

Using the organic-mineral binder for molybdenum concentrate granulation in metallurgy

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When we use the traditional composition of the batch mixture in the production of cinder, the proportion of Mo in the granules is reduced to 4% (Table 1). In addition, it is known that the presence of kaolin in cinder makes difficult sublimating rhenium oxide and impairs its commodity indices such as the fullness of ammonia leaching, Au and Ag extraction from a cake. To improve these technical and economic indicators was an idea to replace, completely or partially, kaolin with organic binder to be burned at a sintering of Mo-concentrate and causing no dilution of the product. The purpose of our study is to develop such a binder for JSC "Almalyk GMK" with the specific requirements. It should not contain any "technological poisons" (such as phosphates) adversely affecting the redistribution of cinder: leaching, sorption of Mo (VI) ions, hydrogen reduction to metal, sintering rods.

Keywords: Mo concentrate, cinder, kaolin, organic polymer, granulation, metallurgy

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Introduction

Technology of production of the pyrite cinders of molybdenum middlings at JSC "Almalyk GMK" (Uzstandart, 2013) includes the mixture granulation (composition: Mo-concentrate 90%, kaolin 10%) and firing of pellets at 600 °C to oxidize sulfide minerals and to recover rhenium oxide. As a result of the dilution of the original Mo concentrate with kaolin there is a "dilution" of the pyrite cinders upon molybdenum. In this context, the search of pellet-forming scheme that minimizes this rate is the topical issue (Table. 1).

When we use the traditional composition of the batch mixture in the production of cinder, the proportion of Mo in the granules is reduced to 4% (Table 1). In addition, it is known that the presence of kaolin in cinder makes difficult sublimating rhenium oxide and impairs its commodity indices such as the fullness of ammonia leaching, Au and Ag extraction from a cake. To improve these technical and economic indicators was an idea to replace, completely or partially, kaolin with organic binder to be burned at a sintering of Mo-concentrate and causing no dilution of the product. The purpose of our study is to develop such a binder for JSC "Almalyk GMK" with the specific requirements. It should not contain any "technological poisons" (such as phosphates) adversely affecting the redistribution of cinder: leaching, sorption of Mo (VI) ions, hydrogen reduction to metal, sintering rods.

Subjects and methods

Batch of Mo concentrate granulation was prepared using bindering: kaolin, bentonite, liquid glass LG, Na-carboxymethylcellulose (Na-CMC), polyvinyl acetate (PVA),

sulfonated cellulose (FIPS, 1995; 2004), hydrolysis product of waste of production of polyacrylonitrile fiber SC. Their composition (binder content,%; Mo concentrate - the rest): No.1 (without a binder), No.2 (kaolin 10%), No.3 (SC 3%), No.4 (kaolin 2%, SC 3%), No.5 (bentonite 2%, SC 3%), No.6 (bentonite 2%, CMC 2%), No.7 (bentonite 2%, PVA 2%), No.8 (bentonite 2%, sulfonated cellulose 2%), No.9 (SC 1%), No.10 (SK 1.5%, LG 1.5%), No.11 (bentonite 2%, SC 1.5%, LG 1.5%), No.12 (kaolin 2% , SC 1.5%; LG 1.5%), No.13 (LG 3%), No.14 (bentonite 2%, CMC 1.5%); No.15 (bentonite 2%, SC 0.5%), No.16 (kaolin 2%, SC 0.5%), No.17 (bentonite 1%, CMC 0.5%), No.18 (bentonite 1%, SC 0.5%).

Limiting wetting angle of batch material compacted under a pressure of 20 MPa (\varnothing 12, height: 4 mm) was determined from the profile of water droplets thereon (Voyutsky, 1964). The granules were obtained in the disc pelletizer, then dried at 20 °C, 24 hr. Their crushing strength was evaluated with the following methods: 1) of integrity of the granules dropped from a height of 2 m onto concrete; 2) of compression fracture. Their comparison revealed allowable strength criterion: $F \geq 1.2$ MPa. The content of elements in the raw materials and technological solutions was determined by ultimate analysis carried by AAS "Perkin-Elmer" PE 3030V with a flaming atomizer, and Aligent 7500 ICP MS. Thus, Au and Ag in the samples were determined at wavelengths of 242.8 and 328.1 nm with preconcentration extraction in a toluene solution of sulfide oil at a ratio of organic / aqueous phases = 1/10, respectively.

IR absorption spectra were recorded in the range of 400-4000 cm^{-1} with AVATAR-360 spectrometer Nicolet. Thermograms were recorded by Paulik-Paulik-Erdey derivatograph at gradient 10 degrees per min, sample weight 0.200-0.250 g, in corundum crucible \varnothing 10 mm, with T-900, TG-200, the DTA-1/10, DTG1/20 sensitive galvanometers and Al_2O_3 as a standard. Rontgenograms were recorded by DRON-2.0 X-ray crystal analyzer with Cu-anticathode. To calculate the interplanar distances table of ASTM standard card index was used. The relative intensity of the lines $I / I (J, \%)$ was determined as a percentage of reflex expressed at the maximum.

Results and discussions

The composition supplied to the granulating of Mo concentrate was the following, %: Mo 38; Re 0.7; Cu 2.5; P 0.009; Sb 0.025; WO_3 0.05; S 25.2; SiO_2 10.8; humidity 0.42; characteristic for Mo concentrate quantities of Au and Ag were present there too. Limiting wetting angles, strength of the granulates were determined (FIPS, 1995) (Table. 2). From Table 2 it is shown that the sample No.1 is identified as hydrophobic. Decrease of its hydrophobicity was facilitated with binders allowing it to be granulated. Selection of the best of them for the role of alternative to kaolin was intended to experiment aimed at a comparison between the strength of granules with a diameter of 3-5 mm, made of MoS_2 -containing batch materials with binders, after their drying-firing at 20, 250, 600°C (Table 3). From Table 3 it is shown that the current charge mixture based on kaolin No.2, as well as a mixture based on kaolin or bentonite: No.4, 5, 15-16, 18 provide a required granules' strength: $F \geq 1.2$ MPa.

When replacing the SC polymer with CMC (No.6, 14, 17) strength values are being worse, but in the range of high concentration of bentonite and CMC (No.6, 14) they do satisfy the requirements for strength. At low concentration of both binder agents in No.17 mixture, the durability was dissatisfied. For SC-exchange on sulfonated cellulose (No.8) or water glass (WG) (No.11, 13), for turning mineral binder of the mixture, but in the presence of SC (No.3, 9), unsatisfactorily decrease of pellet's strength took place.

Increasing of the temperature from 20 up to 600 °C leads to the increasing of pellets' strength. An advantage of the compositions with an organic binder, for example, No.15-18, to mixtures without its supplement consists in a fact that the organic additives SC, CMC, PVA at thermo treating burn to the ground causing no downblending of a calcine. Mineral binders (bentonite, kaolin) on the contrary result its downblending although

imparting strength of the pellets. The addition of WG degrades the strength of granules, baked at 600 °C.

Thus, effective binder compositions are developed providing the required strength to Mo-concentrate granules being alternative to existing kaolin mixture (Mo concentrate 90%, kaolin 10%) and basing on the combinations: 1) kaolin (1-2%) - polymer (0.5-3%); 2) bentonite (1-2%) - polymer (0.5-3%), Mo concentrate - the rest in both of them, where kaolin or bentonite are present in a concentration range of 1-2%, and an organic polymer - any of the group SC, CMC or PVA are present in the range of 0.5-3%. The polymer SC is preferable among them, in terms of strength.

It was of interest to compare the technological properties of mixes No.1,2,15, for which of them pellets had been made, burned & subjected to ammonia leaching. From the obtained cakes Au, Ag were extracted after cyanide leaching. At all stages the samples were analyzed for the content of Mo, Re, Au, Ag.

It was found out that granule of a mixture №15 had been relatively enriched with Mo before and after their firing, with minimum content of unoxidized MoS₂ and maximum of MoO₃ in their composition. Ag and Au content in the cinder were maximal, facilitating their removal from the cakes. At 600 °C rhenium in the form of Re₂O₇ sublimated to the maximum extent (Table 4).

Pellets of mixes No.2-5 before and after firing (indicated as No.2t-5t) of Mo concentrate, SC, kaolin, bentonite were subjected to IR spectrometry (Kazitsyna and Kupletskaya, 1979; Gosstandart, 1984; 1989), gravimetric (Paulik, Paulik, and Erdey, 1958) and X-ray analyses.

IR spectra of individual components obtain the specific characteristic frequencies and their mixtures often do obtain the frequencies' and bands intensities' changes, suggesting the existence of interaction between them. By exposing samples No. 1,2,3,4 at 600 °C the thermolysis products appeared with frequencies of valent and deformation oscillation character for Al₂O₃, MoO₃, SiO₂, Fe₂O₃, calcium carbonate (Figure 1 and Table 5).

Analysis of the IR spectra showed that the initial components of mixtures: MoS₂, kaolin, bentonite, polymer SK are characterized with their own frequencies.

In Mo concentrate's mixtures with the additives a change in the frequency and intensity of the absorption bands takes place which suggests the presence of interaction between them. When samples No.1, 2, 3, 4 are exposed to 600 °C, the thermolysis products appear characterized with valence and deformation oscillation of MoO₃, CaCO₃, Al₂O₃, SiO₂, Fe₂O₃.

Sample of Mo concentrate demonstrated 11 endothermic effects observed in the range of 120-300 °C: at 140, 160, 200, 230, 255, 285, 348, 365, 383, 756, 852 °C and 4 - exothermic, at 410, 478, 565, 590 °C. The first 11 were accompanied by a smooth mass loss: the greatest - at 500-680 °C: 8.51%, and the total, up to 900 °C, reached 15.66%. Kaolin demonstrated 2 exothermic effects at 257, 400 °C and 2 endothermic - at 569 and 730 °C. The first 2 were accompanied by a small mass loss: 1.0% at 80-280 °C, and in the temperature range 280-660 °C, decrease was 9.02% and the total, up to 900 °C, reached 13.05%. Bentonite revealed 7 endothermic effects at 115, 167, 190, 234, 355, 430, 474, 7 exothermic - under 284.395, 410, 465, 572, 620, 710 °C: first endothermic effect was characterized by a decrease in water mass loss at 60-140 °C, amounting to 5.60%; weight loss in the range 140-640 °C - 6.40 %, while at 900 °C it reached 12.80%. The polymer SC demonstrated 2 endothermic effects at 110 and 170 °C, and 9 exothermic, at 240, 325, 427, 468, 498, 554, 582, 684, 850 °C; the first 2 were accompanied by mass loss in the range of 40-195 °C: 55.77%, and total up to 900 °C: 74.04%. The nature of its SC thermal effects was conditioned with its decomposition steps.

At heating curves of the following samples there were: No.2 - 9 endothermic effects at 90, 140, 172, 209, 338, 357, 367, 435, 735 °C; 8 exothermic at 295, 395, 408, 480, 570, 598, 791, 820 °C; thermal effects were accompanied by weight loss: at 80-500 °C, when it amounted to 2.75%, at 80-900 °C - 12.84%; No.3 - 5 endothermic effects at 155, 270,

385.709, 733 °C and 6 - exothermic at 322, 448, 463, 560, 748, 850 °C; thermal effects at 500 °C proceeded with weight loss: 2.27%, at 900 °C - 14.77%; №4 - 12 endothermic effects at 132, 172, 202, 234, 330, 338, 351, 366, 380, 390, 703, 738 °C and 10 exothermic at 310, 426, 439, 448, 462, 565, 597, 622 750, 821 °C; thermal effects in the range 60-500 °C proceeded with weight loss: 1.98%, at 60-900 °C: 11.90%; №5 - 5 endothermic effects at 100, 120, 158, 183, 740 °C and 9 of the exothermic at 323, 450, 480, 563, 598, 768, 825, 860 °C; 4 of the first endothermic effects occurred with the weight loss: in the range 50-200 °C - 0.95%, and up to 900 °C - 16.72%;

On heating curves of preliminary fired (at 600 °C) sample No.2t - 10 endothermal effects at 135, 175, 190, 242, 338, 355, 375, 435, 482, 745 °C and 8 exothermic at 212, 284, 390, 408, 470, 620, 658, 790 °C; thermal effects at 600 °C proceeded without weight loss; last 4 - with its loss: at 50-900 °C it reached 7.73%; No.3t - 9 endothermic effects at 135, 152, 200, 225, 285, 370, 715, 738, 900 °C; 2 - exothermic effects at 428, 575, 600 °C; effects occurred without weight loss, and up to 900 °C - with its loss 8.58%; №4t - endothermic effects at 155, 177, 230, 340, 358, 372, 390, 422, 736 °C; and the exothermic at 289, 460, 610, 747, 820 °C; first 4 of them occurred with a weight loss of 0.76%, with no its losing in 300-600 °C range and up to 900 °C - destruction of the sample with a step, and the weight loss of up to 9.16%; No.5t - 3 endothermic effects at 180, 710, 740 and 6 exothermic at 198, 280, 339, 418, 450, 600 °C; first 3 thermoeffects proceeded with mass loss of 0.42%, subsequent thermal effects, up to 600 °C took place without weight losing, with a total loss in the range of 50-900 °C - 7.07%.

Rontgenograms of the non-fired (dried only) samples have shown the following. For No.1 sample 89 of the interplanar distances with a relative intensity of 1-100% were identified. Among them with expressed intensity in the range of 20-100% there were the following, $d, \text{Å} (J, \%)$: 6.10 (100); 2.26 (43); 2.04 (39); 1.818 (33) 1.529 (34). For kaolin sample 111 interplanar distances with a relative intensity 1-100% were revealed. From them - the expressed intensity were as follows, $d, \text{Å} (J, \%)$: 7.07 (39); 4.22 (28); 3.56 (84); 3.35 (100); 2.33 (21), being characteristic to establish the presence of kaolin. For bentonite sample 113 interplanar distances with relative intensity 20-100%, $d, \text{Å} (J, \%)$: 4.43 (20); 4.19 (20); 3.30 (100); 2.89 (20) were revealed being characteristic to establish the presence of bentonite. For polymer SC sample 140 interplanar distances with relative intensity 27-100% resembling amorphous substance were found out suitable for identification as well.

- No.2 sample showed 85 interplanar distances with a relative intensity of 1-100%; of which the following had the expressed intensity in the range 20-100%, $d, \text{Å} (J, \%)$: 5.89 (100); 3.05 (21); 2.02 (47); 1.520 (46); their comparison with roentgenogram of No.1 and of kaolin samples revealed changes in the structure, indicating the chemical interactions in the No.2 sample.
- No.3 sample revealed 97 interplanar distances, similar to the No.2 sample; introduction of the polymer SC into compositions No.1-2 did not affect the intensity of interplanar distances of No.2 sample, but affected the relative intensity of interplanar distances of diffraction patterns of No.1.
- No.4 sample revealed 131 interplanar distances similar to No.2 sample, characterized by parameters, $d, \text{Å} (J, \%)$: 5.92 (100); 2.25 (34); 2.02 (24); 1.811 (33); 1.523 (31); joint presence of kaolin and SC polymer had no effect on X-ray, little to distinguish it from the sample №1. but affected the relative intensities of the interplanar distances, indicating the interaction between the components.
- No.5 sample revealed 129 interplanar distances, similar to to No.2 sample, characterized by parameters, $d, \text{Å} (J, \%)$: 6.08 (100); 2.27 (52); 2.04 (31); 1.818 (70); 1.529 (32) 1.527 (34); the presence of the SC polymer and bentonite in the No.5 sample mixture affected the relative intensities of the expressed distances. indicating their interaction with MoS₂.
- Rontgenograms of the fired (at 600 °C, on air) samples have shown the following. No.2t sample revealed 95 interplanar distances with relative intensity 5-100%. Expressed interplanar distances were the following: $d, \text{Å} (J, \%)$: 6.83 (30); 3.88 (24); 3.85 (41); 3.80 (48); 3.45 (100); 3.33 (20); 3.25 (32); 3.10 (20); 2.64 (26); 2.30 (68); 2.26

- (27); 1.953 (26); 1.728 (30); 1.591 (31); 1.565 (37) 1.475 (22); 1.431 (20) substantially different from X-ray of initial substances' sample and No.2 sample because of disintegration and decomposition of the SC polymer and components during firing.
- No.3t sample revealed 125 interplanar distances with relative intensity 3-100%, among which there were those of expressed distances, $d, \text{Å}^\circ (\text{J},\%)$: 6.81 (32); 3.83 (32); 3.78 (59); 3.44 (100); 3.25 (88); 2.64 (31); 2.30 (58); 2.25 (28); 1.951 (24); 1.725 (21); 1.591 (26); 1.561 (29) different from the initial materials and No.3 sample due to the destruction of components during firing, resembling sample No.2t due to Mo concentrate high concentration there in both samples.
 - No.4t sample revealed 115 interplanar distances with relative intensity 4-100%; among which there were those of expressed distances, $d, \text{Å}^\circ (\text{J},\%)$: 6.79 (37); 6.02 (70); 3.82 (25); 3.76 (49); 3.42 (100); 3.21 (85); 2.63 (26); 2.29 (60); 2.26 (34); 1.961 (25); 1.942 (21); 1.834 (26); 1.588 (20), 1.554 (29), different from the initial materials and samples No.4 because of its thermolysis: its product was characterized with individual crystal structure;
 - No.5t sample revealed 122 interplanar distances with relative intensity 3-100%; expressed distance, $d, \text{Å}^\circ (\text{J},\%)$: 6.49 (28); 4.21 (20); 3.92 (26); 3.73 (59); 3.67 (59); 3.35 (100); 3.16 (77); 2.88 (20); 2.59 (33); 2.56 (25); 2.26 (42); 2.22 (23); 1.926 (25); 1.704 (25); 1.573 (25); 1.546 (28) different from the initial materials and sample No.5 because of its thermolysis: it was characterized with individual crystal structure;

Thus X-ray analysis of the samples revealed the interaction between the components and the difference in the composition and content of the thermolysis products.

Conclusion

Analysis of patents relating to the ore concentrates' granulation showed interest to the reduction of the traditional kaolin binder part in the batch's composition due to doping of organic binder SC, burning during firing, reducing the proportion of mineral composition of the cinder and increasing there the proportion of the metal. The research made with respect to Mo concentrate containing either 10% conventional granulating binder kaolin or its organic competitors in the field of granules, cinder and cakes from cinder leaching based on data of their colloidal-chemical & physical properties. Results made possible to develop new batch for Mo concentrate granulation's compositions differing from the traditional one with the best hydrometallurgical processing's results.

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Appendix

FIGURE 1. IR SPECTRA OF THE SAMPLES. DESIGNATION: CURVES 1-4, 5-8 ARE IN COMPLIANCE WITH MIXTURES NO.2-5 AND NO.2T-5T, CURVES 9-12 CORRESPOND TO MO CONCENTRATE, KAOLIN, BENTONITE, SC POLYMER ACCORDINGLY

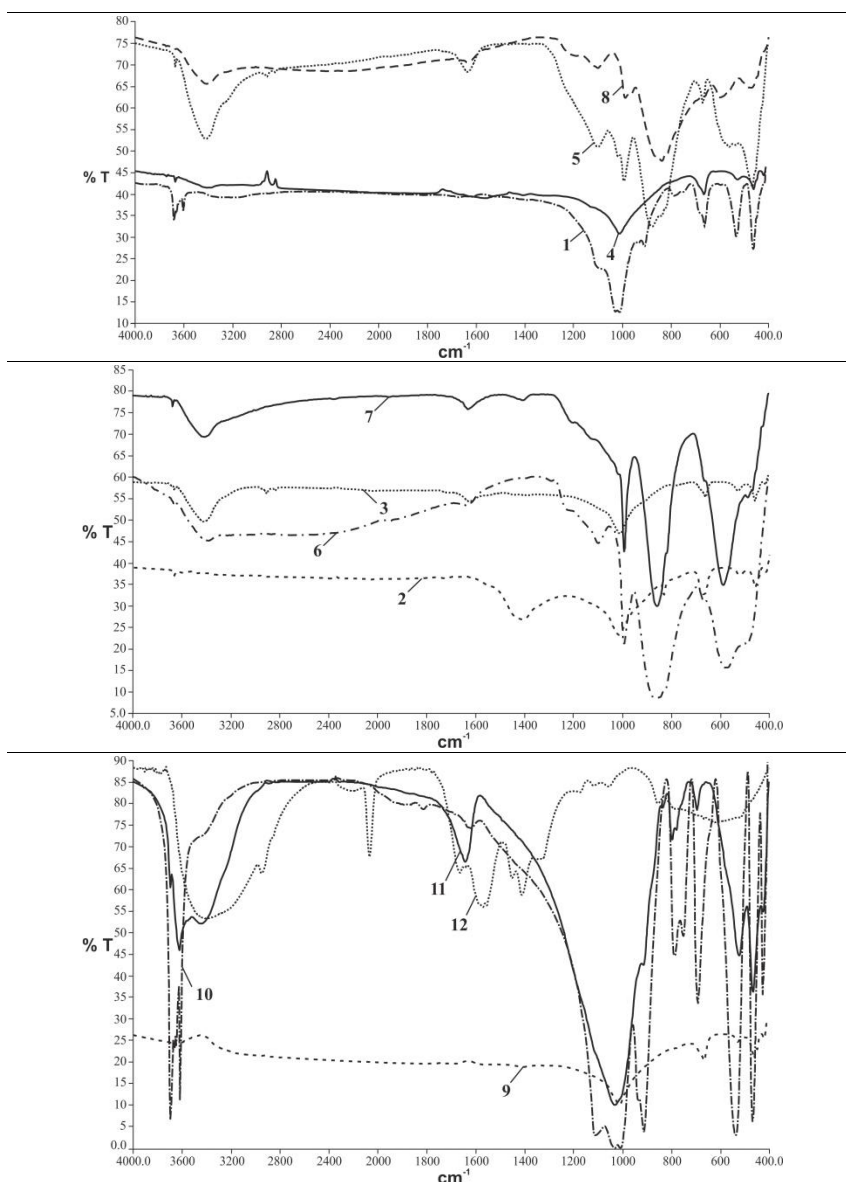


TABLE 1. DILUTION UPON MO WITH KAOLIN OF CINDER WITH ITS INITIAL MO CONCENTRATION 40-34%
(BATCH MIXTURE'S COMPOSITION: MO CONCENTRATE 90-100%, KAOLIN 0-10%)

Kaolin in a batch mixture, %	0	1	2	3	4	5	6	7	8	9	10
Mo in a cinder 1, %	40.0	39.6	39.2	38.8	38.4	38.0	37.6	37.2	36.8	36.4	36.0
Mo in a cinder 2, %	38.0	37.6	37.2	36.9	36.5	36.1	35.7	35.3	35.0	34.6	34.2
Mo in a cinder 3, %	36.0	35.6	35.3	34.9	34.6	34.2	33.8	33.5	33.1	32.8	32.4
Mo in a cinder 4, %	34.0	33.6	33.3	32.9	32.6	32.2	31.9	31.6	31.2	30.9	30.6

TABLE 2. WETTING OF QUARTZ, TALC, BATCH MIXTURE, THE STRENGTH OF THESE PELLETS
(+ SATISFACTORY; - NOT SATISFACTORY)

Batch, No. of the mixture	quartz*	talc*	1	2	3	4	5	17	18
Limiting wetting angle, degrees	0	69	95	36	33	32	30	34	33
Palette's durability	none	none	-	+	+	+	+	-	-

Notes: * FIPS, 1995. Patent of Russia No.2034055; C22B1/243; Application 5051372/02, dated 08.07.1992; Publ. 04.30.1995 [source in Russian language]

TABLE 3. GRANULES' STRENGTH DEPENDING ON THE BATCH'S COMPOSITION & DRYING TEMPERATURE

T, °C	Durability of granules \varnothing 3-5 mm, under loading before destruction, MPa																	
	Batch pelletizing based on Mo-concentrate, mixture No.																	
	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
20	0.7	1.1	2.0	1.9	0.2	1.6	0.9	0.5	1.5	1.6	1.8	2.8	0.3	1.5	1.5	0.3	1.2	
250	2.4	1.6	1.8	3.2	0.5	0.2	0.8	0.6	1.9	2.2	2.7	2.5	0.4	3.1	1.9	0.9	1.8	
600	6.4	1.2	4.1	8.4	0.6	0.6	1.2	0.7	0.1	0.2	0.2	0.3	0.7	7.3	4.0	1.1	4.5	

TABLE 4. EFFECT OF FIRING OF PELLETS MADE OF MIXTURES NO.1,2,15 TO METALS EXTRACTION

Element	Mixture No.1		Mixture No.2		Mixture No.15	
	before firing	after it	before firing	after it	before firing	after it
Au (solid), g/t	38.1	39.9	34.7	36.1	36.7	38.2
Au (liquid), g/t	19.06	19.96	17.37	18.05	18.35	19.12
Ag (solid), g/t	62.2	65.0	56.9	59.2	60.0	62.0
Ag (liquid), g/t	3.11	3.25	2.85	2.96	3.01	3.10
Mo, % w	41.3	43.1	37.7	39.1	39.9	42.2
Re, % w	0.07	0.05	0.063	0.05	0.07	0.05
Mineralogical composition						
Mo, gross %	34.30		36.23		35.12	
MoO ₃ , % w			31.72		35.01	
MoS ₃ , % w			1.44		1.16	
Re, % w	0.038		0.035		0.038	
			0.020		0.014	
					0.0092	

TABLE 5. CHARACTERISTIC OSCILLATION FREQUENCIES IN THE IR SPECTRA OF THE SAMPLES *

Component or mixture, No.	Temperature, on air	Frequency, cm ⁻¹	Character of a bond
Kaolin	20 °C	3696, 3620, 3654, 1114, 1032, 1007, 795, 757, 696, 539, 470, 431	O-H in H ₂ O, Al-O in Al ₂ O ₃ Bonds in oxides of Al, Si, Fe, Ca
Bentonite	20 °C	3698, 3624, 3440, 1643, 1032, 915, 934, 797, 778, 695, 525, 469, 425	O-H in H ₂ O, H-O-H in H ₂ O; fragments of CaCO ₃ , Al ₂ O ₃ , SiO ₂ , Fe ₂ O ₃ , etc
Polymer SC	20 °C	3410, 2849, 2068, 1642, 1662, 1567, 1553, 1452, 1411, 1354, 1326, 1172, 1116, 1055, 853, 786, 623	R C=CH or C=C=C, CHR=CHR' cis-acting & CHR =CH ₂ ; Aromatic, C-O-H
No.1	20 °C	3677, 1018, 669, 531, 466, 422	H ₂ O, -O-Si-O-, =O
No.2	20 °C	3696, 3621, 1097, 1029, 1012, 940, 912, 794, 755, 669, 537, 468, as well as of Mo lines	Hydrogen bond
No.2T	600 °C	3430, 3261, 2919, 2952, 1638, 1102, 1015, 993, 878, 839, 820, 669, 562, 531, 467 as well as of Mo lines	Valence oscillation frequencies of bonds O-Si-O- & Al-O
No.3	20 °C	3675, 1413, 1018, 839, 677, 529, 466, 422 as well as of Mo lines	Presence of interaction between components
No.3T	600 °C	3393, 1639, 1292, 1228, 1099, 992, 865, 666, 567, 487	Disintegration and decomposition of polymer SC. Lines 3393 & 1639 of H-O-H & O= groups' bonds of Mo, Si, Al, Fe oxides, CaCO ₃
No.4	20 °C	3433, 2919, 2852, 1613, 1017, 797, 668, 531, 466, 422, Mo lines & a spectral line of polymer SC in high-frequency area	Presence of valence oscillation of C-H bond, interactions between components
No.4T	600 °C	3429, 1631, 1404, 1206, 1122, 1015, 995, 862, 590, 487	Disintegration and decomposition of polymer, valence & deformation oscillation of bonds in Mo, Si, Al, Fe oxides, CaCO ₃
No.5	20 °C	3421, 2980, 1558, 1407, 1061, 669, 529, 566, 422, Mo lines & spectral lines of polymer SC and bentonite	Interaction between components due to hydrogen bonds
No.5T	600 °C	At 3422, 1636, 1192, 1104, 992, 968, 842, 820, 666, 604, 678	Disintegration and decomposition of polymer, valence & deformation oscillation of bonds in Mo, Si, Al, Fe oxides, CaCO ₃

Source: See Kazitsyna and Kupletskaya, 1979; Gosstandart, 1984; 1989.