Oil Shale, Vol. 13, No. 4 pp. 265-285

ISSN 0208-198X © 1996 Institute of Chemistry Estonian Academy of Sciences

LOW-SULPHUR OIL SHALE RESEARCH AND EXPERIMENTAL PROCESSING

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Low-sulphur oil shales which in most cases yield paraffinic oil upon retorting have been studied. Oils obtained have high values for solidification point (25-30 °C) and a relatively low density – about 900 kg/m³. Compared to high-sulphur oils, low-sulphur ones contain more paraffins and olefins and less aromatic hydrocarbons. The content of phenols in paraffinic oils is negligible – 2-4 %.

Low-sulphur oil shales studied may be divided into two groups. The first group comprises oil shales for which 70-100 % of the total sulphur remains in the semicoke during retorting, for the second group this percentage is 50-70.

The overwhelming majority of oil shale of the world yield low-sulphur paraffinic oil upon retorting. This oil is similar to low-sulphur paraffinic petroleums in its physical and chemical properties [1]. Quite naturally such shale oil is therefore considered a good substitute for petroleum and its subsequent refining can be accomplished with traditional petrochemical methods.

The world-wide experience in processing low-sulphur shales to produce liquid fuel is quite extensive. In China, shales have been processed on an industrial scale since 1927. In the USA, large pilot-scale retorts have been in operation and they still are in Brazil. Several smaller pilot and test units are used for oil shale research in many countries of the world.

The authors' present tests have shown (Tables 1 and 2) that oil shales which yield paraffinic oil upon retorting have a relatively low density (about 900 kg/m³) and, as a rule, a low content of sulphur (Tables 3 and 4). The majority of oil shales in the world yield retort oils with higher contents of nitrogen compounds than kukersite oil (sample No. 1) produced from Estonian shale. Some oil shales contain arsenic, and the presence of arsenic compounds makes the subsequent processing of such oil more difficult since those compounds poison the catalysts used for hydrogenation.

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| dices | Estonia, | Russia | | Kazakhstan | | Ukraine, | Byelorus, | Bulgaria | |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|--------------|-------------|------------|----------------------|----------|-----------|-----------------------|---------|
| ente pri les pri severa tind 2) relative supplu effer a pri fre ca | Estonian (kukersite) | Ukhta | Eckibastuse | Kenderlyck | Ust-Kame- nogorsk | Boltysh | Luban | Gurkovo- Nikolayev | Breznik |
| ili ini ili ini i i i i i i i i i i i i i i i i i | Investigated | shale sample | e number | | d pa es fa | | | | |
| in pi bies bies bies bies bies bies bies bie | 1 | 2 | 3 | 4 | 5 | 9 | 7 | 8 | 6 |
| scher assay product yield (shale samp | le 200 g), % | | | | | | | | |
| Shale oil | 1 | 1 | 3.9 | 1 | 1 | 1 | 1 | 2.8 | T |
| Pyrogenetic water | 1 | 1 | 1.8 | 1 | 1 | 1 | I | 3.2 | 1 |
| Semicoke | 1 | 1 | 86.5 | 1 | 1 | 1 | 1 | 91.4 | I |
| Gas and losses (by difference) | - | 1 | 7.8 | I | 1 | 1 | 1 | 2.6 | 1 |
| scher assay oil of organic matter, % | 1 | T | 15.5 | I | I | I | 1 | 20.7 | 1 |
| h composition, %: | | | | | | | | | |
| SiO ₂ | 28.5 | 66.4 | 60.3 | 57.4 | 57.2 | 65.8 | 36.8 | 59.9 | 40.0 |
| Fe ₂ O ₃ | 5.5 | 1.5 | 14.0 | 6.3 | ANCI | 8.6 | 5.8 | 8.3 | 7.5 |
| Al ₂ O ₃ | 6.7 | 4.5 | 17.6 | 14.0 | 7 - 1.0 | 17.6 | 10.2 | 19.1 | 14.0 |
| K20 | 2.1 | 110 | 1.2 | 1.1 | 177 | 2.6 | 1 | 1 | 1.9 |
| Na ₂ O | 0.4 | 1.0 | 0.6 | 1.6 | 7 7 | 1.7 | I | 1 | 6.0 |
| MgO | 4.4 | 1.3 | 1.3 | 1.3 | 2.9 | 1.5 | 2.8 | 2.0 | 3.8 |
| CaO | 44.8 | 22.8 | 2.1 | 13.4 | 4.9 | 2.1 | 29.4 | 8.4 | 23.1 |
| SO ₃ | 6.5 | 1.6 | 0.2 | 3.3 | 2.5 | Ĩ | 5.0 | 1.6 | 8.8 |
| Total | 98.9 | 99.1 | 97.3 | 98.4 | 99.3 | 6.66 | 0.06 | 99.3 | 100.0 |

| Indices | | Russia | 0.5 | Kazabhetan | 0.1 | 2.3 | | | 28 |
|-----------------------------------------|-------------------------|-------------|-------------|---------------|----------------------|----------|-----------|-----------------------|-----------|
| TARTINGS STREET STREET STREET | Estonia, | picchyi | | INAZANJISIAJI | # Renard Stor | Ukraine, | Byelorus, | bulgaria | |
| Milling value (bomb culorimeter), | Estonian (kukersite) | Ukhta | Eckibastuse | Kenderlyck | Ust-Kame- nogorsk | Boltysh | Luban | Gurkovo- Nikolayev | Breznik |
| (Pythe (by difference) | Investigated | shale samp. | le number | Control Inc. | gTe No | 0.88 | 1 | 1.0 | 5 0.03 |
| Support Instructure | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Moisture of oil shale tested | 0.02 | | From P | 1 01 | | | | | |
| in experimental retort, % | 5.1 | i | 7.3 | 2.8 | 1.0 | 4.4 | 1.2 | 10.7 | 0.7 |
| Carbon dioxide $(CO_2)^d$ | 20.8 | 13.0 | 4.0 | 5.5 | 3.3 | 0.5 | 1 17.0 | 1 43 | 140 |
| Ash Ad | 46.2 | 75.5 | 70.9 | 57.4 | 74.7 | 57.5 | 67.0 | 82.2 | 66.5 |
| Organic matter* | 33.0 | 11.5 | 25.1 | 37.1 | 22.0 | 42.0 | 16.0 | 13.5 | 18.6 |
| Total sulphur S_t^d | 1.90 | 0.39 | 1.32 | 2.1 | 1.0 | 1.40 | 1.6 | 0.38 | 2.47 |
| Including. | 0.05 | 10.2 | | 20 | | | | | |
| Sulphate Pvrite | 0.0 0.1 | 1.1 | 0.01 | | | 0.12 | 0.1 | - 0.21 | 0.08 |
| Organic (by difference) | 0.55 | I | 0.23 | 0.64 | 1 | 0.17 | 0.4 | 10.0 | 0 12 |
| Heating value (bomb calorimeter), | | shule smith | Tudanun 5 | | | | | | |
| MJ/kg | 12.43 | 3.56 | 7.58 | 12.94 | 16.2 | 12.73 | 5.65 | 3.27 | 7.12 |
| Fischer assay product yield (standard 1 | retort), %: | | | | | | neibil | | - Statute |
| Shale oil | 21.8 | 4.6 | 5.2 | 19.8 | 10.9 | 17.5 | 8.8 | 5.3 | 1 97 |
| Pyrogenetic water | 2.4 | 0.4 | 2.1 | 2.1 | 0.5 | 3.9 | 1.2 | 1.4 | 2.4 |
| Semicoke | 70.2 | 93.3 | 87.8 | 71.9 | 83.3 | 72.9 | 86.6 | 90.7 | 83.5 |
| Gas and losses (by difference) | 5.6 | 1.7 | 4.9 | 6.2 | 5.3 | 5.7 | 3.4 | 2.6 | 4.4 |
| Fischer assay oil of organic matter, % | 66.1 | 40.0 | 20.7 | 53.4 | 49.5 | 41.7 | 55.0 | 39.3 | 52.1 |

Low-Sulphur Oil Shale Research and Experimental Processing

| Table 2. Properties of Low-Sulphur | Oil Shale | s from Var | ious Depos | sits of the V | Vorld (Shale | e Samples 1 | (61-0 | | | |
|--------------------------------------------------------------------------------------------|---------------|--------------------------|---------------|--------------------------|-------------------|----------------------|----------------------|--------------|-------------|--------------|
| Indices | USA, Green | Brazil, Par oil shale | aiba valley | Yugoslavia, Aleksinac | Roumania, Anin | Thailand, Mae Sot | Australia, Stuart | China | 202 | 60 L 60 Z |
| hidloogynta org harton wens, huognor Ango (enuigang - hitler | River | papery | lump sized | R. 168 | 0.01 | | | Hua- dian | Fu- shun | Mao- ming |
| Heating value (boup calorimeter). | Investigate | d shale sam | ple number | | | | | | | |
| LAURS Properties | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| Moisture of oil shale tested in experimental retort, % | | 3. | 2 | 2.5 | 1.5 | | 1 | 1 | I | -I |
| Content (dry basis), $\%$: Carbon dioxide (CO ₃) ^d _A | 17.3 | 0.2 | 0.3 | 6.6 | 3.8 | 10.5 | 1.8 | 5.4 | 3.9 | 1.0 |
| Ash Ad | 68.3 | 60.3 | 82.3 | 75.2 | 74.4 | 60.5 | 78.9 | 62.4 | 81.4 | 73.2 |
| Organic matter* | 14.4 | 39.5 | 17.4 | 18.2 | 21.8 | 29.0 | 19.3 | 32.2 | 14.7 | 25.8 |
| Total sulphur S_t^d | 0.65 | 1.28 | 1.60 | 2.78 | 0.67 | 0.87 | 1.0 | 1.2 | 0.78 | 1.22 |
| Including: | 000 | 0.16 | 210 | 0.05 | - | | | | | |
| Sulphate Pvrife | 0.35 | 0.10 | 0.54 | co.0 02.5 | 0.51 | 0.056 | 1 1 | 1 1 | 0.55 | 0.16 |
| Organic (by difference) | 0.28 | 0.57 | 0.89 | 0.23 | 0.16 | 0.28 | 1 | I | 0.12 | 0.08 |
| Heating value (bomb calorimeter), | 17 | 10 | | | 1 NOBOUSA | | | 1 Martin | and a state | 1 |
| MJ/kg | 5.36 | 13.27 | 3.68 | 6.32 | 5.32 | 11.26 | 5.48 | 11.64 | 3.68 | 7.68 |
| Fischer assay product yield (standard ru | etort), %: | | | | | | | | | 1 |
| Shale oil | 9.7 | 21.1 | 4.0 | 8.4* | 4.8 | 18.5 | 6.9 | 15.9 | 3.8 | 10.3 |
| Pyrogenetic water | 1.2 | 4.2 | 3.9 | 2.7 | 0.7 | 2.3 | 3.3 | 3.7 | 1.8 | 2.8 |
| Semicoke | 86.7 | 71.7 | 89.4 | 85.2 | 88.0 | 74.7 | 85.6 | 74.6 | 89.9 | 83.5 |
| Gas and losses (by difference) | 2.4 | 3.0 | 2.7 | 3.7 | 6.5 | 4.5 | 4.2 | 5.8 | 4.5 | 3.4 |
| Fischer assay oil of organic matter, % | 67.4 | 53.5 | 23.0 | 46.2 | 22.0 | 63.8 | 35.7 | 49.4 | 25.8 | 39.9 |

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| Table 2. Properties of Low- | -Sulphu | r Oil Shale | s from Va | rious Depo | sits of the W | Vorld (Shale | e Samples | 10-19) (end) | 104 | | |
|--------------------------------|---------|---------------|-------------------------|---------------|--------------------------|-------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------|--------------|-------------|--------------|
| Indices | | USA, Green | Brazil, Pa oil shale | uraiba valley | Yugoslavia, Aleksinac | Roumania, Anin | Thailand, Mae Sot | Australia, Stuart | China | 17.6 | 171 |
| | | River | papery | lump sized | | | - And | 1.027 | Hua- dian | Fu- shun | Mao- ming |
| | | Investigate | d shale san | nple number | 1 10 10 10 | | 0 44 | 1.02 | 1 20 - | 15 20 - 1 | 132 |
| | | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| Ash comnosition %. | (Crous | | 11 N. | | | | | S later | | NA SHO | C.N.O.N. |
| SiO2 | | 44.3 | 55.0 | 58.0 | 53.9 | 50.8 | 46.2 | 65.8 | 53.1 | 60.5 | 58.1 |
| Fe ₂ O ₃ | | 5.5 | 10.2 | }32.5 | 9.5 | 4.3 | 8.2 | 8.0 | 7.8 | 12.0 | 9.8 |
| K ₂ O3 | | 2.8 | 0.02 | 0.01 | 1.5 | | 1.21 | - | 1.6 | 3.0 | 1 - 1 |
| Na ₂ O | | 3.5 30 | }3.2 | }2.9 | 1.3 | 1 | }1.5 | 1 | 0.3 | 2.3 | }J.4 |
| MgO | | 7.4 | 2.9 | 3.2 | 2.3 | 1.2 | 7.8 | 2.8 | 2.0 | 1.8 | 2.0 |
| CaO | | 20.5 | 6.0 | 1.6 | 9.4 | 1.3 | 15.4 | 1.7 | 12.9 | 1.7 | 1.4 |
| SO ₃ | | 2.4 | 1.1 | 1.3 | 7.9 | 1 | 2.4 | 0.8 | 3.8 | 9.0 | 0.3 |
| L | otal | 99.2 | 6.66 | 99.5 | 99.2 | 89.7** | 100.0 | 93.8 | 98.3 | 100.0 | 9.66 |

Table 3. Properties of Fischer Assay Products from Low-Sulphur Oil Shales of Various Deposits of the World (Shale Samples 1-9)

| Indices | Investigate | d shale sampl | e number (see | e Table 1) | | | | | |
|-------------------------------------------------------------------------------------------|---------------|---------------|---------------|------------|-------|-------|-------|-------|---------|
| | I | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| To obtain the semicoking products t Fischer retort was applied with shale sample, g | the oil 20 | 20 | 200 | 20 | 20 | 20 | 20 | 200 | 20 |
| | | | Shal | e 0i1 | | | | | |
| Density at 20 °C, kg/m ³ | 968 | 975 | 915 | 923 | 906 | 898 | 925 | 878 | 934 |
| Molecular mass | 276 | - | 188 | - | | 1 | 294 | 1 | q |
| Heating value (bomb calorimeter), | | | | | | | | | 1 412 1 |
| MJ/kg | 40.19 | 39.35 | 42.08 | 41.66 | 42.83 | 42.70 | 41.45 | 43.54 | 42.83 |
| Elemental composition (dry basis), %: | | | | | | | | | They a |
| C | 83.12 | 83.1 | 85.30 | 85.0 | 84.5 | 84.66 | 84.4 | 86.78 | 84.57 |
| Н | 10.13 | 9.6 | 11.34 | 11.3 | 12.0 | 11.95 | 11.2 | 12.20 | 11.09 |
| S | 0.84 | 0.6 | 0.44 | 1.0 | 0.8 | 0.82 | 2.0 | 0.46 | 1.35 |
| N | 0.20 | 1.8 | 0.63 | 0.5 | 1.6 | 0.64 | 0.6 | Ln sk | 1.75 |
| O (by difference) | 5.71 | 4.6 | 2.29 | 2.2 | 1.1 | 1.93 | 1.8 | 00.02 | 1.24 |
| | | | Sem | icoke | | | | | |
| Content (dry basis), %: | | | | | | | | | |
| Carbon dioxide $(CO_2)^d_M$ | 28.1 | 13.6 | 0.9 | 6.9 | 2.8 | 0.3 | 19.4 | 4.7 | 17.1 |
| Ash A ^d | 64.8 | 82.6 | 79.6 | 80.1 | 89.3 | 81.6 | 76.4 | 88.7 | 76.2 |
| Carbon C ^d | 7.6 | 3.5 | 14.3 | 10.2 | 6.4 | 10.5 | 4.2 | 4.0 | 6.5 |
| Total sulphur S_t^d | 1.5 | 0.3 | 1.34 | 2.35 | 1.0 | 1.3 | 1.1 | 0.4 | 1.7 |
| Heating value (bomb calorimeter), MJ/kg | 2.64 | 1.34 | 5.32 | 4.60 | 2.72 | 4.98 | 1.46 | 1.38 | 2.60 |
| | | | | | | | | | |

Table 4. Properties of Fischer Assay Products from Low-Sulphur Oil Shales of Various Deposits of the World (Shale Samples 10-19)

| Indices | Investigate | ed shale sam | iple number | (see Table 2 | 2) | | | | | |
|-----------------------------------------------------|-------------|--------------|-------------|--------------|-------------|-------|------------|-----------|-------|-------|
| minutas henzinis | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| To obtain the semicoking products the | | | 20 . 01 | an at | D | 4 | 3.3 1/2 | d1 2 10 | 10 | 6.1 |
| Fischer retort was applied with oil shale sample, g | 20 | 20 | 20 | 200 | 20 | 50 | 50 | 50 | 50 | 50 |
| | | 51 | S | hale Oil | | | ····· | | ····· | |
| Density at 20 °C, kg/m ³ | 927 | 910 | 920 | 908 | 913 | 889 | 897 | 899 | 893 | 606 |
| Molecular mass | 233 | 9 | 1 | 230 | 1 | 278 | 234 | 236 | + | 1 |
| Heating value (bomb calorimeter), | | and . | 1.21 | 4 · 12-8 | | | 5 | 11 | 103 | |
| MJ/kg | 42.58 | 43.21 | 41.66 | 42.91 | 43.84 | 44.00 | 42.91 | 42.83 | 43.75 | 45.80 |
| Elemental composition (dry basis), %: | | 2 | 200 | | | 0 | | 2013 11 | 24.2 | |
| C | 83.89 | 85.7 | 85.5 | 83.15 | 87.0 | 84.14 | 83.2 | 80.19 | 85.37 | 83.04 |
| Н | 11.87 | 11.9 | 11.6 | 11.31 | 12.3 | 12.04 | 11.5 | 11.42 | 12.20 | 12.01 |
| S | 0.84 | 1.1 | 2.3 | 1.75 | 0.5 | 09.0 | 0.6 | 0.43 | 0.48 | 0.31 |
| N O | 1.30 | }13 | 30.6 | · 1.21 | 10.2 | 1.81 | 0.7 | 0.10 | 1.32 | 0.61 |
| O (by difference) | 2.10 | | | 2.58 | 4:0 | 1.41 | 4.0 | 7.86 | 0.63 | 4.03 |
| | | | S | emicoke | | | | | | 30.0 |
| Content (dry basis), %: | | | | | | | | | | |
| Carbon dioxide $(CO_2)^d_M$ | 19.5 | 0.3 | 0.1 | 7.1 | 1.1 | 13.8 | 1.1 | 7.9 | 2.2 | 1.4 |
| Ash A ^d | 78.2 | 84.3 | 90.8 | 86.9 | 84.4 | 6.61 | 91.3 | 80.6 | 88.9 | 85.3 |
| Carbon C ^d | 2.7 | 9.8 | 4.5 | 5.3 | 8.2 | 6.0 | 7.6 | 9.6 | 4.9 | 6.8 |
| Total sulphur S_t^d | 0.4 | 1.3 | 1.3 | 2.29 | 0.75 | 69.0 | 1.0 | 1.1 | 0.74 | 1.28 |
| Heating value (bomb calorimeter), | | inet in the | History Oh | STORE TROOPS | Server-weer | | Stor OL AR | Gone Debe | 1 | |
| MJ/kg | 0.92 | 3.56 | 1.46 | 2.43 | 3.18 | 1.97 | 2.34 | 3.81 | 1.67 | 2.39 |
| Continent of the Scinet | 1 007 | | | | | | | | | |

| Table 5. Yield and Characteristics of the World (Shale Samples 1-9) | of Gas* Obt | ained in the | Fischer Re | etort from I | ow-Sulphur | Oil Shales | of Various I | Deposits | |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|--------------|--------------|--------------|------------|------------|----------------|----------|-----------|
| Cathon Ca | 12 | 9.8 | 2.4 | 212 | | | | 0.0 | 0.0 |
| Indices | Investigated | shale sample | e number (se | e Table 1) | 844 | | | | 82.8 |
| Coursein (qu' puere)" & | I | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Specific gas yield, m ³ /t | 38.2 | 17.0 | 38.1 | 35.2 | 33.1 | 51.0 | 22.0 | 22.7 | 30.0 |
| Content of components, vol.%: | | 113 | 1000101 | 1 2002 | 203 | No. INT. | 87 | 20.0 A | \$0.4×8 - |
| CO ₂ | 23.7 | 24.2 | 50.5 | 19.5 | 18.8 | 25.3 | 26.7 | 17.5 | 13.5 |
| H ₂ S | 14.6 | 5.0 | 0.0 | 2.8 | 0.8 | 4.3 | 9.3 | 0.4 | 25.7 |
| H ₂ | 5.3 | 34.9 | 12.1 | 25.0 | 44.5 | 24.4 | 23.2 | 40.7 | 20.5 |
| CO CO | 4.2 | 5.0 | 2.1 | 7.7 | 9.9 | 8.9 | 2.2 | 2.5 | 3.4 |
| C _n H _{2n+2} | 35.6 | 26.6 | 28.5 | 34.3 | 21.0 | 28.4 | 26.3 | 24.3 | 29.3 |
| Including: | | 10.28 | | Elit park | 4 24 64 | 11.00 | 01 10 43 8 | | 1 #2.80 |
| CH4 | 14.7 | 17.2 | 18.1 | 17.2 | 9.7 | 13.3 | 11.2 | 10.5 | 15.9 |
| C ₂ H ₆ | 8.6 | 6.4 | 5.9 | 9.4 | 6.4 | 10.1 | 7.3 | 7.4 | 6.4 |
| C ₃ H ₈ | 5.6 | 2.2 | 2.4 | 4.7 | 2.8 | 3.0 | 4.7 | 3.5 | 4.9 |
| C4H10: | | | | 110 -11 | | | | | |
| <i>n</i> -butane | 2.0 | 9.0 | 0.0 | 2.0 | 1.4 | 1.3 | 1.9 | 1.3 | 1.4 |
| iso-butane | 0.0 | 0.1 | 0.1 | 0.1 | 0.1 | 1 | 1 | 0.3 | 21 |
| C ₅ H ₁₂ : Common and | 10 | | | | | | | | |
| n-pentane | 3.0 | 0.1 | 0.6 | 6.0 | 9.0 | 0.7 | 1.2 | 1.0 | 0.7 |
| iso-pentane | 0.8 | - | 0.1 | | - | ľ | 1 | 0.3 | 1 |
| C ₆ H ₁₄ : | | | | | | and the | and the second | | |
| n-hexane | INVC-IEBIC | ala - ann | 0.4 | ap Table-2) | 1 | 1 | 1 | | - |
| * Here and later on all characteristics of gas | are given at 20 ° | C and 760 mm | 1 Hg. | | | | | | |

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Table 5 Yield and Characteristics of Gas* Obtained in the Fischer Retort from Low-Sulphur Oil Shales of Various Denosits

| IndicesInvestigated shale sample $r_{\alpha}H_m$ i C_nH_m i C_nH_m i C_2H_4 i C_2H_4 i C_2H_4 i C_3H_6 i C_3H_6 i C_3H_6 i C_4H_8 : i C_4H_1 : i C_6H_{10} : i <th>igated shale sample number 2 3 .6 4.3 6.5</th> <th>see Table 1)</th> <th></th> <th></th> <th></th> <th></th> <th></th> | igated shale sample number 2 3 .6 4.3 6.5 | see Table 1) | | | | | |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|---------------|--------|---------|---------|---------|--------|
| C _n H _m I 2 $C_{a}H_{m}$ 16.6 4.3 Including: $C_{2}H_{4}$ 15.6 4.3 $C_{2}H_{4}$ $C_{3}H_{6}$ 6.1 1.8 $C_{3}H_{6}$ 6.1 1.8 0.6 $C_{4}H_{8:}$ 0.1 0.1 0.1 $C_{4}H_{10:}$ 0.1 0.2 0.2 $C_{4}H_{10:}$ 0.5 0.2 0.2 c_{ib} -buttene-2 0.5 0.5 0.2 c_{ib} -buttene-2 0.5 0.5 0.2 c_{ib} -buttene-2 0.5 0.5 0.5 c_{ib} -buttene-2 0.5 0.5 0.6 $rams$ | .6 4.3 6.5 | acc I and I) | | | | | |
| $C_n H_m$ 16.6 4.3 $C_2 H_4$ 1.5 $C_2 H_4$ $C_2 H_4$ $C_3 H_6$ 6.1 1.5 $C_4 H_8$: $C_4 H_8$: $C_4 H_8$: $Dutene-1$, iso-butene $transbutene-2$ cis -butene-2 cis -butene-2 cis -butene-2 cis -butene-2 $cis-butene-2 ramspentene-1 cishutene-1 $ | .6 4.3 6.5 | 4 | | 1 10 01 | 7 22 10 | 8 | 9 |
| $ \begin{array}{ c c c c c c c c c c c c c c c c c c c$ | | 10.7 | 8.3 | 8.7 0.1 | 12.3 | 14.6 | 7.6 |
| $\begin{array}{c cccc} C_3^{2}H_6 & 6.1 & 1.8 \\ C_4H_8 & 0.1 & 0.6 \\ \text{buttene-1}, iso-butene & 3.3 & 0.6 \\ \text{trans-butene-2} & 0.8 & 0.1 \\ \text{cis-butene-2} & 0.5 & 0.2 \\ C_5H_{10} & 0.1 & 0.1 \\ \text{pentene-1} & 2.6 & 0.1 \\ \text{trans-pentene-2} & 0.2 \\ C_6H_{12} & 0.2 & 0.2 \\ \text{cis-pentene-2} & 0.2 & 0.2 \\ C_6H_{12} & 0.1 & 0.1 \\ \text{trans-pentene-2} & 0.1 & 0.1 \\ \text{trans-pentene-2} & 0.2 & 0.2 \\ C_6H_{12} & 0.1 & 0.1 \\ \text{trans-pentene-2} & 0.2 & 0.2 \\ C_6H_{12} & 0.1 & 0.1 \\ \text{trans-pentene-1} & 0.1 & 0.1 \\ \text{trans-pentene-1} & 0.1 & 0.1 \\ \text{trans-pentene-2} & 0.2 & 0.2 \\ \text{constant} & 0.1 & 0.2 \\ \text{trans-pentene-1} & 0.1 & 0.1 \\ \text{trans-pentene-1} & 0.1 & 0.1 \\ \text{trans-pentene-2} & 0.2 & 0.2 \\ \text{trans-pentene-1} & 0.1 & 0.1 \\ tran$ | 1.3 1 1.5 1 1.8 | 2.9 | 2.4 | 2.9 | 4.4 | 4.8 | 1.7 |
| C4Hs: 3.3 0.6 buttene-1, iso-buttene 3.3 0.6 <i>trans</i> -buttene-2 0.8 0.1 <i>cis</i> -buttene-2 0.5 0.2 C ₅ H ₁₀ : 0.5 0.2 pentene-1 0.5 0.2 <i>cis</i> -buttene-2 0.5 0.2 C ₆ H ₁₂ : 2.6 0.1 2.nethylbutene-1 - - 3-methylbutene-1 - - Deterne-1 - - betterne-1 - - 2-methylbutene-1 - - 1 - - - Selentified - - - Internet - - - 3-methylbutene-1 - - - Deterne-1 - - - Deterne-1 - - - Cot i | i.1 1.8 2.2 | 4.2 | 2.9 | 3.7 | 3.9 | 4.6 | 3.1 |
| buttene-1, iso-buttene 3.3 0.6 <i>trans</i> -buttene-2 0.8 0.1 <i>cis</i> -buttene-2 0.5 0.2 C_5H_{10} : $pentene-1$ 0.2 C_5H_{10} : $pentene-1$ 0.2 cis -buttene-2 0.5 0.1 cis -pentene-2 $ cis$ -pentene-1 $ fout identified$ $ dot identified$ <t< td=""><td>T.A 0.0</td><td>2.0 1.8</td><td>10.5</td><td>6.3</td><td>1.0</td><td></td><td>63</td></t<> | T.A 0.0 | 2.0 1.8 | 10.5 | 6.3 | 1.0 | | 63 |
| <i>trans</i> -butene-2 0.8 0.1 <i>cis</i> -butene-2 0.5 0.2 C_5H_{10} : 0.1 0.2 C_6H_{12} : 2.6 0.1 <i>trans</i> -pentene-2 $ -$ <i>cis</i> -pentene-1 $ -$ <i>suchylbutene-1</i> $ -$ < | | 1.8 | 1.5 | 1.0 | 2.1 | 1.9 | 2.5 |
| cis-buttene-2 0.5 0.2 C5H ₁₀ : 2.6 0.1 pentene-1 2.6 0.1 <i>trans</i> -pentene-2 - - cis-pentene-2 - - - cis-pentene-2 - - - C ₆ H ₁₂ : 2-methylbuttene-1 - - 3-methylbuttene-1 - - - Not identified - - - Zelculated heating value, MJ/m ³ : A6.51 24.58 | 0.1 0.4 | 0.4 | 0.3 | 0.3 | 0.4 | 0.7 | 1 |
| $\begin{array}{c c} C_5H_{10};\\ pentene-1\\ trans-pentene-2\\ cis-pentene-2\\ cis-pentene-2\\ C_6H_{12};\\ 2-methylbutene-1\\ 3-methylbutene-1\\ nexene-1\\ nexene-1\\ nexene-1\\ - \\ - \\ - \\ - \\ - \\ - \\ - \\ - \\ - \\ $ | 0.2 0.3 | 0.4 0 | 0.3 | 0.6 | 0.2 | 0.3 | + |
| pentene-1 2.6 0.1 <i>irans</i> -pentene-2 $ -$ <i>cis</i> -pentene-2 $ C_{6}H_{12}$: $ C_{6}H_{12}$: 2 -methylbutene-1 $ 2$ -methylbutene-1 $ 3$ -methylbutene-1 $ hexene-1$ $ -$ </td <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> <td></td> | | | | | | | |
| <i>trans</i> -pentene-2 cis -pentene-2 cis -pentene-2 C_6H_{12} :2-methylbutene-1- 2 -methylbutene-1 3 -methylbutene-1 $hexene-1$ Not identified $To t a 1$ 100.0100.0Calculated heating value, MJ/m^3 :46.5124.58 | 6 0.1 0.3 | 0.7 30 | 0.6 | 0.2 | 1.3 | 6.0 | 0.3 |
| cis-pentene-2 C_6H_{12} : $2-methylbutene-1$ $3-methylbutene-1$ $3-methylbutene-1$ $hexene-1$ Not identified $To t all$ 100.0100.0Calculated heating value, MJ/m^3 :46.5124.58 | - 0.1 | 10.3 | 30.3 | 7100 - | | 0.1 | Ē |
| $\begin{array}{c c} C_{6}H_{12};\\ 2\text{-methylbutene-1}\\ 3\text{-methylbutene-1}\\ hexene-1\\ hexene-1\\ \hline \\ Vot identified\\ \hline \\ \hline \\ Tot all\\ \hline \\ Tot all\\ \hline \\ 100.0\\ \hline 100.0\\$ | + 03 + 08 - | | P.er | 1939 | | 1.0 | E |
| $\begin{array}{c ccccccccccccccccccccccccccccccccccc$ | | | | | | | |
| $\begin{array}{c c} 3-\text{methylbutene-1} & - & - & - \\ \text{hexene-1} & - & - & - \\ \text{Not identified} & - & - & - & - \\ \hline \hline & - & - & - & - & - \\ \hline & - & - & - & - & - & - \\ \hline & - & - & - & - & - & - \\ \hline & T \text{ ot all} & 1 & 00.0 & - & - \\ \hline & - & - & - & - & - \\ \hline & - & - & - & - & - \\ \hline & - & - & - & - & - \\ \hline & - & - & - & - & - \\ \hline & - & - & - & - & - \\ \hline & - & - & - & - & - \\ \hline & - & - & - & - & - \\ \hline & - & - & - & - & - \\ \hline & - & - & - & - & - \\ \hline & - & - & - & - & - \\ \hline & - & - & - & - & - \\ \hline & - & - & - & - & - \\ \hline & - & - & - & - & - \\ \hline & - & - & - & - & - \\ \hline & - & - & - & - & - \\ \hline & - & - & - & - & - \\ \hline & - & - & - & - & - \\ \hline & - & - & - & - & - \\ \hline & - & - & - & - & - \\ \hline & - & - & - & - & - \\ \hline & - & - & - & - & - \\ \hline & - & - & - & - & - \\ \hline & - & - & - & - & - \\ \hline & - & - & - & - & - \\ \hline & - & - & - & - & - \\ \hline & - & - & - & - & - \\ \hline & - & - & - & - & - \\ \hline & - & - & - & - & - \\ \hline & - & - & - & - & - \\ \hline & - & - & - & - & - \\ \hline & - & - & - & - & - \\ \hline & - & - & - & - & - \\ \hline & - & - & - & - \\ \hline & - & - & - & - \\ \hline & - & - & - & - \\ \hline & - & - & - & - \\ \hline & - & - & - & - \\ \hline & - & - & - & - \\ \hline & - & - & - & - \\ \hline & - & - \\ \hline$ | | 33/81 - 453 | - 34.1 | -5804 | 1000 | 0.2 | E |
| Not identified $T_{0.1}$ and $T_{0.1}$ $T_{0.$ | 0.1 | 1 | 1 | 1 | - | 0.1 | - |
| Not identified $ -$ Total100.0100.0Calculated heating value, MJ/m^3 :46.5124.58 | 0.3 | 1 | 1 | 1- 0.2 | 12-04 | N8 -0.2 | 110 -2 |
| Total 100.0 100.0 Calculated heating value, MJ/m ³ : high 46.51 24.58 | 0.3 | | | - 03 | 1 | I | |
| Calculated heating value, MJ/m ³ : high 46.51 24.58 | .0 100.0 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| high 46.51 24.58 | | | | | | | |
| | .51 24.58 24.07 | 35.37 | 27.34 | 29.26 | 33.75 | 35.08 | 33.50 |
| low 42.92 21.22 | .92 21.22 22.06 | 32.36 | 24.83 | 26.75 | 30.90 | 32.02 | 30.60 |
| Density, kg/m ³ 1.481 0.945 | 481 0.945 1.394 | 1.099 | 0.891 | 1.117 | 1.205 | 0.909 | 1.140 |
| Content of H_2S , g/m^3 206 71 | 06 71 - | 41 | 12 | 61 | 131 | 5.7 | 363 |

| VIEID and CALTERING | CS 01 Gas 0 | DLAINED III | LITE FISCILE | L Netoll III | C-MOT IIIC | no mudm | | an rous | CIICO | |
|------------------------------|--------------|--------------|--------------|---------------|------------|---------|--------|---------|--------|--------|
| orld (Shale Samples 10 | 100 | | | | | | | | | |
| Tor | Investigated | d shale samp | ole number (| (see Table 2) | P.M. | 100 0 | 100.0 | 0.001 | 10.001 | 100'0 |
| | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| gas yield, m ³ /t | 19.0 | 31.0 | 20.2 | 32.9 | 42.0 | 34.1 | 28.4 | 43.9 | 30.5 | 36.2 |
| of components, vol.%: | 27.3 | 16.0 | 18.0 | 26.7 | 52.3 | 19.9 | 45.5 | 28.6 | 32.0 | 32.7 |
| | 5.3 | 6.0 | 8.7 | 9.4 | 0.0 | 5.5 | 0.7 | 4.4 | 0.7 | 0.7 |
| | 24.3 | 38.1 | 40.7 | 25.7 | 27.4 | 14.5 | 11.4 | 12.3 | 44.6 | 29.4 |
| | 2.6 | 8.1 | 6.1 | 3.8 | 6.3 | 4.5 | 7.0 | 6.4 | 4.4 | 5.4 |
| 2 | 31.0 | 26.2 | 19.3 | 25.0 | 10.0 | 37.2 | 26.7 | 34.7 | 12.4 | 24.2 |
| ding: | 18.7 | 149 | 110 | 1 12 2 | 1 6.6 | 1 18.8 | 1 15.6 | 18.2 | 5.8 | 12.3 |
| | 7.2 | 6.9 | 4.7 | 7.0 | 1.8 | 10.5 | 6.5 | 9.1 | 3.4 | 6.3 |
| | 3.5 | 2.6 | 2.2 | 3.4 | 0.9 | 4.9 | 2.4 | 3.9 | 1.7 | 3.0 |
| 0: | 3.3 | | | 8.1 | 5.0 | 24 | | | | T. ILY |
| utane | 1.1 | 1.1 | 0.7 | 1.3 | 0.5 | 1.7 | 1.0 | 1.6 | 0.7 | 1.2 |
| butane | 0.3 | 0.2 | 0.4 | 0.1 | 1 | 0.2 | 0.1 | 0.2 | 0.1 | 0.3 |
| 2: | | | | | - | | | - | 1 05 | |
| entane | 9.0 | 0.5 | 0.3 | 6.0 | 0.2 | 1.1 | 1.0 | 1.0 | C.U | 1.0 |
| pentane | 0.1 | 660 20010 M | - | 0.1 | 1 | 1 | 0.1 | 0.1 | 1.0 | 0.1 |
| 4: | | | | | | _ | | 1 0.6 | 10 | |
| lexane | 1 | 1 | 1 | | | | c.U | 0.0 | 1.0 | C.U |

Table 6. Yield and Characteristics of Gas Obtained in the Fischer Retort from Low-Sulphur Oil Shales of Various Deposits of the World (Shale Samples 10-19) (end)

| Indices | Investigated | d shale samp | le number (| see Table 2) | Sincer of | 1 March 10/ added | borthe File | handor had | Waara . | 1 Delice |
|------------------------------------------------------------------------------|--------------|--------------|--------------|--------------|------------|-------------------|-------------|-------------|----------|----------|
| | 10 | II | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| C _n H _m | 9.5 | 10.7 | 7.2 | 9.4 | 4.0 | 17.9 | 8.5 | 13.1 | 5.7 | 7.3 |
| Including: C ₂ H ₄ C ₃ H ₆ | 4.1 2.6 | 2.7 3.1 | 1.8 3.1 | 3.1 3.1 | 1.0 | 4.9 5.4 | 2.7 | 3.7 | 1.5 | 2.0 |
| C ₄ H ₈ : butene-1, <i>iso</i> -butene | 1.7 | 1.8 | 1.3 | 1.6 | 1.0 | 3.8 | 1.2 | 2.2 | 1.1 001 | 1.3 |
| trans-butene-2 cis-butene-2 | 0.2 0.2 | 0.5 | 0.5 | 0.4 0.3 | | 0.5 | 0.4 | 0.6 | 0.3 0.2 | 0.3 |
| C ₅ H ₁₀ : | 50 | 04 | | | 00 | - | 0.4 | 07 | 03 | V U |
| trans-pentene-2 cis-nentene-2 | }0.2 | }0.5 | | 0.2 | 3 | }1.9 | 0.1 | 0.3 | 0.2 | 0.2 |
| C6H13: | | | 0141 60 | a nutre of | | - | - | - | - | _ |
| 2-methylbutene-1 | 0.1 | 1 | 1 | 0.1 | 1 | 1 | 0.1 | 0.2 | 0.1 | 0.1 |
| 3-methylbutene-1 | 1 | I | 1 | 0.1 | 1 | 1 | E | 1 | 1 | |
| hexene-1 | - ni | THE STATE OF | solar - side | (see - 1010 | 1 | 1 | 0.2 | 0.4 | 0.2 | 0.2 |
| Not identified | 0.1 | 1 | 1 | 1 | 1 | 0.5 | 0.2 | 0.5 | 0.2 | 0.3 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| Calculated heating value, MJ/m ³ : | nd Doared | abautan 2 | | A STADER T | chantle of | the Motor | ul menue | ada badabar | Severe 1 | 0.001 |
| high | 30.35 | 30.87 | 25.28 | 29.85 | 12.89 | 44.34 | 25.54 | 37.72 | 19.82 | 26.71 |
| low | 27.67 | 28.13 | 22.92 | 27.26 | 11.68 | 40.91 | 23.70 | 34.83 | 17.98 | 24.45 |
| Density, kg/m ³ | 1.127 | 0.925 | 0.912 | 1.149 | 1.228 | 1.292 | 1.391 | 1.344 | 0.960 | 1.135 |
| Content of H ₂ S, g/m ³ | 75 | 13 | 123 | 133 | 1 | 78 | 10 | 62 | 10 | 10 |

| Table 7. Heat Balance of Retorting | g Low-Sulp | hur Oil Sha | ales from | Various Dep | osits of | the World | l in the Fi | scher | Retort, | %, | | |
|--------------------------------------------------------------------------|-------------|--------------|-----------|---------------|----------|-----------|-------------|-------|---------|-------|------|-----|
| and Sulphur Distribution between F | Retorting P | roducts, % | (Shale Sa | umples 1-9) | | | | | | | | |
| Not heating | 1.10 | | | | | 10 | | | | | | [|
| Indices | Investigate | d shale samp | le number | (see Table 1) | | | | | | | | 0.2 |
| Cellin. | 1001 | 2 | 3 | 4 | 5 | 9 | 10.2 | 7 | 8 | 150% | 6 | 10 |
| Co. cp-pentene-3 | 27.3. H | Ch | emical | heat of s | hale | 10.00 | 10.1 | | 1.0. | 000 | | 13 |
| Shale oil | 70.5 | 50.9 | 28.9 | 63.8 | - | 59.0 | 58.7 | 64 | .5 | 37.3 | 5 | 8.4 |
| Gas | 14.3 | 11.7 | 12.1 | 9.6 | 10 | 11.4 | 11.7 | 13 | .102 | 24.4 | 14 | 4.1 |
| Gasoline, unregarded losses and | 0.2 | ~ ~ | 96 | 01 | 0.0 | 01 | 11 | | - | 0.2 | | 00 |
| Semicoke | 0.0 | 35.1 | 616 | 25.6 | 1 | 28.6 | 28.5 | 22 | 5 | 38.6 | 3(| 0.4 |
| | 1000 | 1.00 | 0.10 | | | | | 1001 | + | | | |
| 10141 | 1 100.0 | 1 100.0 | 100.0 | 1 100.0 | - | 1 0.00 | 100.0 | 100 | - n. | 100.0 | 101 | 0.0 |
| C'IIC | | To | tal sulp | hur of s | hale | | | | | | | St. |
| Shale oil | 9.6 | 5.2 7.1 | 1.7 | 9.4 | 00 | 8.7 | 10.2 | 11 | 0. | 3.4 | | 5.3 |
| Gas (in the form of H ₂ S) | 39.0 | 28.0 | - | 6.2 | | 3.5 | 20.8 | 17 | 0. | 3.2 | 4 | 1.5 |
| Semicoke | 55.4 | 64.5 | 89.1 | 80.5 | 0.0 | 87.5 | 67.7 | 59 | .5 | 84.2 | 5. | 7.5 |
| Other species of sulphur in gas and analytical errors (by difference) | -4.0 | 0.4 | 9.2 | 3.9 | | 0.3 | 1.3 | 12 | .5 | 9.2 | 17.2 | 4.3 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 | | 0.00 | 100.0 | 100 | 0. | 100.0 | 100 | 0.0 |
| Callin a hereine | | | | 10 110-11 | | | | | | | | |

| Table 8. Heat Balance of Retorting and Sulphur Distribution between I | g Low-Sul Retorting | phur Oil Sh Products, % | ales from (Shale Sa | Various De amples 10- | posits of th 19) | ie World in | the Fische | er Retort, | % | |
|--------------------------------------------------------------------------|------------------------|----------------------------|------------------------|--------------------------|---------------------|-------------|----------------------------------------------------------------------------------------------------------------|------------|-------|-------|
| fadicity contourney to | a province of a | lyste supple p | sunder free | Tables 1 38 | 0 20 1 43 | 0.1 | 20 | 8.0 | 1.4 | 0.1 |
| Indices | Investigate | ed shale samp | le number (| (see Table 2) | 7.582 | 8,000 | 9,300 | 111,293 | 1,503 | 1 202 |
| Benerical index age. | 10 | II | 12 | 13 | 14 | 15 - 30 | 16 | 17 50 | 18 30 | 19 |
| stacoardiouses 22 to | 58 | Ch | lemical | heat of | shale | 0.00 | 100 K | tol l | 701 | 102 |
| Shale oil | 77.1 | 68.7 | 45.2 | 55.0 | 39.6 | 72.3 | 54.0 | 58.5 | 45.1 | 61.6 |
| Gas | 8.7 | 7.2 | 13.9 | 15.5 | 10.2 | 13.4 | 13.2 | 14.2 | 16.4 | 12.6 |
| Gasoline, unregarded losses and | 1 (A) | 0 | | | 040 | | 22.0 | | NO I | 50 |
| analytical errors (by difference) | -0.7 | 4.9 | 5.3 | -3.1 | -2.5 | 1.3 | -3.8 | 2.9 | -2.4 | 0.7 |
| Semicoke | 14.9 | 19.2 | 35.6 | 32.6 | 52.7 | 13.0 | 36.6 | 24.4 | 40.9 | 25.1 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| Vield of shake oil, %: | | T. | otal sul | phur of | shale | | | | | |
| Shale oil | 12.5 | 17.8 | 5.7 | 5.1 | 3.6 | 12.6 | 4.1 | 5.7 | 2.3 | 2.6 |
| Gas (in the form of H ₂ S) | 20.6 | 2.9 | 14.6 | 14.8 | 1 | 28.6 | 2.6 | 21.4 | 3.6 | 2.8 |
| Semicoke | 53.3 | 72.8 | 72.6 | 70.0 | 98.5 | 59.2 | 85.6 | 68.4 | 85.3 | 87.6 |
| Other species of sulphur in gas and | satisated sh | ante sumple w | | Eppled 1 sure | 15) 82 | | 1 1 84.71 | 1 84.2 | 84.28 | 810 |
| analytical errors (by difference) | 13.6 | 6.5 | 7.1 | 10.1 | -2.1 | -0.4 | 7.7 | 4.5 | 8.8 | 7.0 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| | | | | | | | all and a second se | | | |

| hales | |
|------------------|----------------|
| S lic | |
| ulphur (| |
| I Low-S | |
| fron | |
| Retort | |
| Experimental | |
| the | |
| Obtained in | |
| Oils | |
| of Shale | |
| Characteristics | s of the World |
| Yield and | is Denosit |
| e 9. | arion |
| Tabl | of V. |
| | - |

| of Various Deposits of the Wor | pi | | | | | | | | | | |
|---------------------------------------------------------|--------------|---------------|-------------|---------------|------------|-------|-------|-------|-------|-------|-------|
| Indices | Investigate | d shale sam | Iple number | r (see Table | s 1 and 2) | | | 11 | 2.00 | | |
| Common on the form of H18) | I | 3 | 4 | 5 | 9 | 7 | 8 | 6 | 11-12 | 13 | 14 |
| Yield of shale oil, %: | | | 10101 | sarb un | 1 01 8 8 1 | - | | | | | |
| Plant yield (raw shale basis) | 20.6 | 2.4 | 16.62 | 9.5 | 10.0 | 6.2 | 2.8 | 7.3 | 9.1 | 7.36 | 1.72 |
| Yield of Fischer assay oil | 99.5 | 50.0 | 86.4 | 88.0 | 60.0 | 71.0 | 59.2 | 71.2 | 78.3 | 90.3 | 36.5 |
| Density at 20 °C, kg/m ³ | 988 | 936 | 916 | 936 | 908 | 931 | 913 | 952 | 910 | 897 | 891 |
| Water, % | 6.5 | 46.2 | 5.8 | 6.8 | 14.5 | 6.4 | 1.0 | 11.6 | 12.4 | 0.4 | 1.2 |
| Entrained fines, % | 0.50 | 2.98 | 0.92 | 0.85 | 0.80 | 0.49 | 0.46 | 0.65 | 0.27 | 0.06 | 0.04 |
| Ash, % | 0.24 | 0.72 | 0.11 | 0.50 | 0.10 | 0.13 | 0.10 | 0.06 | 0.14 | 0.04 | 0.003 |
| Viscosity at 75 °C, 10 ⁻⁶ ·m ² /s | 11.4 | 5.3 | 19.6 | 8.1 | 5.2 | 5.6 | 6.06 | 96.6 | 7.07 | 5.91 | 3.64 |
| Flash point, °C | 65 | 77 | 52 | 09 | 84 | 32 | 112 | 44 | 101 | 125 | 52 |
| Pour point, °C | -25 | 18 | + | T | 22 | -8 | 30 | 28 | 27 | 30 | 25 |
| Refraction index, $n^{20}D$ | 1.549 | 1.483 | 1.512 | 1.470 | 1.517 | 1.518 | 1.516 | 1.501 | 1.512 | 1.510 | 1.496 |
| Molecular mass | 249 | 222 | 178 | 298 | 184 | 285 | 275 | 300 | 293 | 293 | 305 |
| Phenolic compounds, % | 26.1 | 3.5 | 1.9 | 2.1 | 3.7 | 4.3 | 1.9 | 0.5 | 0.8 | 1.4 | 1.6 |
| Heating value (bomb | cat Microstr | and a reserve | ral an thu | and thereiche | Total and | 00 | | | | 9.2 | 5.44 |
| calorimeter), MJ/kg | 39.77 | 41.75 | 42.87 | 41.95 | 42.58 | 41.62 | 42.79 | 42.58 | 43.29 | 42.62 | 43.96 |
| Initial boiling point, °C | 116 | 185 | 153 | 158 | 135 | 100 | 199 | 165 | 200 | 183 | 148 |

| Table 9. Yield and Characte of Various Deposits of the V | Vorld (end) | | 1.00 | 22 | 58 | - I Junes | | 10.1 | | | |
|-------------------------------------------------------------|-------------|---------------|-----------|-------------|-------------|-----------|-------|-------|-------|-------|------|
| Indices Mere | Investiga | ted shale sar | nple numb | er (see Tab | les 1 and 2 | (| | | | | |
| | I | 3 | 4 | 5 | 6 | 7 | 80 | 9 | 11-12 | 13 | 14 |
| Distillation, vol.%, at: | | 7 | 00 | The After | 1870 | | 1 | | | 2 | 10 1 |
| 160 °C | 3 | 0.50 | 2 | 1 | 1 | 9 | 1 | 1 | 1 | 1 | 1 |
| 180 °C | 4 | I | 7 | 1 | 2 | 8 | 1 | 1 | I | 1 | 2 |
| 200 °C | ∞ | | 6 | 3 | 4 | 13 | 1 | 2 | 1 | 2 | 3 |
| 220 °C | 12 | 4 | 15 | 4 | 9 | 20 | 2 | 5 | 3 | 4 | 7 |
| 240 °C | 14 | 10 | 19 | 8 | 12 | 30 | 5 | 8 | 7 | 8 | 13 |
| 260 °C | 18 | 20 | 24 | 13 | 17 | 39 | 10 | 14 | 13 | 14 | 20 |
| 280 °C | 22 | 26 | 28 | 22 | 23 | 44 | 18 | 21 | 19 | 21 | 31 |
| 300 °C | 26 | 36 | 35 | 28 | 29 | 51 | 26 | 28 | 26 | 27 | 39 |
| 320 °C | 30 | 48 | 42 | 36 | 35 | 61 | 36 | 34 | 34 | 35 | 49 |
| 340 °C | 35 | 54 | 52 | 43 | 43 | 76 | 44 | 43 | 41 | 43 | 64 |
| 360 °C | 45 | 72 | 68 | 58 | 55 | | 56 | 54 | 50 | 65 | 83 |
| Elemental composition (dry ba | sis), %: | 481-70 | 10016 | 5748 | THE . | 32 | | | | | |
| C and exclosing and | 81.8 | 84.33 | 84.0 | 84.2 | 84.45 | 82.3 | 84.60 | 84.75 | 84.2 | 84.28 | 87.0 |
| Н | 10.1 | 10.88 | 10.8 | 10.4 | 11.63 | 11.7 | 12.01 | 11.12 | 11.9 | 11.84 | 12.3 |
| S | 0.0 | 1.51 | 0.4 | 1.3 | 0.76 | 1.4 | 0.73 | 1.13 | 0.6 | 1.16 | 0.5 |
| Z | 0.2 | 0.65 | 110 | 141 | 0.81 | 146 | 0.80 | 1.50 | 122 | 1.25 | 102 |
| O (hy difference) | 7.0 | 2.63 | 54.0 | 7+.1 | 25 6 | 5+.0 | 1 86 | 1 50 | C.C2 | 1 47 | 7.02 |

Table 10. Chemical Group Composition of Light-Middle Fractions of Shale Oil Obtained in the Experimental Retort from Low-Sulphur Oil Shales of Various Deposits, wt.%

4.7 28.8 6.91 17 45 9 30 19 19 19 43 15 28 10 50. 43 30 00 15 4 14 53 84 23.7 10 17. 18 35 28 16 3 225 221 337 337 13 36 17 36 15 48. 35 9 27 11-12 2.5 37.2 12.5 40 61 26 33 33 17 .61 25 6 36 25 26 19 19 4 0 26.8 43.0 2.6 13.6 28 24 17 21 21 28 19 233 28 10 10 27 13 29 25 9 4 00 43 26 15 32 36 16 10 26 26 13 27. 00 10 23 27 17 48. 0 50 Investigated shale sample number (see Tables I and 2) 300 350 P-200 300-350 15.6 19.9 44.2 00 24 220 233 333 15 36 28 18 31 9 21 17 31 200d IB B 9 raction action 12.13 Fraction ction 40.0 21.37 6.5 223 223 223 17 34 26 31 16 30 24 25 r a 5 LL L 13.43 12.84 44.17 6.11 31 337 19 13 32 19 22 11 27 8 30 35 30 21 26 23 4 7.6 16.5 11.8 35.9 23 20 5 12 25 26 21 13 27 17 15 27 27 27 16 4 Neutral heteroatomic compounds Neutral heteroatomic compounds Neutral heteroatomic compounds Neutral heteroatomic compounds Alkanes and cycloalkanes Alkanes and cycloalkanes Alkanes and cycloalkanes Alkanes and cycloalkanes Aromatic hydrocarbons Aromatic hydrocarbons Aromatic hydrocarbons Aromatic hydrocarbons Fraction yield Fraction vield Fraction yield Fraction yield Compounds Alkenes Phenols Alkenes Phenols Alkenes Phenols Alkenes Phenols

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| $ \begin{array}{ c c c c c c c c c c c c c c c c c c c$ | Deposit (sample Nr.) | Shale oil | | Percentage into | of sulphur tr | ansferred | Content of total | Share in tot of shale, % | al sulphur | Sulphur in semi- | H ₂ S in gas, g/m ³ |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------|-------------------------------------------|--------------------------|-----------------|------------------------|-----------|------------------------|-----------------------------|-----------------|---------------------|-----------------------------------------------|
| The first group Anin (14) 913 0.50 98.5 - 174 81.8 Anin (14) 913 0.50 98.5 - 1.7 1.32 1.74 81.8 Maoming (19) 0.90 0.31 87.6 2.8 2.6 1.22 6.6 80.3 Maoming (19) 0.90 0.31 87.5 3.5 3.5 8.7 1.00 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - <t< th=""><th>Mörscriffe u Daufa v v Nurse v Nurse v</th><th>Density at 20 °C, kg/m³</th><th>Content of sulphur, %</th><th>semicoke</th><th>gas (H₂S)</th><th>oil</th><th>sulphur in shale, %</th><th>Organic S</th><th>Pyrite S</th><th>coke, %</th><th>our shale - in mos onding v the sulp</th></t<> | Mörscriffe u Daufa v v Nurse v Nurse v | Density at 20 °C, kg/m ³ | Content of sulphur, % | semicoke | gas (H ₂ S) | oil | sulphur in shale, % | Organic S | Pyrite S | coke, % | our shale - in mos onding v the sulp |
| Anin $(I4)$ Description of the second set of the set of th | Politicourie | raf ler tel | | L | he first | group | | ly ce la ¹ | ine asi m | | |
| Eckibastus (3)915 0.44 89.1 $ 1.7$ 1.32 17.4 81.8 Maoming (19)9090.31 87.6 2.8 2.6 1.22 6.6 80.3 Ust-Kamenogorsk (5)9060.80 87.5 3.5 8.7 1.00 $ -$ Stuart (16)8970.60 85.6 2.6 4.1 1.00 $ -$ Stuart (16)8930.48 85.5 3.5 8.7 1.00 $ -$ Stuart (17)8930.48 85.3 3.6 2.3 0.78 15.4 70.5 Fushun (18)8730.46 84.2 3.2 9.4 2.10 $ -$ Curkovo-Nikolayev (8)878 0.46 84.2 3.2 9.4 2.10 $ -$ Paraiba valley oil shale (11)910 1.00 72.8 4.1 1.00 $ -$ Paraiba valley oil shale (12)920 2.30 72.6 14.6 5.7 1.60 55.6 33.7 Paraiba valley oil shale (12)920 2.30 72.6 14.6 5.7 1.60 55.6 33.7 Paraiba valley oil shale (12)920 2.30 72.6 14.6 5.7 1.60 55.6 33.7 Paraiba valley oil shale (17)899 0.43 68.4 21.4 5.7 1.60 55.6 33.7 Puddian (17)899 0.43 68.4 21.4 5.7 1.6 | Anin (14) | 913 | 0.50 | 98.5 | | 3.6 | 0.67 | 23.9 | 76.1 | 0.75 | - 00 P |
| Maoning (f) Maoning (f) Maoning (f) 909 0.31 87.6 2.8 2.6 1.22 6.6 80.3 Ust-Kamenogorsk (f) 897 0.60 87.5 3.5 8.7 100 $ -$ Stuart $(I6)$ 897 0.60 87.5 3.5 8.7 100 $ -$ Stuart $(I6)$ 893 0.48 87.5 3.5 8.7 100 $ -$ Stuart $(I6)$ 893 0.48 85.5 3.5 8.7 100 $ -$ | Eckibastuse (3) | 915 | 0.44 | 89.1 | | 1.7 | 1.32 | 17.4 | 81.8 | 1.34 | - 378 |
| Ust-Kanenogorsk (5) 906 0.80 87.5 3.5 8.7 100 $ -$ Stuart (16) 897 0.60 85.6 2.6 4.1 1.00 $ -$ Fushun (18) 893 0.48 85.3 3.6 2.3 0.78 15.4 70.5 Fushun (18) 893 0.46 84.2 3.2 3.4 0.38 18.4 81.6 Fushun (18) 873 0.46 84.2 3.2 3.4 0.38 18.4 81.6 Curkovo-Nikolayev (8) 873 0.46 84.2 3.2 9.4 2.10 100 $ -$ <td>Maoming (19)</td> <td>606</td> <td>0.31</td> <td>87.6</td> <td>2.8</td> <td>2.6</td> <td>1.22</td> <td>6.6</td> <td>80.3</td> <td>1.28</td> <td>10</td> | Maoming (19) | 606 | 0.31 | 87.6 | 2.8 | 2.6 | 1.22 | 6.6 | 80.3 | 1.28 | 10 |
| Stuart (16)Stuart (16)8970.6085.62.64.11.00 $ -$ Fushun (18)8930.4885.33.62.30.7815.470.5Gurkovo-Nikolayev (8)8780.4684.23.23.40.3818.481.6Kenderlyck (4)9231.0080.56.29.42.1010.5 $-$ Paraiba valley oil shale (11)9101.0072.82.917.81.2844.543.0Paraiba valley oil shale (12)9201.0072.614.65.71.6055.633.7Paraiba valley oil shale (12)9202.3072.614.65.71.6055.633.7Aleksinac (13)9081.7570.014.85.12.788.38.9.9Boltysh (6)8930.4368.421.45.71.6055.633.7Macksina (17)8990.4368.421.45.71.20 $ -$ Boltysh (6)9320.5567.720.87.10.39 $ -$ Macksina (7)9380.8267.720.87.10.39 $ -$ Macksina (17)9390.6059.517.011.01.00 $ -$ Mutadian (17)8390.6659.514.45.71.6025.653.7 $-$ Macksing (6)9320.6359.517.014.8 | Ust-Kamenogorsk (5) | 906 | 0.80 | 87.5 | 3.5 | 8.7 | 1.00 | 10-0 | 1 | 1.00 | 12 |
| Fushun $(I\hat{\delta})$ 8930.4885.33.62.30.7815.470.5Gurkovo-Nikolayev $(\hat{\delta})$ 8780.4684.23.23.40.3818.481.6Kenderlyck (4) 9231.0080.56.29.42.1010.5 $-$ Paraiba valley oil shale (II) 9101.0080.56.29.42.1010.5 $-$ Paraiba valley oil shale (II) 9101.0072.82.917.81.2844.543.0Paraiba valley oil shale $(I2)$ 9081.7572.614.65.71.6055.633.7Aleksinac $(I3)$ 9081.7570.014.85.12.788.389.9Huadian (17) 8990.4368.421.45.71.20 $ -$ Boltysh (δ) 9750.6064.528.07.10.39 $ -$ Mae Sot $(I5)$ 9341.3557.541.553.22474.991.9Breznik (g) 9341.3557.541.553.843.153.8Green River $(I0)$ 930.6541.553.20.6564.553.264.4Bortysh (δ) 9341.3557.541.553.264.464.4Breznik (g) 9341.3553.320.612.564.464.4Breznik (g) 9341.3553.320.612.50.6564.4 <td< td=""><td>Stuart (16)</td><td>897</td><td>0.60</td><td>85.6</td><td>2.6</td><td>4.1</td><td>1.00</td><td>518 - 812</td><td>1</td><td>1.00</td><td>10</td></td<> | Stuart (16) | 897 | 0.60 | 85.6 | 2.6 | 4.1 | 1.00 | 518 - 812 | 1 | 1.00 | 10 |
| Gurkovo-Nikolayev ($\$$) 878 0.46 84.2 3.2 3.4 0.38 18.4 81.6 Kenderlyck (4) 923 1.00 80.5 6.2 9.4 2.10 10.5 $-$ Paraiba valley oil shale (II) 910 1.00 72.8 2.9 17.8 1.28 44.5 43.0 Paraiba valley oil shale (II) 910 1.00 72.8 2.9 17.8 1.28 44.5 43.0 Paraiba valley oil shale (II) 910 1.00 72.8 2.9 17.8 1.28 44.5 43.0 Paraiba valley oil shale (IZ) 920 2.30 72.6 14.6 5.7 1.60 55.6 33.7 Aleksinac ($I3$) 908 0.43 68.4 21.4 5.7 1.60 55.6 33.7 Mackina ($I7$) 899 0.43 68.4 21.4 5.7 1.20 - - Ukhta (2) 995 0.60 64.5 28.0 7.1 0.39 | Fushun (18) | 893 | 0.48 | 85.3 | 3.6 | 2.3 | 0.78 | 15.4 | 70.5 | 0.74 | 10 |
| Kenderlyck (4)9231.0080.56.29.42.1010.5 $-$ Paraiba valley oil shale (11)9101.0072.82.917.81.2844.543.0Paraiba valley oil shale (12)9081.0072.82.917.81.2844.543.0Paraiba valley oil shale (12)9202.3072.614.65.71.6055.633.7Aleksinac (13)9081.7570.014.85.12.788.389.9Boltysh (6)8990.4368.421.45.71.20Boltysh (6)8990.8267.720.810.21.4012.179.3Ukhta (2)9750.6064.528.07.10.39Luban (7)9252.0059.517.011.01.6025.068.7Mae Sot (15)9341.3557.541.55.32.474.991.9Green River (10)9270.845.3.320.612.50.6543.153.8 | Gurkovo-Nikolayev (8) | 878 | 0.46 | 84.2 | 3.2 | 3.4 | 0.38 | 18.4 | 81.6 | 0.40 | 9 |
| Paraiba valley oil shale (II) 910 1.00 72.8 2.9 17.8 1.28 44.5 43.0 Paraiba valley oil shale (IZ) 920 1.00 72.8 2.9 17.8 1.28 44.5 43.0 Paraiba valley oil shale (IZ) 920 2.30 72.6 14.6 5.7 1.60 55.6 33.7 Aleksinac $(I3)$ 908 1.75 70.0 14.8 5.1 2.78 8.3 89.9 Boltysh (6) 908 1.75 70.0 14.8 5.7 1.60 55.6 33.7 Boltysh (6) 899 0.43 68.4 21.4 5.7 1.60 55.6 33.7 Ukhta (2) 899 0.82 67.7 20.8 10.2 1.40 12.1 79.3 Mae Sot $(I5)$ 925 2.00 59.5 17.0 11.0 1.60 25.0 68.7 Mae Sot $(I5)$ 934 1.35 57.5 41.5 5.3 2.47 4.9 91.9 Green River $(I0)$ 934 1.35 53.3 20.6 | Kenderlyck (4) | 923 | 1.00 | 80.5 | 6.2 | 9.4 | 2.10 | 10.5 | 1 | 2.35 | 41 |
| The second groupThe second groupParaia valley oli shale $(I2)$ 9202.3072.614.65.71.6055.633.7Huadian (17) 9081.7570.014.85.12.788.389.9Boltysh (6) 9081.7570.014.85.12.788.389.9Ukhta (2) 9750.6064.528.07.10.39 $ -$ Luban (7) 9252.0059.517.011.01.6025.068.7Mae Sot $(I5)$ 8890.6059.228.612.60.8732.264.4Breznik (9) 9341.3557.541.55.32.474.991.9Creen River $(I0)$ 9270.8453.320.612.564.453.8 | Paraiba valley oil shale (11) | 910 | 1.00 | 72.8 | 2.9 | 17.8 | 1.28 | 44.5 | 43.0 | 1.30 | 43 |
| Paratiba valley oit shale $(I2)$ 9202.3072.614.65.71.6055.633.7Aleksinac $(I3)$ 9081.7570.014.85.12.788.389.9Huadian (17) 9081.7570.014.85.12.788.389.9Boltysh (6) 9750.4368.421.45.71.20 $ -$ Ukhta (2) 9750.6064.528.07.10.39 $ -$ Luban (7) 9252.0059.517.011.01.6025.068.4Mae Sot (15) 9341.3557.541.55.32.474.991.9Green River (10) 9270.8453.320.612.50.6543.153.8 | | | | T | le secon | 1 group | | | | | |
| Aleksinac (I_3) 908 1.75 70.0 14.8 5.1 2.78 8.3 89.9 Huadian (17) 899 0.43 68.4 21.4 5.7 1.20 $ -$ Boltysh (6) 899 0.43 68.4 21.4 5.7 1.20 $ -$ Boltysh (6) 899 0.82 67.7 20.8 10.2 1.40 12.1 79.3 Ukhta (2) 975 0.60 64.5 28.0 7.1 0.39 $ -$ Luban (7) 925 2.00 59.5 17.0 11.0 1.60 25.0 68.7 Mae Sot $(I5)$ 889 0.60 59.5 17.0 11.0 1.60 25.0 68.4 Mae Sot $(I5)$ 934 1.35 57.5 41.5 5.3 2.47 4.9 91.9 Green River $(I0)$ 927 0.84 53.3 206 12.5 0.65 43.1 53.8 | Paraiba vallev oil shale (12) | 920 | 2.30 | 72.6 | 14.6 | 5.7 | 1.60 | 55.6 | 33.7 | 1.30 | 123 |
| Huadian (17) 899 0.43 68.4 21.4 5.7 1.20 $ -$ Boltysh (6) 898 0.82 67.7 20.8 10.2 1.40 12.1 79.3 Ukhta (2) 975 0.60 64.5 28.0 7.1 0.39 $ -$ Luban (7) 925 2.00 59.5 17.0 11.0 1.60 25.0 68.7 Mae Sot (15) 889 0.60 59.2 28.6 12.6 0.87 32.2 64.4 Breznik (9) 927 0.84 53.3 20.6 12.5 64.4 4.9 91.9 | Aleksinac (13) | 908 | 1.75 | 70.0 | 14.8 | 5.1 | 2.78 | 8.3 | 89.9 | 2.29 | 133 |
| Boltysh (δ) 898 0.82 67.7 20.8 10.2 1.40 12.1 79.3 Ukhta (2) 975 0.60 64.5 28.0 7.1 0.39 $ -$ Luban (7) 925 2.00 59.5 17.0 11.0 1.60 25.0 68.7 Mae Sot (15) 889 0.60 59.2 28.6 12.6 0.87 32.2 64.4 Breznik (9) 934 1.35 57.5 41.5 5.3 2.47 4.9 91.9 Green River (10) 927 0.84 53.3 20.6 12.5 0.65 43.1 53.8 | Huadian (17) | 899 | 0.43 | 68.4 | 21.4 | 5.7 | 1.20 | R Thorse | 1 | 1.10 | 62 |
| Ukhta (2) 975 0.60 64.5 28.0 7.1 0.39 $ -$ Luban (7) 925 2.00 59.5 17.0 11.0 1.60 25.0 68.7 Mae Sot (15) 889 0.60 59.2 28.6 12.6 0.87 32.2 64.4 Breznik (9) 934 1.35 57.5 41.5 5.3 2.47 4.9 91.9 Green River (10) 927 0.84 53.3 20.6 12.5 0.65 43.1 53.8 | Boltysh (6) | 898 | 0.82 | 67.7 | 20.8 | 10.2 | 1.40 | 12.1 | 79.3 | 1.30 | 61 |
| Luban (7) 925 2.00 59.5 17.0 11.0 1.60 25.0 68.7 Mae Sot (15) 889 0.60 59.2 28.6 12.6 0.87 32.2 64.4 Breznik (9) 934 1.35 57.5 41.5 5.3 2.47 4.9 91.9 Green River (10) 927 0.84 53.3 20.6 12.5 0.65 43.1 53.8 | Ukhta (2) | 975 | 0.60 | 64.5 | 28.0 | 7.1 | 0.39 | | - | 0.30 | 71 |
| Mae Sot (I5) 889 0.60 59.2 28.6 12.6 0.87 32.2 64.4 Breznik (9) 934 1.35 57.5 41.5 5.3 2.47 4.9 91.9 Green River (10) 927 0.84 53.3 20.6 12.5 0.65 43.1 53.8 | Luban (7) | 925 | 2.00 | 59.5 | 17.0 | 11.0 | 1.60 | 25.0 | 68.7 | 1.10 | 131 |
| Breznik (9) 934 1.35 57.5 41.5 5.3 2.47 4.9 91.9 Green River (10) 927 0.84 53.3 20.6 12.5 0.65 43.1 53.8 | Mae Sot (15) | 889 | 0.60 | 59.2 | 28.6 | 12.6 | 0.87 | 32.2 | 64.4 | 69.0 | 78 |
| Green River (10) 927 0.84 53.3 20.6 12.5 0.65 43.1 53.8 | Breznik (9) | 934 | 1.35 | 57.5 | 41.5 | 5.3 | 2.47 | 4.9 | 91.9 | 1.70 | 363 |
| | Green River (10) | 927 | 0.84 | 53.3 | 20.6 | 12.5 | 0.65 | 43.1 | 53.8 | 0.40 | 75 |

| ndices | Heat carrier gas the retort bed | single flow through | Contact material | of oil vapou | irs with hot (50 | 0-600 °C) s | olid |
|-------------------------------------------------------------------------|------------------------------------|---------------------|---------------------|------------------|------------------|----------------|------------|
| | Experimental | Hot model of the | e retorting o | chamber of | Solid heat carr | rier units (S) | HC) |
| | retort | a heat carrier gas | cross-flow | retort [4] | Bench-scale | SCH-5 | 009 |
| | Kul | kersite Eston | ian dep | osit | 1 3/14 | 1 30 | 12 |
| Density at 20 °C, kg/m ³ Molecular mass | 988 249 | 1000 278 | | 021 251 | 10,64 | 100 | 975 220 |
| rlash point, °C | 65 | + | 110 | - 102 | I | 5 12 | 6 |
| | Bul | garia Breznik | deposi | t | | | |
| Density at 20 °C, kg/m ³ Molecular mass Pour point. °C | 952 300 28 | 960 303 29 | 28.8 | 980 218 16 | 1 | <u>n a i</u> | + |
| 000 1000 | Bul | garia Gurkov | o-Nikol | ayev de | posit | 1.85.1 | |
| Density at 20 °C, kg/m ³ Molecular mass | 913 275 | | 1 22 | - 233 | | N CO | 877 |
| our point, °C lash point, °C | 30 112 | La Ricord | | | | | 20 |
| | Yug | goslavia Aleks | sinac de | posit | | | |
| Density at 20 °C, kg/m ³ Molecular mass Pour point, °C | 897 293 30 | | a and | | 899 212 15 | 1 20 | 111 |
| | Mo | rocco Timahd | it depo | sit | | | |
| Density at 20 °C, kg/m ³ Molecular mass | 981 262 | 11 | | 11 | 959 180 | | |
| our point, °C Tash point, °C | 88 | Tou-Subme On | Simles ho | A Autom | -21 6 | the laouty- | 11 |

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Low-sulphur shales yield retort gas which contains only a little hydrogen sulphide - in most cases no more than 50-100 g/m³ (Tables 5 and 6). The corresponding value for high-sulphur shales is 300-500 g/m³ [1]. Considering the sulphur present in oil shale, up to 10 % (with some exceptions) is transferred to oil (Tables 7 and 8), and the main portion of it remains in the semicoke.

In order to make a more thorough study of the physical and chemical properties of retort oil (which is the main product of oil shale thermal destruction) some of the samples have been processed in an experimental retort with semicoke gasification. The retort had a throughput of 500-1000 kg/day [2, 3]. As seen from Table 9, processing of low-sulphur shales yields shale oil which comprises from 50-80 % of the Fischer assay oil, dropping to 36 % only in the case of Romanian shales from the Anin deposit (Banata province).

Retort oils obtained in such a fashion are characterized by relatively low density, high solidification temperature, and very low content of oxygen and, consequently, of phenols, too. Compared to high-sulphur oils, low-sulphur ones contain more paraffins and olefins and less aromatic hydrocarbons (Table 10).

Low-sulphur oil shales which yield paraffinic retort oil, as investigated by the authors, may be divided into two groups (Table 11) rather precisely. All paraffinic oils are characterized by low density as already mentioned above (about 900 kg/m³). The first group comprises the oil shales for which retorting results in having 70-100 % of the sulphur remain in the semicoke, and only 5-6 % is transferred into the gas (the H₂S content of gas is low and does not exceed 40 g/m³). The second group comprises the oil shales for which 50-70 % of the original sulphur remains in the semicoke and the portion converted into gaseous components is significantly higher (14-40 %). The H₂S content of this gas is up to 60-135 g/m³.

Neither the form of the sulphur nor the proportion of the different forms seem to influence its distribution between retorting products (see data in Table 11). Some other factors are probably impacting on those processes.

Solidification of paraffinic oils (i.e. products of thermal processing of oil shale samples under study) causes serious troubles during retorting. Therefore, it is extremely expedient to find possible routes for obtaining oils with lower values for oil solidification point. As seen from Table 12, this is attainable when processing oil shale in units with a solid heat carrier or using the reverse process in vertical retorts, i.e. repeated contact of vapour and gas mixture with heated semicoke (up to 500-600 $^{\circ}$ C) [4].

Conclusions

Oil shales which form low-sulphur paraffinic oil upon retorting have been studied. The total sulphur content of the studied samples is within the range 0.38-2.78 % and the organic sulphur content varies between 0.07 and 0.89 %. During the oil shale processing in Fischer retorts, sulphur is transferred to the products in the following proportions: 1.7-17.8 % to the oil, traces-41.5 % to the gas (as H₂S), and 53.3-98.5 % to the semicoke. The oils obtained from the studied oil shales have decreased values for density (about 900 kg/m³). The tested shales produce light-middle fractions which contain less aromatic hydrocarbons and more paraffins and olefins than oils obtained during the retorting of high-sulphur oil shales. Paraffinic oils contain only small amounts of phenolic compounds - 2-4 %.

It is suitable to conditionally divide the oil shales studied into two groups. The first group is comprised of the oil shales for which 70-100 % of the total sulphur remains in the semicoke during retorting, and the portion of sulphur transferred into the gas (as H_2S) is very negligible - below 5-6 % (the H_2S content of this gas does not exceed 40 g/m³).

The second group is comprised of the oil shales for which 50-70 % of the total sulphur remains in the semicoke upon retorting, and 14-40 % is transferred into the gas (the H₂S content of this gas rises up to 60-135 g/m³). The form of sulphur present in oil shale and the proportion of different forms do not affect its distribution between the products; some other factors seem to be responsible for this separation.

The world-wide experience of thermal processing of low-sulphur shales which yield paraffinic oil upon retorting is very large. High values for solidification point (25-30 $^{\circ}$ C) of the produced oils very often complicate their transport and further chemical treatment. To avoid these problems, one should process those shales in retorting units with a solid heat carrier or in vertical retorts with repeated contact of oil vapours with the semicoke.

Acknowledgements

This work and the research published in **Oil Shale** Vol. 12, No. 4, pp. 317-340 were financially supported by the Estonian Science Foundation under Grant No. 2029.

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Received April 1, 1996