required for the pairing of nitrogen atoms in the reduction of nitric oxide to nitrogen.

Table II						
Comparison of Activity and Selectivity between Stabilised and Non-stabilised Ruthenium Catalysts. System NO-H ₂						
Temperature °C	Ru Catalyst		Ru-BaO Catalyst		Ru-La ₂ O ₃ Catalyst	
	% NO Converted	p.p.m. NH ₃ Formed	% NO Converted	p.p.m. NH ₃ Formed	% NO Converted	p.p.m. NH ₃ Formed
250	60	10	20	20	22.5	12.5
300	96	62.5	96	147	90	180
350	100	230	100	190	100	250
400	100	250	100	210	100	275
450	100	240	100	218	100	250
500	100	—	100	205	100	95

Conditions: Space velocity : 20,000/h
 Inlet NO concentration: 1000 p.p.m.
 Inlet H₂ concentration : 1.43 per cent
 Catalyst support : low-shrinkage American Cyanamid alumina pellets
 Ru content : 2000 p.p.m.
 La or Ba (as metal) : 3 per cent by weight

Table III						
Comparison of Activity and Selectivity between Stabilised and Non-stabilised Ruthenium Catalysts. System NO-CO-H ₂						
Temperature °C	Ru Catalyst		Ru-BaO Catalyst		Ru-La ₂ O ₃ Catalyst	
	% NO Converted	p.p.m. NH ₃ Formed	% NO Converted	p.p.m. NH ₃ Formed	% NO Converted	p.p.m. NH ₃ Formed
250	85	45	35	30	80	55
300	100	85	92.5	80	98	150
350	100	118	100	135	100	210
400	100	135	100	210	100	208
450	100	137	100	250	100	190
500	100	—	100	220	100	50

Conditions: Space velocity : 20,000/h
 Inlet NO concentration: 1000 p.p.m.
 Inlet CO concentration: 1.5 per cent
 Inlet H₂ concentration : 1.43 per cent
 Catalyst support : low-shrinkage American Cyanamid alumina pellets
 Ru content : 2000 p.p.m.
 La or Ba (as metal) : 3 per cent by weight

Temperature °C	NO-H ₂ System		NO-H ₂ -CO System		NO-CO-H ₂ O System	
	% NO Converted	p.p.m. NH ₃ Formed	% NO Converted	p.p.m. NH ₃ Formed	% NO Converted	p.p.m. NH ₃ Formed
202	23.9	18.9	56.8	60.5	N.M.	N.M.
255	89.6	75.0	100	212	N.M.	N.M.
278	100	92.4	100	228	100	380
320	100	186	100	233	100	310
360	100	190	100	263	100	260
447	100	63.2	100	251	100	175

Conditions: Space velocity : 20,000/h
 Inlet NO concentration: 100 p.p.m.
 Inlet CO concentration: 1.5 per cent
 Inlet H₂ concentration : 1.43 per cent
 Inlet H₂O concentration: 10 per cent
 Catalyst support : Corning monolith

N.M. = not measured

Laboratory Experiments

Both monolithic and pelleted catalysts were tested in the laboratory in the flow apparatus used in our earlier studies (2, 4) and the observed activity has borne out these expectations.

Tables II and III give the comparison between a pelleted catalyst containing 2000 p.p.m. of ruthenium alone and the catalysts containing the same amount of ruthenium but stabilised by 3 per cent barium as BaO or 3 per cent lanthanum as La₂O₃. As seen from

the tables, the stabilisation does not impair the activity and affects the selectivity only very slightly, if at all. At the conditions of these runs the catalysts were not reduced to the metallic state of ruthenium, because the temperature was too low (see Fig. 2).

Table IV gives the activity and selectivity in laboratory conditions of a presynthesised BaRuO₃ catalyst deposited on to a monolithic support. Similar behaviour is exhibited by the presynthesised LaRuO₃.

Catalyst Identification	Stabilising Element	Ru Loading p.p.m.	NO Reduction Activity in Screening Dynamometer Test at 230,000/h, A/F ratio 13.8, 1000°F	
			Total	Net
M-176A	Ba	200	85	82
M-177AP2	La	200	88	80
M-168	Presynthesised BaRuO ₃	2000	78	N.M.

Table VI				
The Operation Parameters of the Engine Dynamometer in the Catalyst Durability Tests				
Mode	A	B	C	
Engine speed (r.p.m.)	2200	800	800	
Load (ft-lb)	92	27	27	
Air fuel ratio (at catalyst)	13.6	13.4	15.0	
Space velocity (per hour)	95,000	25,000	30,000	
Exhaust O ₂ (per cent)	0.1	0.1	3.0	
Exhaust temperature (°F)	1350	950	950	
Time (min)	41.6	5.2	5.2	
At periodic intervals of about 70 hours of accumulated durability time, the NO, HC, and CO conversion efficiencies are measured with the following engine and exhaust conditions:				
Air-fuel ratio	12.7	13.5	14.1	14.7
Engine speed (r.p.m.)	1430	1430	1430	1430
Vacuum (in Hg)	11.2	11.2	11.2	11.2
Torque (ft-lb)	86	86	86	86
Space timing (BTC)	40	40	40	40
Fuel flow (lb/hr)	14.6	13.9	13.1	12.7
Inlet temperature (°F)	1000	1000	1000	1000
Space velocity (per hour)	60,000	60,000	60,000	60,000
Lead-sterile fuel and ashless oil were used for the durability tests.				

Dynamometer Experiments

The monolithic catalysts made in the laboratory were subjected to prolonged durability tests on engines mounted on dynamometers. Many formulations were tested, but we limit ourselves here to the presentation of a few examples only. The compositions of the catalysts of which the dynamometer tests results are discussed here are given in Table V. The last column in the table gives the performance of a fresh catalyst in a high-space-velocity screening test.

The operating parameters of the engine dynamometer are given in Table VI. The engine was a six-cylinder 200 CID Ford engine, and the exhaust of each cylinder was

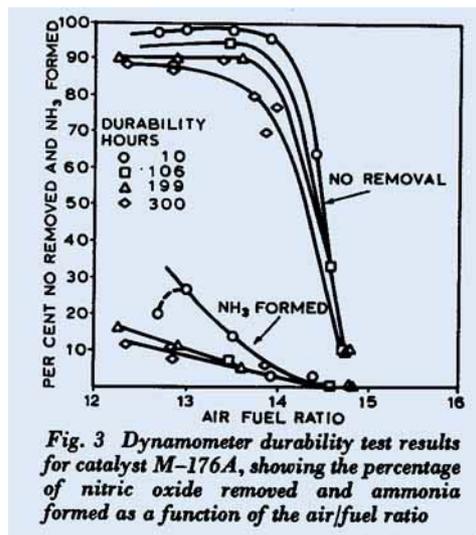
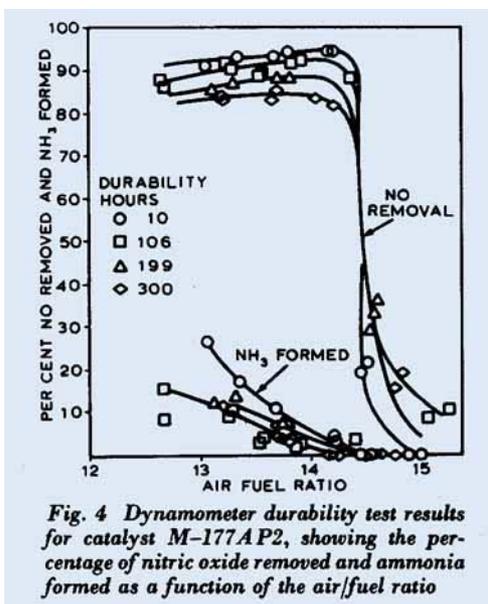
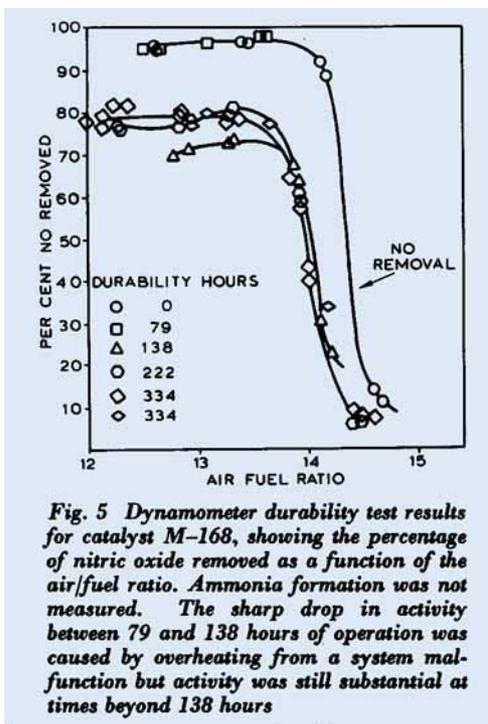


Fig. 3 Dynamometer durability test results for catalyst M-176A, showing the percentage of nitric oxide removed and ammonia formed as a function of the air/fuel ratio



led over a three inch diameter, three inch long monolithic catalyst.

Figures 3, 4 and 5 give, respectively, the durability testing results in the form of



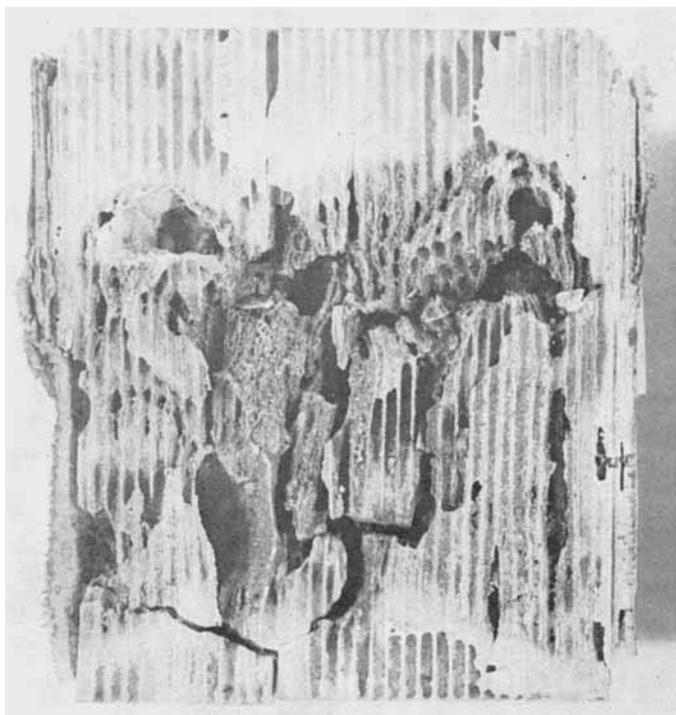
percentage of nitric oxide removed and ammonia formed as a function of air/fuel ratio at increasing times of running for catalysts M-176A, M-177AP2 and M-168. The decrease in activity for the first two catalysts is very minor, notwithstanding the low loading of ruthenium. On Fig. 5 it can be seen that catalyst M-168 has suffered a sharp drop in activity in the period between 79 and 138 hours of operation. This was traced to a sharp overheating associated with a malfunction of the system. The malfunction resulted in the physical damage shown in Fig. 6. Nevertheless, a substantial activity was still exhibited by the catalyst as shown by the plots on Fig. 5 at times beyond 138 hours of operation.

Vehicle Results

The durability results accumulated in actual vehicle operation are included here to demonstrate that, notwithstanding the encouraging laboratory and dynamometer activity and stability, the catalysts deteriorated more rapidly in vehicle tests than in laboratory or dynamometer evaluation. The deterioration was faster than required for the satisfaction of the U.S. Federal 1976 requirements. As a substantial number of these catalysts have been analysed and some have shown no appreciable loss of the active component ruthenium, it is obvious that other causes of deterioration, such as poisoning or overheating (or both) operate also in the catalysts for the reduction of NO_x , which is hardly surprising.

The data in Table VII were obtained on cars equipped with exhaust gas recirculation devices, with the exception of vehicle 22-C-58. The EGR was calibrated to substantially reduce inlet levels of NO_x , as seen in the table. This may have resulted in increased HC and CO emissions, which does, however, not bear directly on the subject-matter of the paper. This explains the low level of NO_x emissions without the use of the catalysts. The data in the table clearly indicate that in vehicle operation the ruthenium catalysts

Fig. 6 Melting of catalyst M-168 caused by overheating from a system malfunction. The catalyst still retained substantial activity after this damage with little further deterioration of performance



deteriorate. The stabilisation procedure is designed to minimise the deterioration associated with the volatilisation of the Ru. The extent of success in preventing volatilisation can be judged from the analytical data of the next paragraph.

Table VII
Vehicle Durability Tests of Stabilised Ruthenium Catalysts

Vehicle	Initial CVS (C/H) Results, NO _x			Durability CVS (C/H) Results, NO _x			
	Wt. % Catalyst	With Catalyst	Efficiency (%)	Mileage	Wt. % Catalyst	With Catalyst	Efficiency (%)
21A91 (M-177B) Galaxie, 429 CID	1.40	0.45	68	12,000a	1.05	0.77	26.6
31A73 (M-190) Galaxie, 400 CID	1.27	0.48	62	16,000b	1.25	0.77	38.4
22-C-58 (M-176B and M-177) Capri, 2.6 l, d	2.5	0.47	82	8,000b	2.0	0.92	45.5
110-T-713 (M-150C2)c Galaxie, 351 CID	1.19	0.39	67	10,000a	1.49	0.87	41.6
110-T-714 (M-190) Galaxie, 351 CID	1.69	0.44	74	12,500b	1.20	0.64	46.6
110-T-718 (M-150G)c T-Bird, 429 CID	0.83	0.26	76.6	5,000a	1.14	0.93	18.4

a At termination
b Latest available data
c The stabilisation did not include the 'fixation' step
d Based upon hot CVS test.

Table VIII
Analyses of Ruthenium Catalysts

a: Fresh Catalysts				
Catalyst Designation		Nominal Ruthenium Content p.p.m.	Average Ruthenium Content X-ray Fluorescence p.p.m.	Average Ruthenium Content Activation Analysis p.p.m.
M-176		2000	2537	2462
M-190		500	636	499
M-190-A		1000	1630	not measured
b: Dynamometer Tested Catalysts				
Catalyst Designation	Hours of Service	Nominal Ruthenium Content p.p.m.	Average Ruthenium Content X-ray Fluorescence p.p.m.	
M-177B-1	200	700	643	
M-176B-1	100	700	676	
M-177B	200	500	425	
M-190-3	100	500	500	
M-87C2-1 a	130	2000	1320	
c: Vehicle Tested Catalysts				
Catalyst Designation	Mileage	Nominal Ruthenium Content p.p.m.	Average Ruthenium Content X-ray Fluorescence p.p.m.	Average Ruthenium Content Activation Analysis p.p.m.
M-177B	12,000	500	206	238
M-176	3000 b	2000	2388	2644
M-150G (right) a	5000	2000	1053	2144
M-150G (left) a	5000	2000	851	not measured
M-150C-2A a	10,000	2000	540	not measured
M-150C-2B a	10,000	2000	600	not measured
a Catalysts stabilised without fixation				
b Operating under oxidising A/F ratio				

Analysis of Used Catalysts

To assess the extent of loss of ruthenium from used catalysts the chemical analysis of this element was carried out by two different analytical techniques.

The X-ray fluorescence analysis using the Siemens SRS-1 instrument was carried out for a series of elements present on the catalyst. These included both the active elements added in the preparation of the

Pollutant molecules labelled by isotopes such as ^{15}N , ^{18}O and D are used in the study of the mechanisms of their catalytic removal. The mass spectrometer serves as an important analytical tool in these studies



catalysts and some of the contaminants accumulated during testing. Since this article deals specifically with stabilisation, the analysis results presented here are limited to ruthenium only. As mentioned before, the presence of other contaminants may have an effect on the catalyst deterioration noticed in Table VII and this matter is now under intensive investigation.

A word of caution is in order with respect to the X-ray fluorescence analysis. The presence of several contaminants on the used catalysts requires the preparation of a large matrix of standard samples. The matrix was prepared using a support from only one of the suppliers, while the actual catalysts were made with different support materials. Since all of them (with the exception of catalyst M-150G) were aluminosilicates, the effect on the analysis should not be large. Secondly, not all the interelement intensity corrections, associated with minor contaminants, were accounted for in the X-ray fluorescence analysis.

The activation analysis for ruthenium was carried out by irradiation for three minutes in the core of the Ford Nuclear Reactor at the University of Michigan. After a decay period of ~ 14 days, the samples were counted on a high-resolution gamma ray spectroscopy

system. The 0.497 MeV radiation from ^{103}Ru (half life 39.5d) is analysed by computer for the quantitative determination. A ground specimen of the sample is compared with another specimen to which a known amount of ruthenium has been added. Both samples are irradiated simultaneously, and the flux variations are not more than 1 per cent.

Examination of Table VIII shows considerable improvement in the prevention of ruthenium volatilisation under the conditions of dynamometer testing. This particular cycle consisted of 48 minutes of testing at 870°C , 140,000/h, under reducing conditions and 6 minutes of testing at 650°C , 50,000/h under oxidising conditions. The stabilisation without reduction followed by fixation brings about improvement, but not complete prevention. The incorporation of the fixation step virtually eliminates ruthenium loss under the dynamometer test conditions.

Under vehicle conditions the loss from the first generation of stabilised catalysts (the M-150) series is still higher than acceptable.

The data from the second generation of catalysts are not all available as yet, as these are still being tested on vehicles and the mileage accumulation is continuing (see Table VII).

In the single case where the analysis is available (catalyst M-177B, after 12,000 miles, Table VIII), there is still an apparent loss of ruthenium. This qualification is associated with the fact that no analysis is run on a fresh catalyst and the nominal intended loading can be different from the actual loading. It is, however, realised that the achieved degree of stabilisation can still be substantially improved, while mastering the technique of catalyst preparation. Further improvements can be expected by minimising the opportunities for phase separation during repeated oxy-reduction of the catalyst. This will mainly be achieved by ruthenium dilution and smaller particle-size distribution. On the other hand, better control of the air/fuel ratio in the operation of the vehicle system should also minimise the loss of ruthenium.

Another area currently under intensive investigation is the poisoning of the ruthenium-containing catalysts in the environment exhaust. A detailed effort using the techniques used previously in the poisoning studies of oxidation catalysts (14) is in progress.

We owe gratitude to many more individuals at the Ford Motor Company than we can list by name. Most importantly, we acknowledge the help of Joe Kummer, Vern Bergman, Eric Daby, Carol Smith, Gene Hancock, Henry Stepien and numerous members of the Technical Services Department.

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Russian Progress in Platinum Chemistry

The centenary of Lev Aleksandrovich Chugaev (*Platinum Metals Review*, 1973, **17**, (4), 144-148), was the occasion for numerous biographical articles in the Russian scientific press. However, one of the most interesting manifestations was the October 1973 issue of *Zhurnal Neorganicheskoi Khimii*. This was entirely devoted, apart from a valedictory article on Chugaev, to papers on coordination chemistry in celebration of the anniversary.

Russian chemists have for years published more contributions in this field than has any other nation, and the Russian Journal of Inorganic Chemistry, to give its translated title, publishes several articles on the chemistry of the platinum metals every month. In this issue 13 of the 44 articles on coordina-

tion chemistry deal with the platinum metals.

Three papers from the Novosibirsk State University concern platinum(II) complexes with norleucine, platinum(II) chelates with glycylglycine, and optical activity of platinum (II) complexes with mono- and bidentate L-proline. Two papers from the Leningrad Technical Institute concern platinum(II) complexes with hydrogen sulphide, and with N-methylhydroxylamine. Two from the Moscow Institute of Fine Chemical Technology deal with hydrolysis of pentahalooxocomplexes of nitrosoruthenium, and with tert-phosphonium iridium salts. The remaining six papers originate at six other separate universities and institutes, showing the wide interest in this subject in the U.S.S.R.