CONFIRMED by
Chief engineer
of Transbaikal Railways

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A.N. Bolshakov

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Task

The objective is to carry out research of the effect of the RVS geoactivators on the effectiveness of planned preventive and restoration repairs of friction pairs of different types of machines and mechanisms with developing technologies of their use by using the scientific and technical potential of NP Scientific Technical Association NVTs, Chita, NPO Ruspromremont, St. Petersburg, Transbaikal Railway Transport Institute, Chita State Technical University, Central Scientific Research Laboratory of the Priargun Production Mining-Chemical Association, Automobile Engine and System Test Center of Changchun University of Science and Technology, P.R. China. The research was carried out between April 1999 and December 2002.

Results of research

1. The research of the RVS compound in the Lubrication Material Laboratory of Central Scientific Research Laboratory of the Priargun Production Mining-Chemical Association testifies that the compound does not change the physical-chemical properties of oils. Neither is it an abrasive material as it does not change the wear point when tested in a four-ball machine. When the load is increased up to 700 N and the oil temperature up to 70 °C, the wear point is decreased down to a third if compared with basic oil. Furthermore, the form of the wear point is strictly round and it has clear boundaries.
2. Metallography research of piston pins of low and high pressure cylinders of a KT-6 compressor and piston rings of UAZ-469 engines carried out in the Laboratory of Physical Metallurgy of Chita State Technical University with an MIM-8 microscope showed that, as a result of a treatment of the compressor with the RVS Technology, metal ceramic protective layer was formed on the pin and ring surfaces. An analysis of the research results showed that the regularity of the metal ceramic protective layer depends on the wear rate of the friction pair. The higher the wear rate, the less regular the protective layer, and, on highly worn friction pairs, the metal ceramic protective layer is formed as contact points. The surface hardness of the metal ceramic layer is by 30 to 60 percent higher than the hardness of the basic metal, on which the metal ceramic is formed.
3. Research of metal ceramic protective layer carried out in the Laboratory of Machine Parts of Transbaikal Railway Transport Institute showed that the sliding friction coefficient measured in the DM-29 machine with the load of 500 N decreased down to a third and constituted 0.06 instead of 0.18 in the original state. In a “seizing” test of a steel-to-steel pair without lubricant, the non-treated pair seized at the load of 3,000 N while the treated pair stood the load of 4,500 N.
4. Experimental research of parameters of a carburetor petrol engine of BJ 2000 automobile after a single treatment procedure carried out in a Disystem 845 machine of Changchun Technological University showed that the resistance friction moment on the axle reduced by

6 percent, the specific fuel consumption reduced by 5 percent without regulating the carburetor, the CO and HC figures reduced by 25 and 23 percent accordingly.

5. Experimental research of parameters of a PDG-4A diesel engine of a TEM2UM No 1028 locomotive with the use of a computerized rheostatic test post KIPARIS carried out at locomotive depot of the Shilka station showed that the compression pressure in the cylinders increased by 12 percent on the average and reached the nominal level, the oil pressure increased by 12 percent, turbo blow increased by 50 percent and reached the recommended level, fuel consumption by hour decreased by 12.7 percent. The locomotive has been used for 18 months and still being operated without repairing the diesel engine.
6. Experimental research of parameters of two-stroke 14D40 diesel engines of the 3M62 locomotive No 0086 carried out at the locomotive depot of the Borzia station with the use of an automatic computerized rheostatic research post showed that the fuel consumption by hour on idle decreased by 24 percent, the specific fuel consumption at maximum power decreased by 16 percent, the turbocompressor revolution number increased by 28 percent. When checking the clearances between the crankshaft journal and the bearing shells, it was noticed that, during three months of operation of the locomotive after it had been treated with the RVS Technology, the clearances decreased and reached optimal values.
7. Experimental treatments of D12 diesel engines of TU-2 locomotives, D50 diesel engine of a mobile electric power station of the locomotive depot of the Chita station, IaMZ-240 diesel engines of RSM rail lubricating machines No 004 and 005 of the locomotive depot of Shilka station showed that the RVS treatment made it possible to restore the parameters of the engines up to the nominal values, prevent planned repairs and overhauls. The effect duration of a preventive repair by now is 26 months of operation. The expected economical effect is at least 50 percent due to decreased repair and energy consumption costs.
8. Experimental treatments of VP20/8 piston compressors of wagon depot of Chita station and Karymskaia compressor depot showed that the current of the electric motors decreased by 9 percent: the compressor output increased by 14 percent; oil pressure increased by 18 percent and reached nominal values. The effect duration is at least two years of operation. The expected effect is at least 60 percent of the costs.
9. Experimental research of treating roller bearings with the RVS Technology carried out in the locomotive depot of Chita station showed that radial beating (clearances) decreases by 40 percent on the average (the geometric parameters of rolling tracks and roller parts are restored), the noise and vibration of the bearing operation are decreased, service life is increased. Industrial experiments of the technology of restoring a 3003792N bearing of a stone crusher SMD-118 at a crushed stone plant in the village of Taldan showed that the bearing parameters were fully restored and the profitability of the repair was 1,700 percent.
10. Experimental research of the effect of the RVS treatment on the parameters of tooth coupling carried out in drive gearboxes of wheel-motor blocks (WMB 2, WMB 5) of the locomotive TEM2A No 222 of the locomotive depot of Chita station showed that the geometric parameters of the teeth of the gearing were restored (0.2 mm of increase of the tooth thickness) and the surface roughness of the teeth was decreased. A measurement of the dynamic parameters of a WMB carried out with the computer vibration diagnostic equipment Prognoz showed that the vibration level in the anchor and axle-box bearing points decreased on the average by 12 dB. When researching the duration of the effect of an RVS treatment and the stability of the metal ceramic protective layer, the oil was drained off the treated gearboxes and the locomotive was operated without oil in the gearboxes in heavy conditions within the temperatures of -45 and +40 °C from April 14th, 2000 until February 14th, 2001. During that time the metal ceramic protective layer wore by 95 percent in WMB 2, by 75 percent in WMB 5. Furthermore, the wear in WMB 2 was caused by warp of the pinion axle due to disrepair of fastening of the motor axle bearing case. The expected

economic effect constitutes 82 percent of the costs due to longer useful life of the gearboxes and bearings as well as due to reduced operation costs.

11. Experimental research of the effect of the RVS geoactivators on the wear process speed of wheel flanges of the $VL80^S$ locomotive No 850/876 carried out in conditions of carrying heavy loads by the route Chita – Khabarovsk – Chita – Khabarovsk – Chita – Khabarovsk – Chita with the total mileage of 15,000 km showed that the wear of the wheel flanges wasreduced down to a third, the micro hardness of the flange surfaces in the contact zone with the rail was increased on the average by 20 percent. The expected economic effect constitutes 16,000 roubles per wheel pair due to the reduced number of turnings and increased useful life of the band.

Reports of the researches are enclosed

Conclusions

Results of the experimental researches and treatments of mechanisms prove the high technical and economical effect of the RVS Technology.
Using the RVS Technology makes the following possible:

- increase the inter-repair interval of friction pairs of mechanisms and machines at least two-fold
- reduce energy consumption by 7 to 15 percent
- reduce dynamic loads on axle supports
- restore geometric parameters of friction pairs
- reduce toxicity of exhausts of internal combustion engines
- restore effective power of worn internal combustion engines
- reduce operation costs down to a half or lower

Recommendations

To continue the research of the rail-to-wheel tribosystem in order to reduce the wear of wheel flanges and the side surface of rails.
To recommend the sub-organisations of the railways to use the RVS Technology in planned and preventive as well as in restoration repairs of heavy and high-costs equipment.

Vice chief engineer, manager of the technical policy division, Transbaikal Railways — O.I. Ladygin

Director, Transbaikal Railway Transport Institute — N.P. Sigachev

General director, NPO Ruspromremont — I.F. Pustovoi

Director, NTO NVTs — V.A. Iarilov

REPORT
ON EXPERIMENTAL RESEARCH OF
PISTON COMPRESSOR KT-6EL

1. Parameters of the compressor before the RVS treatment

№	P_M , MPa	T_M , °C	T_{air} , °C	Time of collecting the pressure	Operation time, minutes
1	4,9	18	40		10
2	6,0	24	60		10
3	5,8	28	100		10
4	5,6	32	140	37 sec	10
∑					40

2. Parameters of the compressor after the RVS treatment

The repair and restoration compound was added into the oil of the crankcase and as a mixture with oil into the cylinders above the pistons.

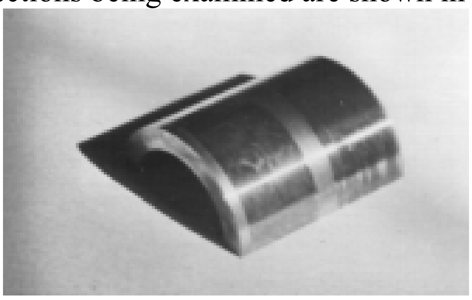
№	P_M , MPa	T_M , °C	T_{air} , °C	Time of collecting the pressure	Operation time, minutes
1	4,8	16	60		10
2	6,1	18	100		10
3	6,0	20	140	32 sec	10
4	5,9	25	145		10
5	5,9	31	145		10
∑					50

3. Control measurement

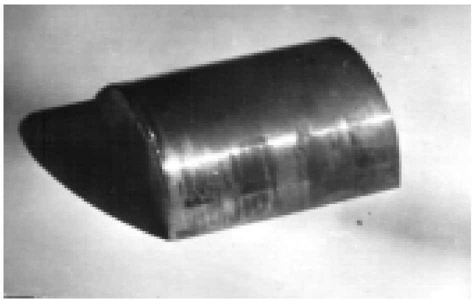
№	P_M , MPa	T_M , °C	T_{air} , °C	Time of collecting the pressure	Operation time, minutes
1	4,2	10	70		10
2	4,5	10	100		10
3	5,9	20	140	30 sec	10
∑					30

4. Analysis of the micro structure of the metal

The sections being examined are shown in Pictures 1 and 2.



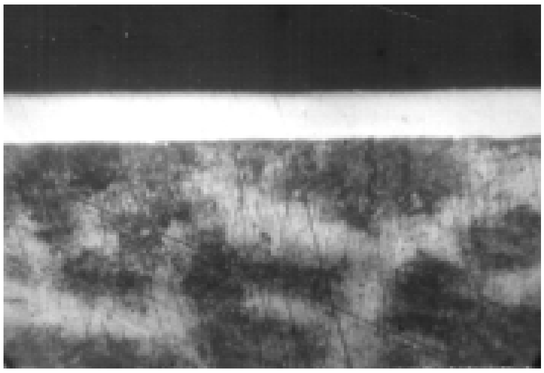
Picture 1: Section of pin of the low pressure cylinder



Picture 2: Section of pin of the high pressure cylinder

The structure of the metal of the pins of high and low pressure cylinders was examined with a metallography microscope MIM-8. The magnifying rate constituted 200 to 400. Photographs of the structure of the metal of the high and low pressure cylinders are shown in Pictures 3 and 4 accordingly.

Picture 3: Structure of the metal of the high pressure cylinder (magnifying 200-fold)



Picture 4: Structure of the metal of the low pressure cylinder (magnifying 400-fold)

It was determined that the material of the pin of the high pressure cylinder was carbon steel 45 in annealed condition after rolling (half-finished product in a form of round bar). In Picture 3, one can see the characteristic orientation of perlite and ferrite layers

In the periphery of the section, one can see a white layer of metal ceramic that does not corrode. The layer has a local character of coating, and its thickness does not exceed 20 µm. However, there are local points of metal ceramic coating of the thickness of 20 to 50 µm on the high pressure cylinder piston pin surface in the places of intensive contact with the bearing shell of the crankshaft.

When examining the structure of the material of the low pressure cylinder piston pin, it was determined that it has been manufactured of the steel 30Kh or 20KhGS in annealed condition without orientation of grain after pressure treatment. In Picture 4, the coarse-grained character of the perlite and ferrite layers can be seen.

In the periphery of the section, one can see a white layer of metal ceramic that does not corrode. The layer has a uniform character all over its length and its thickness varies between 25 and 40 µm. Simultaneously, in the zone of the greatest wear of the pin-to-bearing shell friction pair, the layer of metal ceramic is up to 10 µm thick with a uniform character of distribution.

The measurement of the macro hardness of the basic material of the high and low pressure cylinder piston pins was carried out with a Rockwell hardness meter by using a diamond cone ($\alpha = 120°$) as the indentor. The measurements were made in three control points.

Measurement results:

- hardness of the high pressure cylinder piston pin – 25 to 30 HRC
- hardness of the low pressure cylinder piston pin – 40 to 46 HRC

The hardness measurements of the metal ceramic coating were carried out with a micro hardness meter PMT-3 by comparing the hardness with the hardness of chrome galvanised surface. A tetrahedral diamond pyramid with a square basis was used as the indentor. Furthermore, we used the restored imprint method that is similar to the method of measuring hardness in the Vickers scale (HV).

In our case, we pressed a tip on the model surface restored with chrome and RVS Technology with the force of 4.9 N for 10 to 15 seconds. The micro hardness value (MHV) in the Vickers scale is defined according to the formula:

$$\mathbf{MHV = 4CF/(d_1+d_2)^2},$$

jossa C = 0.189

d_1 and d_2 = diagonals of imprint, mm

The measurement and calculation results showed that the micro hardness of the metal ceramic exceeds the micro hardness of chrome galvanised surface two-fold.

5. *Analysis of the research*

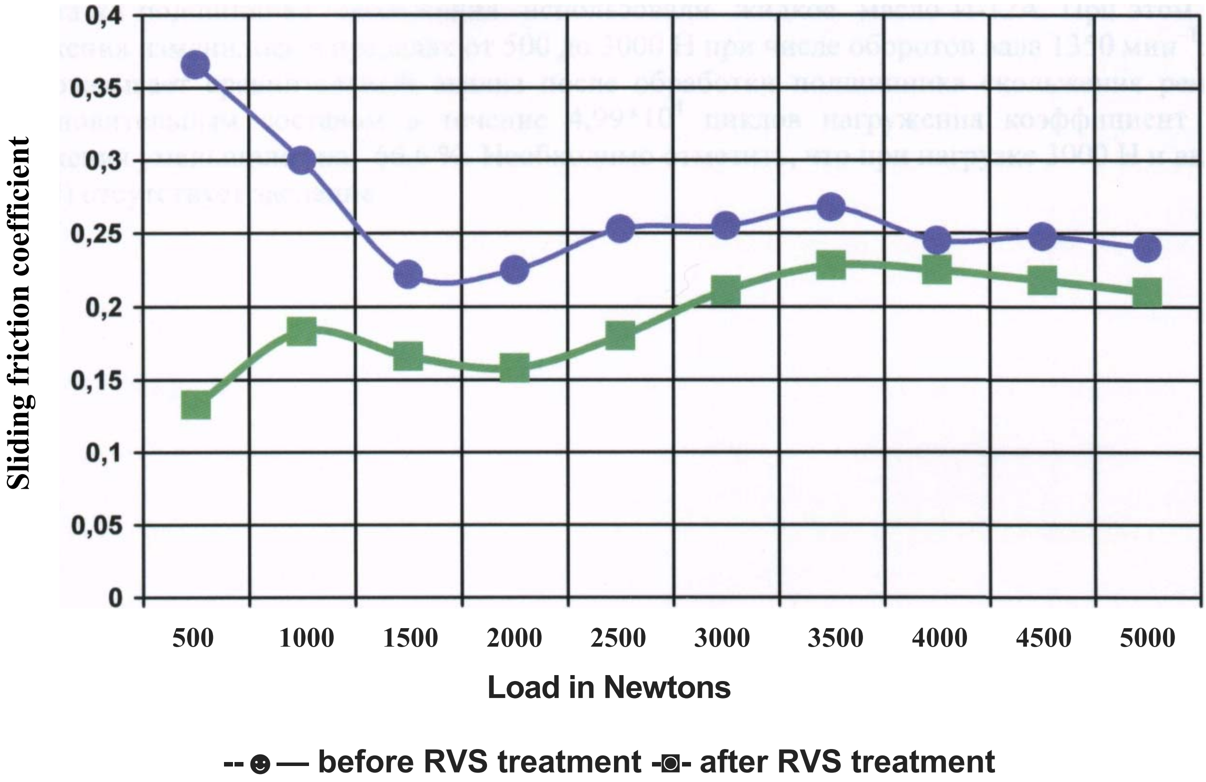
An analysis of the research showed that the use of RVS compounds is possible and necessary as a resource saving technology in order to prevent wear of friction surfaces in crank mechanisms and cylinders of compressors. It is expedient to use the RVS compound before critical wear occurs, i.e. immediately after the compressor has been run in or after it has been run in at a depot after it has been repaired as planned with traditional means. As the RVS Technology increases micro hardness and improves antifriction properties of friction surfaces, inter-repair period is extended at least two-fold. The RVS Technology is not to be regarded as a substitute for repairing technologies traditionally used for compressors in case of extensive wear rate of parts because the RVS Technology does not remove metal wear corrosion or seizing traces on parts of cylinders and pistons. For compressors coming to repair, restoring crank and piston pins with metal ceramic is insufficient as oil clearances between pins and bushings can be up to 1.5 mm as a result of wear. Furthermore, RVS Technology does not allow to remove defects of metal and mechanical damages (cracks etc.) in compressor parts that appear during operation process.

REPORT

on checking the parameters of plain bearings in a friction machine

Research of plain bearings were carried out in a DM-29 plant. The bearing shell was manufactured of bronze Br A5Ts5S5, the shaft of steel 45. The macro hardness of the shaft journal constituted HRC 30. The loading force was 50 to 500 kgf at the shaft speed of 1,350 min”^{1}. For lubricating the bearing shell, liquid oil I-20 (GOST 20799-75) was used. The repair and restoration compound was added directly into the lubricant. The sliding friction coefficients of the shaft-to-bearing shell pair were defined with a method developed in the Moscow State Technical University n.a. N.E. Bauman. The results of the research are shown graphically in Picture 5.

Picture 5: The dependence of friction coefficient on load



The plain bearing researches were acarried out by using a DM-29M plant with the methods of Moscow State Technical University n.a. N.E. Bauman.

The bearing shell was manufactured of steel 35 and the shaft of steel 45. The macro hardness of the shell material constituted HRC 30, and that of the shaft HRC 56.

Before treating the plain bearing with the RVS compound, the sliding friction coefficient changed depending on the radial load as shown in Table 1.

Table 1: Values of sliding friction coefficient of steel-to-steel pair without RVS

F	Value of radial load, N					
	500	1000	1500	2000	2500	3000
F_1	0,16	0,25	0,30	0,34	0,39	Corrosion
F_2	0,2	0,28	0,28	0,4	0,39	Corrosion
F_{aver}	0,18	0,26	0,29	0,37	0,39	Corrosion

After the plain bearing had been treated via the lubrication system, the sliding friction coefficient changed depending on the radial load as shown in Table 2.

Table 2: Values of sliding friction coefficient of steel-to-steel pair with RVS

F	Value of radial load, N					
	500	1000	1500	2000	2500	3000
f_5	0,06	0,2	0,21	0,26	0,26	0,26
f_6	0,06	0,16	0,2	0,21	0,26	0,26
F_{aver}^{RVS}	0,06	0,18	0,20	0,23	0,26	0,26

For lubricating the plain bearing, liquid oil I-20A was used. The load force varied between 500 to 3,000 N at the shaft speed of 1,350 min”^{1}. As the comparative analysis shows, after the treatment of the plain bearing with the repair and restoration compound, the sliding friction coefficient decreased by 66.6 percent during 4.99 * 10^4 cycles. It is necessary to note that at the load of 3,000 N and higher (up to 4,000 N) no corrosion occurs.

REPORT
ON EXPERIMENTAL RESEARCH OF TREATING TWO-STROKE DIESEL ENGINES WITH THE RVS TECHNOLOGY

The experiment was carried out at locomotive depot of Borzia station in the area of rheostatic tests equipped with technical apparatuses that allow to control the following parameters of a diesel engine: **compression in cylinders, flash pressure, flash temperature, engine revolution speed, turbo revolution speed, oil pressure, coolant temperature, turbo supercharge, generator power, fuel consumption per hour, specific fuel consumption, surrounding temperature.**
The methods of the experiment were developed on the basis of preliminary results that were available after the diesel engine of Section A of the locomotive 3M62 No 0086 was treated. The method consists of the following: **measure the parameters of the diesel engines 14D40 of the locomotive 3M62 No 0088 and write down the results in a file; treat the diesel engines by adding the repair and restoration compound in the engine oil, cylinders and fuel system; run in the engines on idle during 2 hours; measure the parameters of the operation of the diesel engines and write down the results in a file; operate the engines in normal conditions for one month and check the parameters; operate the engines in normal routes and control the parameters monthly.**
The C section was treated with the RVS Technology on October 2nd, 1999. Sections A and B were treated on October 12th, 1999.
The dynamics of the clearance change and sagging of the crankshaft is shown in Table 3.
The results of the rheostatic tests are shown in Table 4.
The abbreviations used in the tables:
n – engine revolution speed, rpm; n_{turbo} – turbo revolution speed, rpm: G_{fuel} – fuel consumption per hour, kg/h: g_e – specific fuel consumption, g/kWh; P_{gen} – generator power, kWh; p_{turbo} – turbo supercharge, kg/cm^2; T_{surr} – temperature of surrounding air, °C.

Table 3: Dynamics of clearance and crankshaft sagging change

Date	Section A		Section B		Section C	
	Clearance	Sagging	Clearance	Sagging	Clearance	Sagging
Before treatment Sept. 4^{th}, 1999	0.24	0.05	0.22	0.05	0.23	0
	0.24-0.22	0/0.05	0.22-0.21	0.05/**0.06**	0.22-0.22	0.05/**0.09**
	0.22-0.26	**0.06/0.08**	0.2-0.19	**0.06/0.08**	0.21-0.2	**0.07/0.06**
	0.27-0.29	**0.06/0.06**	0.19-0.19	**0.06/0.07**	0.2-0.2	**0.13/0.12**
	0.29-0.25	0.08/0.08	0.2-0.21	**0.18/0.17**	0.18-0.14	**0.16**/0.15
	0.2-0.19	0.08/0.1	0.2-0.2	0.15/**0.18**	0.13-0.13	**0.18/0.17**
	0.22	0.1	0.17	0.15	0.1	**0.17**
After treatment Oct. 17^{th}, 1999	0.23	0	0.18	0.06	0.19	0
	0.22-0.2	0/0	0.18-0.19	00.05/**0.08**	0.19-0.2	0/0
	0.19-0.21	0/0.05	0.18-0.19	**0.08/0.08**	0.18-0.19	0.05/0.05
	0.22-0.21	0.05/0.05	0.18-0.19	**0.08/0.08**	0.18-0.18	**0.06/0.06**
	0.21-0.2	0.06/0.08	0.18-0.2	0.08/0.08	0.19-0.18	0.08/0.07
	0.19-0.18	0.08/0.08	0.19-0.18	0.07/0.08	0.17-0.17	0.08/0.09
	0.19	0.09	0.17	0.07	0.16	0.1
After running-in Dec. 7^{th}, 1999	0.23	0	0.21	0	0.19	0
	0.2-0.22	0/0	0.21-0.23	0/0	0.2-0.2	0/0
	0.19-0.2	0/0	0.23-0.24	0/0	0.19-0.18	0/0
	0.22-0.2	0.05/0.05	0.24-0.23	0.05/0.04	0.18-0.18	0.05/**0.06**
	0.21-0.21	0.07/0.08	0.2-0.2	0.09/0.13	0.19-0.19	0.08/0.08
	0.19-0.19	0.08/0.08	0.19-0.24	0.06/0.09	0.17-0.18	0.09/0.08
	0.2	0.08	0.19	0.08	0.17	0.09
After mileage Jan. 20^{th}, 2000	0.19	0	0.19	0	0.19	0
	0.19-0.21	0/0	0.19-0.19	0/0	0.2-0.2	0/0
	0.2-0.22	0/0	0.19-0.2	0/0	0.19-0.19	0/0
	0.21-0.118	0.04/0.05	0.2-0.21	0/0	0.19-0.118	0/0
	0.17-0.18	0.07/0.08	0.2-00.25	0.15/0.15	0.15-0.13	0.09/0.1
	0.08-0.08	0.07/0.08	0.21-0.2	0.05/0.05	0.1-0.1	0.12/0.13
	0.22	0.05	0.14	0.04	0.11	0.1
After operation Mar. 19^{th}, 2000r.	0.27	0.05	0.19	0	0.21	0.05
	0.27-0.28	0.05/0	0.21-0.21	0/0	0.2-0.18	0.05/0
	0.27-0.27	0.04/0	0.21-0.25	0/0	0.18-0.19	**0.08**/0
	0.27-0.22	0.04/0.05	0.19-0.2	0/0	0.18-0.18	0.06/0.07
	0.2-0.22	0.07/0.09	0.26-0.27	**0.18/0.17**	0.18-0.15	0.14/**0.16**
	0.05-0.06	0.08/0.09	0.24-0.2	0.06/0.06	0.14-0.18	**0.16/0.19**
	0.21	0.08	0.2	0.07	0.19	**0.17**

The bold type values are beyond the allowed norms.
Before the treatment the sagging parameter of the following crankshaft supports did not correspond to the technical requirements: A3, A4,B2, B4, B5, B6, C2, C3, C4, C5, C6, and C7. The category of technical condition of the crank mechanism corresponded to the category of “LIMITEDLY PERMISSIBLE”.

After the treatment and running-in of 1.5 months, the sagging parameter began to correspond to the technical requirements. Thus, the category of the technical condition of the crank mechanism began to correspond to the category of “ACCEPTABLE”.
After the mechanism had been operated for 5.5 months, the sagging parameter of the following supports ceased to correspond to the technical requirements: B2, B3, and B6. When the bearing shells were replaced, it was found out that the antifriction layer had crumbled. Thus, the deterioration of the sagging parameter of the supports above occurred due to aging material but not wear. The crankshaft journals correspond to the technical condition category of “ACCEPTABLE”.

Table 4: Results of rheostatic tests

Date		**Section A**		**Section B**		**Section C**	
	Parameters	Position 0	Position 15	Position 0	Position 15	Position 0	Position 15
Oct. 2nd, 1999 before treatment. T = +7 °C	**n**					400	753
	N_{turbo}					2700	13170
	G_{fuel}					24.62	
	g_e						217
	P_{gen}						1127
	p_{turbo}						0.8
Oct. 12th, 1999 before treatment. T = +5 °C	**n**	400	748	400	750		
	N_{turbo}	3000	13740	3210	16020		
	G_{fuel}	23.4		26.0			
	g_e		228		216		
	P_{gen}		1211		1255		
	p_{turbo}		0.8		0.85		
Oct. 12th, 1999 after treatment T = +5 °C	**n**	400	750	400	750	400	750
	N_{turbo}	2970	14220	**3300**	**16170**	**3330**	**13205**
	G_{fuel}	**22.04**		**20.12**		**22.01**	
	g_e		221		212		**204**
	P_{gen}		1212		1241		1130
	p_{turbo}		0.85		0.85		0.82
Nov. 29th, 1999 after treatment T = -14 °C	**n**			400	748		
	N_{turbo}			**3630**	**16180**		
	G_{fuel}			**19.6**			
	g_e				**181**		
	P_{gen}				1250		
	p_{turbo}				0.9		
Mar. 28th, 2000 after treatment T = -10 °C	**n**	404	752	402	753	400	753
	N_{turbo}	Not controlled	Not controlled	3650	**16230**	**3210**	**16890**
	G_{fuel}	**21.77**		**19.9**		**19.74**	
	g_e		240		**189**		**206**
	P_{gen}		1189		1220		1207
	p_{turbo}		0.88		0.88		0.85

An analysis of the results of the rheostatic tests showed that the fuel consumption per hour on idle (controller position 0) decreased by 7, 23, and 19 percent in Sections A, B, and C accordingly. In section A, during the treatment process, it was noticed that the revolution number varied and the engine even stopped. As it was found out later, the case of the nozzle apparatus of the turbocharger had broken, which led to seizing of the rotor with all the consequences relating to that, and on October 26,th, 1999 the turbochargers of the Section A engines were replaced. Thus, the turbochargers of Section A appeared not to be treated with the RVS Technology.
Due to decreased internal friction in the shaft-to-plain bearing pair of the turbochargers the revolution number increased by 28 percent (Position 15) in Section B. In Section C the increase of the revolution number constituted 13 percent (Position 0), and in Position 15 the increase is insignificant, because the values corresponded to the manufacturers norm even before the treatment. The revolution number of Section A turbochargers was not controlled because of their earlier replacement.
An analysis of the results of the rheostatic tests on the specific fuel consumption showed that the consumption values decrease by 4 percent on the average immediately after the treatment (during 2 to 4 hours of running-in). When checking the specific fuel consumption after 1.5 months of operation, the value of Section B had decreased by 16 percent. A similar check of Sections A and B was not carried out. After the engines had been in operation for 5.5 months, a check of the specific fuel consumption of Sections B and C showed that the final decrease constituted 10 percent on the average.
Thus, the use of the RVS Technology in diesel engines of locomotives is a promising field of planned and preventive repairs and energy saving.

REPORT
ON EXPERIMENTAL RESEARCH OF TREATING A TOOTH COUPLING OF A WHEEL-MOTOR BLOCK OF A SHUNTING ENGINE WITH THE RVS TECHNOLOGY

Research on the effect of treating tooth coupling with the repair and restoration compound was carried out in wheel-motor blocks of the second and fifth wheel pairs of the shunting engine TEM2A No 222 that belongs to the locomotive depot of Chita station.
The treatment of the tooth gearings of the drive gearboxes was carried out three times with a control of the geometry of the teeth and the vibration parameters by using Prognoz diagnosis equipment. Before the treatment the gearing were cleaned of contamination and remainders of oil destruction. The oil in the cases of the wheel pairs to be treated was replaced. After the third treatment and operation running-in the oil was drained off the gearboxes. Further the shunting engine was operated without oil in the gearboxes of the second and fifth wheel pairs. The thickness of marked teeth and the vibration condition of the gearboxes were measured periodically.
The results of tooth thickness measurements are shown in Table 5. The geometric parameters of the teeth of drive gearboxes of the second and fifth wheel-motor blocks were controlled by specialists of the locomotive depot of the Chita station with the methods approved in the Railway Ministry.
Pictures 6 and 7 show the direct and envelope spectra that were made by Prognoz equipment on direct measurement of vibration acceleration. The acceleration sensing elements were installed in the zone of the electric motor bearing and that of the axle-box. The measuring point in the zone of the bearing of the driving electric motor characterises the vibration condition of the pinion driving, whereas the measuring point in the zone of the axle-box characterises the vibration condition of the driven pinion.
The results of the analysis of the vibration condition of the pinions carried out with Prognoz equipment is shown in Table 6.

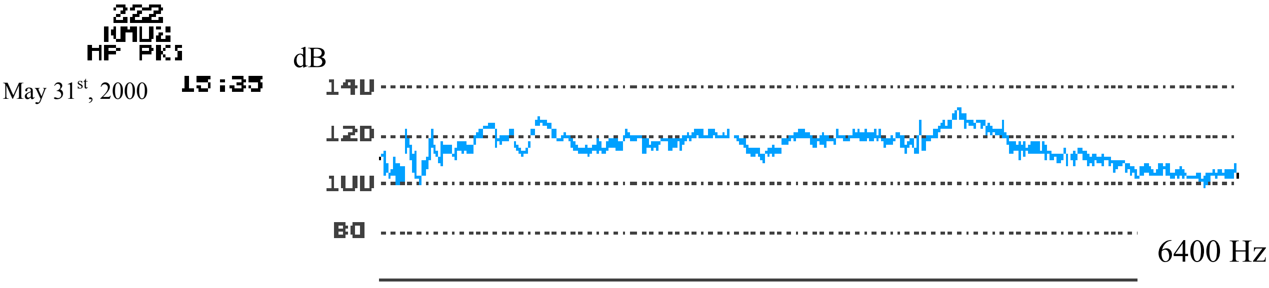
Table 5: Tooth thickness

Tooth thickness		Before treatment	After treatment	After operation without oil in the gearbox	After operation without oil in the gearbox	After operation without oil in the gearbox	After operation without oil in the gearbox
Control date		**Feb. 3, 2000**	**Apr. 4, 2000**	**May 24, 2000**	**Jul. 26, 2000**	**Nov. 10, 2000**	**Feb. 6, 2001**
WMB 2	Tooth № 1	**18,7 mm**	**18,7 mm**	**18,9 mm**	**18,9 mm**	**18,8 mm**	**18,7 mm**
	Tooth № 2	**18,9 mm**	**18,9 mm**	**19,0 mm**	**19,0 mm**	**18,9 mm**	**18,9 mm**
	Tooth № 3	**18,8 mm**	**18,8 mm**	**19,0 mm**	**19,0 mm**	**18,9 mm**	**18,8 mm**
WMB 5	Tooth № 1	**18,5 mm**	**18,6 mm**	**18,7 mm**	**18,7 mm**	**18,6 mm**	**18,55 mm**
	Tooth № 2	**18,5 mm**	**18,6 mm**	**18,7 mm**	**18,7 mm**	**18,6 mm**	**18,55 mm**
	Tooth № 3	**18,5 mm**	**18,6 mm**	**18,7 mm**	**18,7 mm**	**18,6 mm**	**18,55 mm**

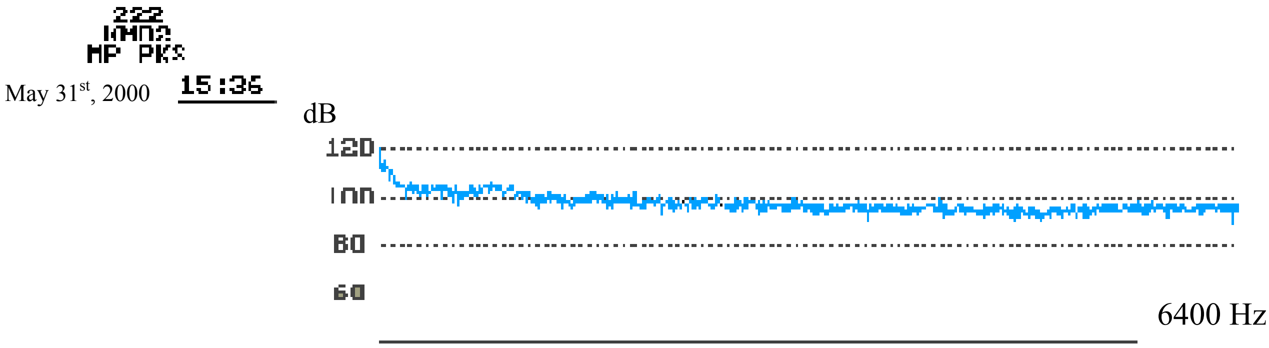
On April 12th, 2000, after the third treatment with the repair and restoration compound and work-hardening of the tooth surfaces, the oil was drained off the WMB 2 and WMB 5. As shown in Table

5, the work-hardening of the friction pairs of the gearbox occurred with the availability of the repair and restoration compound in the oil. Formation of the metal ceramic protective layer did not practically occur with the presence of oil as there was not enough heat energy (secreted by friction) available for the substitution reaction. After the oil had been drained off the gearbox, more heat energy was available, which resulted in more intensive formation of the metal ceramic protective layer. A visual check of the tooth surfaces showed that the contact surfaces are characterised by mat colour with very high purity of the surfaces.

Picture 6: Vibration intensity before treatment

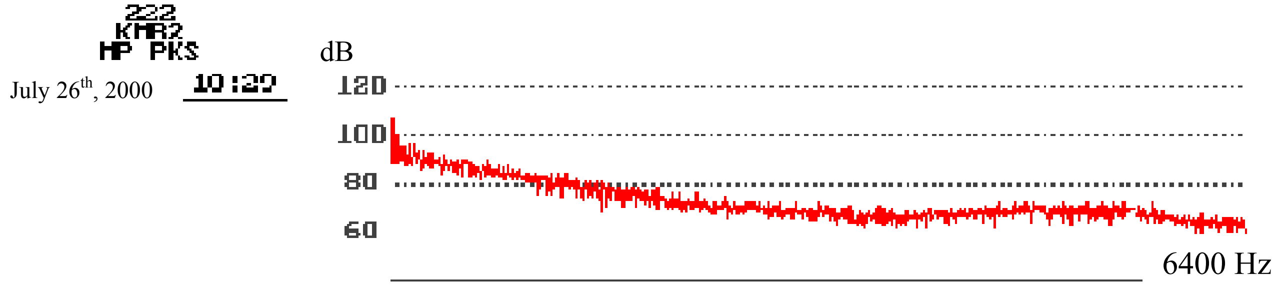


direct spectrum

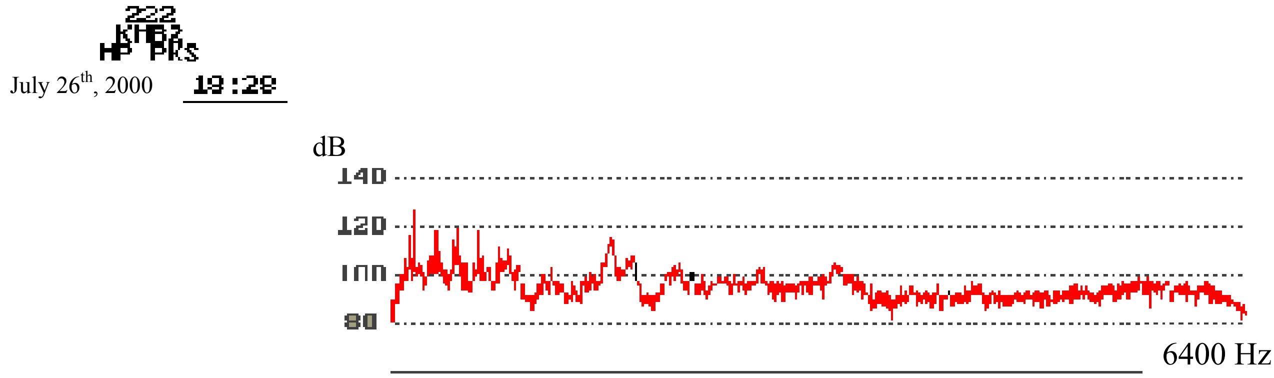


spectrum of envelope

Picture 7: Vibration intensity after treatment



spectrum of envelope



direct spectrum

As one can see in Pictures 6 and 7, after the metal ceramic layer had been run in, the vibration level decreased significantly. The vibration intensity in the direct spectrum decreased on the average by 12 units. The vibration intensity in the spectrum envelope decreased on the average by 20 units. The time of running-in the metal ceramic protective layer can be approximately defined by Table 6 where one can see that the final running-in of the tooth coupling of the gearboxes of WMB 2 and WMB 5 occurred, at the latest, on June 26th, 2000 when the analysis of the vibration condition made with the Prognoz equipment showed that the vibration level had decreased below the level of the steps given in the program.

Table 6: Vibration condition

Date	WMB 2		WMB 5	
	Point of anchor bearing (small pinion)	Point of axle-box (large pinion)	Point of anchor bearing (small pinion)	Point of axle-box (large pinion)
Feb 3. 2000	Defect of small pinion 7 %, weak, likelihood 50 %.	Defect of large pinion 4 %, weak, likelihood 30 %.	Defects not detected	Defect of large pinion 4 %, weak, likelihood 50 %
Feb 18. 2000	Defects not detected	Defect of large pinion 9 %, weak, likelihood 60 %.	Defects not detected	Defect of large pinion 10 %, weak, likelihood 20 %
14.03. 2000г	Defect of small pinion 10 %, average, likelihood 90 %.	Defects not detected	Defects not detected	Defect of large pinion 8 %, average, likelihood 20 %.
May 24, 2000	Defects not detected	Defect of large pinion 10 %, average, likelihood 20 %.	Defects not detected	Defect of large pinion 12 %, average, likelihood 50 %.
Jun 26, 2000	Defects not detected	Defects not detected	Defects not detected	Defects not detected
Oct 10, 2000	Defects not detected	Defects not detected	Defects not detected	Defects not detected
Nov 10, 2000	Defects not detected	Defects not detected	Defects not detected	Defects not detected
Dec 23, 2000	Defects not detected	Defects not detected	Defects not detected	Defects not detected
Feb 6, 2001	Defect of small pinion 5 %, weak, likelihood 30 %.	Defect of large pinion 5 %, weak, likelihood 20 %.	Defects not detected	Defects not detected

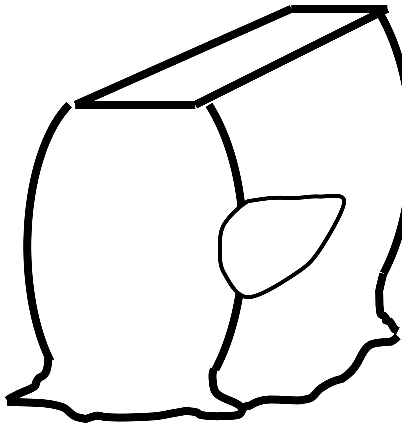
When the drive gearboxes were visually controlled (February 6^{th}, 2001), wear of teeth of the large pinion of WMB 2 was detected, and the character of the wear was evidence of some failure in the regulations of the wheel-motor block. Picture 8 shows the character of the wear of the teeth. On the large pinion of WMB 5, the wear of the teeth is hardly detectable, but at the edge of the teeth the wear is similar to that of the teeth in WMB 2.

When checking the regulations in WMB 5, it was noted that the clearances of the motor axle bearings had increased, due to which the drive pinion had moved in relation to the driven pinion, which had resulted in the wear of the edges of the teeth.

In WMB 2, it was noted that a washer of a bolt of the motor axle bearing cover had broken. It had led to break-down of the regulation gasket, and, as a result, to defect of the linearity of the driving shaft in relation to the driven shaft.

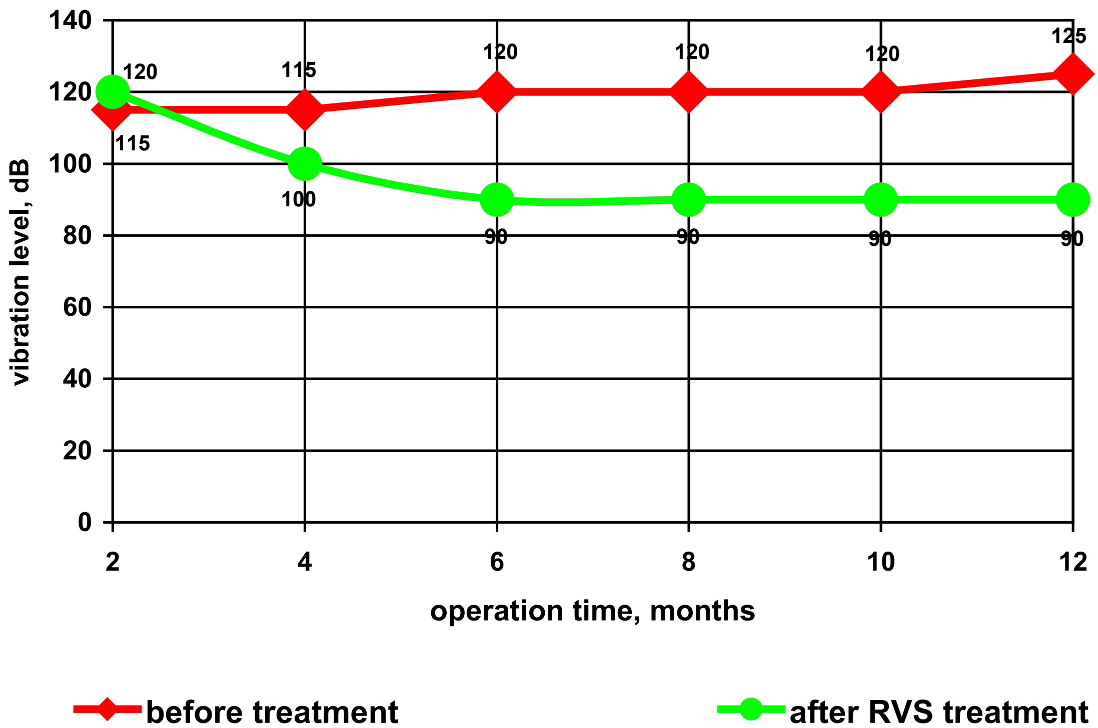
In Picture 8, one can see that the wear of the teeth had begun at the edge and had proceeded to the centre of the teeth.

Picture 8: Character of wear of teeth

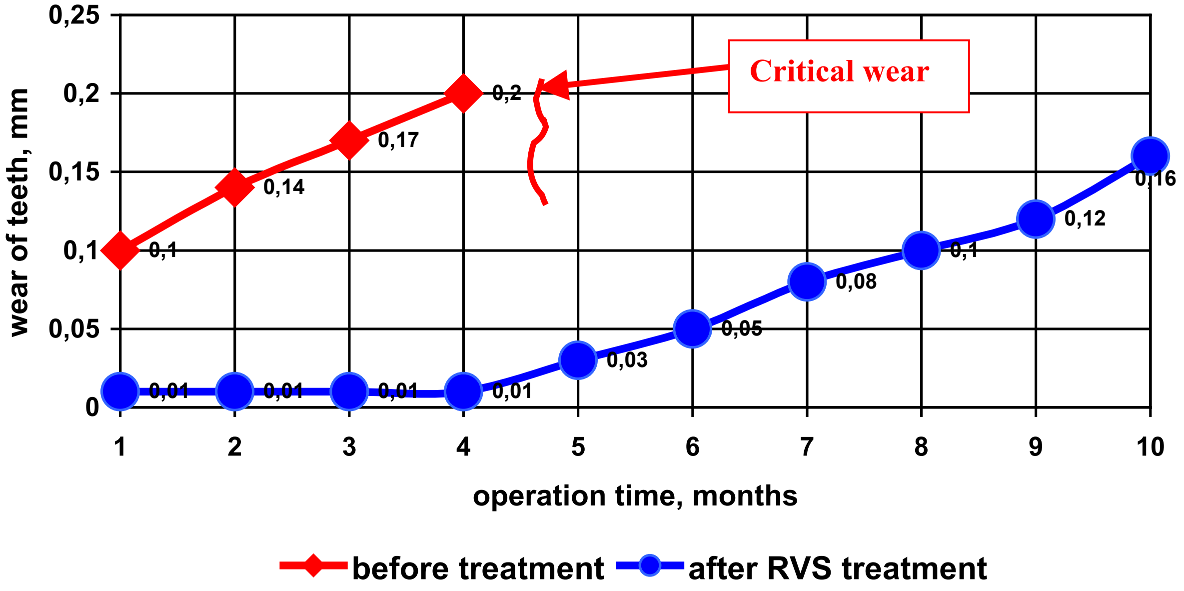


A comparison of the vibration condition on the basis of the envelope spectrum of the wheel-motor blocks is shown in Picture 9.
A comparative analysis of the wear speed of the gearbox wheels when it was operated without lubricant is shown in Picture 10.

Picture 9: Comparison of vibration condition of WMB on basis of envelope spectrum



Picture 10: Comparison of wear speed of gearbox wheels when operated without lubricant



It is necessary to note that, in a straight bevel gearbox, there are no axial loads on the wheels. In bevel gearboxes, due to axial loads, the gear wheels are centred and that kind of a gearbox is better adapted for railway transport use.

Thus, treating drive gearboxes with the RVS Technology makes it possible to restore geometrical parameters of tooth gears and to significantly decrease the vibration loads on supports (bearings) of the shafts of the gear wheels, which undoubtedly increases their durability and longevity.

REPORT

ON EXPERIMENTAL RESEARCH OF TREATING FOUR-STROKE DIESEL ENGINES WITH THE RVS TECHNOLOGY

Research of the effect of RVS Technology treatment on parameters of D12 diesel engines were carried out on branch railway lines in normal operation. Due to unavailability of objective control equipment, the change of the parameters was estimated by comparison and by indirect parameters.
The diesel engines of locomotives TU2 No 208 and No 122 were treated once

Locomotive No 208

- Crank mechanism and cylinders via lubrication system
- Air compressor
- Revolution number regulator
- Fuel equipment

Locomotive No 122

- Crank mechanism and cylinders via lubrication system
- Air compressor
- Revolution number regulator

After a few hours of operation of the diesel engines on idle, the following was noticed:

- Clean exhaust gases, i.e. the smokiness had decreased significantly. Accordingly, the fuel consumption had decreased and the combustion process had become more perfect.
- Noises in the engine decreased.
- The revolution number became invariable due to normalisation of the operation of the revolution number regulator.
- The oil pressure had increased.
- The compression pressure in the cylinders had increased

The locomotives were controlled during all the operation period. In the operation, there were no failures arising from the effect of the RVS Technology. According to information from the team on board, the fuel consumption was reduced by approximately 8 percent.

When the locomotives were put into winter storage, the following parameters were measured:

- Compression in cylinders

CYLINDERS		Left						Right					
		1	2	3	4	5	6	1	2	3	4	5	6
TU 2 No 208	Before treatment kg/cm^2 (May 2000)	23	24	23	24	26	24	25	23	26	23	24	25
	After treatment (Aug 28, 2000)	**26**	**26**	**26**	**26**	**26**	**26**	**26**	**26**	**26**	**26**	**26**	**26**
TU 2 No 122	Before treatment kg/cm^2 (May 2000)	24	26	25	24	26	25	25	26	26	25	26	26
	After treatment (Aug 28, 2000)	**26**	**26**	**26**	**26**	**26**	**26**	**26**	**26**	**26**	**26**	**26**	**26**

- Oil pressure and output of compressors

Locomotive	oil pressure kg/cm^2		Time of filling the main recervoir of brake system with air, min	
	Before treatment	After treatment	Before treatment	After treatment
No 208	6,5	8,0	In position 8: 0 to 8 kg/cm^2	
			6	4
No 122	6,0	8,0	In position 0: 6 to 8 kg/cm^2	
			4	3

- The achieved cleanness of exhaust gases had not changed.
- The engines work smoothly with noticeably lower level of characteristic noises.

Research of PDG-4A diesel engine of TEM2UM locomotive
The efficiency of restoring the parameters of the PDG-4A diesel engines was researched in the TEM2UM locomotive No 1028 at the locomotive depot of the Shilka station. The following mechanisms were treated with the repair and restoration compound: cylinders, crank mechanism, fuel equipment, revolution number regulator. The measurements were carried out with the regular equipment for rheostatic test with Kiparis control apparatus.
The controlled parameters

- Compression in cylinders
- Flash pressure
- Oil pressure
- Supercharge of the turbocharger
- Oil temperature
- Fuel consumption on idle

The results of the measurements are shown in the table.

Parameter	Before treatment						After treatment					
Compression, kg/cm^2	1	2	3	4	5	6	1	2	3	4	5	6
	25	24	25	26	25	24	**28**	**28**	**28**	**28**	**28**	**28**
Flash pressure, kg/cm^2	1	2	3	4	5	6	1	2	3	4	5	6
	50	46	52	46	46	44	**58**	**58**	**60**	**60**	**58**	**58**
Oil pressure, kg/cm^2	2.5						**2.8**					
Oil temperature	68 °C						**65 °C**					
Supercharge of turbocharger, kg/cm^2	0.5						**0.75**					
Fuel consumption, kg/h	7.3						**6.375**					

As a result of the treatment, all the parameters of the diesel engine began to correspond, according to the manufacturer information, to the values of a new engine.
For reference (the manufacturer information on the parameters of the PDG-4A diesel engine):

- compression
  28 – 30 kg/cm^2
- flash pressure
  ≤ 70 kg/cm^2

- oil pressure
  ≥ 2.5 kg/cm^2
- oil temperature ≤ 75 °C
- supercharge of turbocharger
  0.6 ± 0.1 kg/cm^2

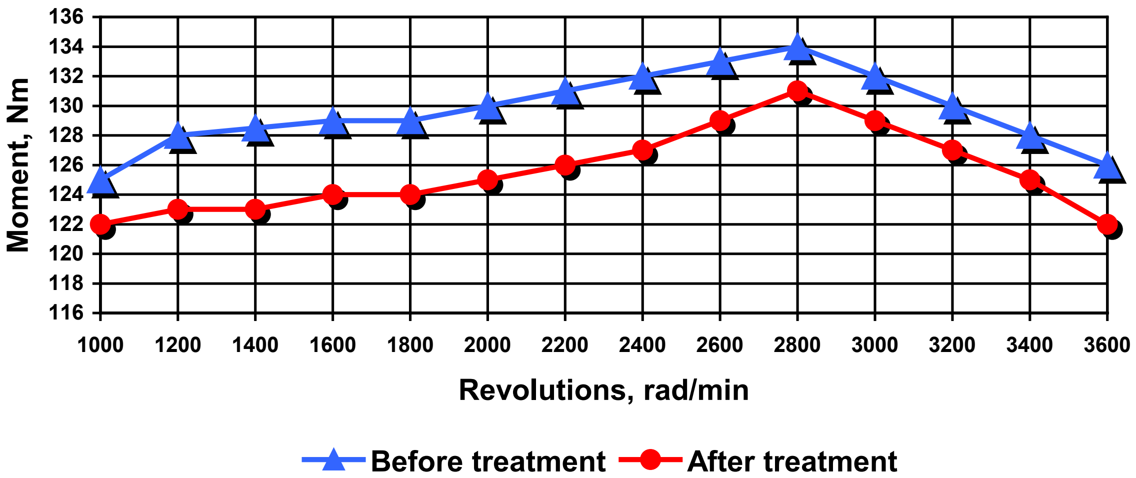
Thus, the technical repair No 3 was substituted by planned preventive repair with the RVS Technology, which has reduced significantly the repair times and increased the repair work quality.

REPORT
on results of experimental works in Changchun Technological University

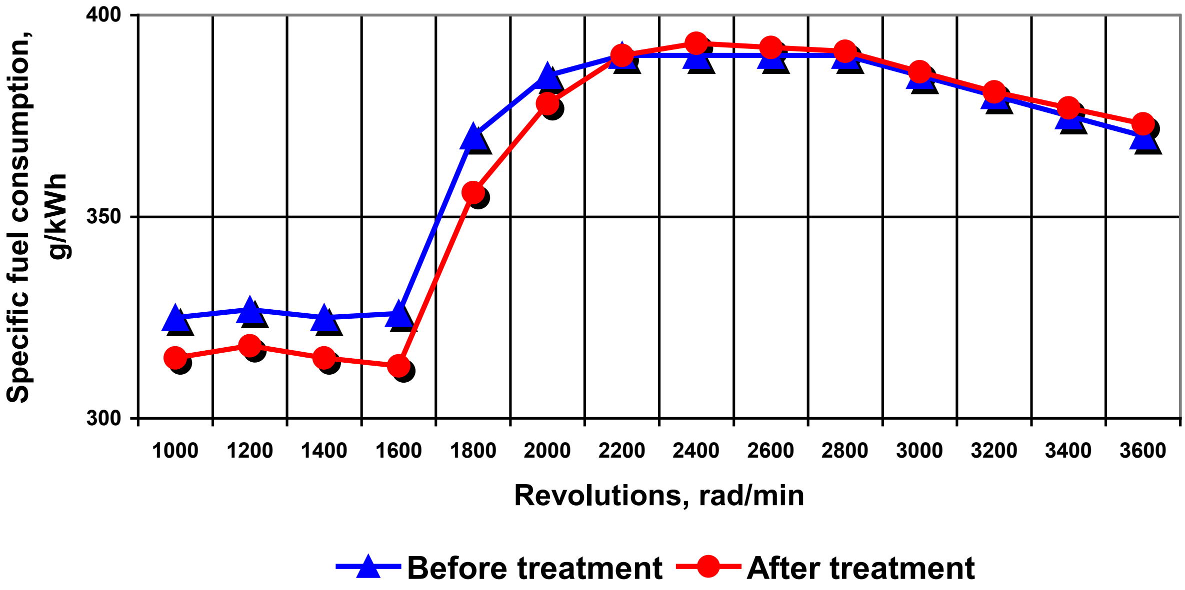
The research carried out by NTO NVTs in the field of the RVS Technology in sub-departments of Transbaikal Railway, as well as the task to distribute the technology outside the Russian Federation, has required experiments to be carried out by using a stationary test bench for internal combustion engines. Due to that, it was decided to carry out the tests in a test centre of Changchun University of Science & Technology (P.R. China).
The experiment was carried out in order to estimate the effect of an RVS Technology treatment of internal combustion engines on its parameters.
The test object was a carburetor petrol engine of an Chinese automobile BJC2000. The engine is four-stroke, four-cylinder, max power 60 kW and maximal revolution number 4,000 rpm. The carburetor consists of two chambers with a main dosing apparatus; the other chamber is activated when the revolution number exceeds 2,000 rpm. Before the beginning of the experiments, the engine had been operated for approximately 2,500 hours. No major repairs had been done. The technical condition of the engine corresponded to the category of "PERMISSIBLE".
For registering the parameters of the engine, a laboratory test bench with the following accessories were used: distant control of the throttle damper, distant control of load of the shaft, power measuring equipment, fuel consumption measuring equipment, and gas analyser.
The experiment was carried out in the following sequence: heat the engine up to the operation temperature; measure the parameters of the engine in the bench; analyse the parameter results in a computer; treat the engine with the RVS Technology; run in the engine in two hours; measure the parameters of the engine in the bench; analyse the parameter results in a computer; Compare and analyse the results.

The results of the experiment
When measuring the parameters in the bench, it was noticed that the gas distribution system of the bench had drawbacks in regulating heat clearances of the pushrods of the inlet and outlet valves. Due to the defect, it seemed to be impossible to carry out reliable measurements of the change of compression in cylinders as a result of the RVS Technology treatment. Due to limited time reserved for the experiment, it was decided to carry out the experiment with the above-named defect.
The results of the experiment are shown graphically in Pictures 11, 12, and 13.

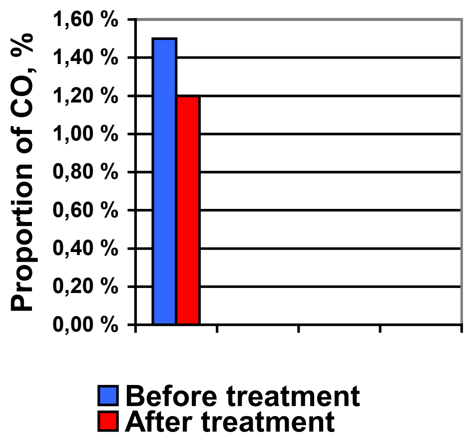
Picture 11: Dependence of resistance moment of motor axle on revolutions

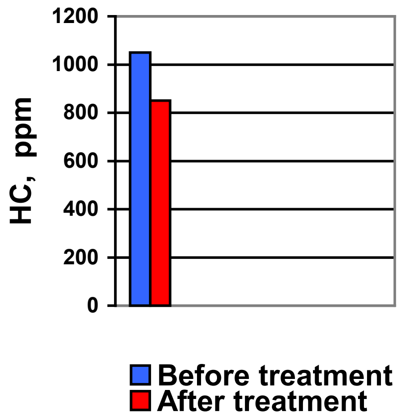


Picture 12: Dependence of specific fuel consumption on revolutions



Picture 13: Proportion of CO and HC in exhaust gases





The data given above on the experimental researches and the analysis show that using the RVS Technology in internal combustion engines significantly decreases the friction resistance moment in the engine and, as a result, reduces fuel consumption, improves processes of combustion of the fuel and air mixture in the cylinders, which significantly reduces harmful exhausts into the atmosphere.

Transbaikal Railways

Foreman of repair department of Locomotive economics section	(signature)	V.M. Krivopishin
Vice chief engineer of locomotive depot of Chita station	(signature)	A.V. Konovalov
Foreman of lubrication department	(signature)	I.A. Kavinin
Foreman of wagon laboratory TEVL, candidate of technical sciences	(signature)	V.K. Verkhoturov

Transbaikal Institute of Railway Transport

First vice director, candidate of economic sciences	(signature)	Ie.V. Iarilov
Foreman of Normative documentation department, candidate of technical sciences, assistant professor	(signature)	V.A. Ilyinykh
Assistant professor of Normative documentation department, candidate of technical sciences	(signature)	H.V. Tishakova

Chita State Technical University

Assistant professor of physical metallurgy, candidate of technical sciences	(signature)	V.S. Grokhovsky

Priargun Production Mining-Chemical Association

Vice foreman of central scientific research laboratory	(signature)	M.I. Bazhenov
Vice chief mechanician	(signature)	P.N. Bezborodov

NTO NVTs

Vice director (science), candidate of technical sciences	(signature)	V.V. Tishakov
Leading specialist		V.A. Logachev