CHAPTER 2

The Soviet Oil and Gas Industry

CONTENTS

	Page
INTRODUCTION	19
LOCATION OF MAJOR PETROLEUM REGIONS	20
West Siberia	20
Volga-Urals	25
The Caspian Basin and North Caucasus	26
Ukraine	27
Central Asia	27
Komi	28
Sakhalin	30
Summary	30
EXPLORATION	31
Introduction	31
The Exploration Process	31
Evaluation of Exploration Efforts	32
The Contribution of Western Equipment and Technology to Exploration	35
Summary and Conclusions	37

Page

DRILLING. 38

Introduction 38
The Drilling Process 38
Soviet Drilling Equipment and practice. 39
The Contribution of Western Equipment and Technology to Drilling. 46
Summary and Conclusions. 47

PRODUCTION 48

Introduction 48
The Production Process. 48
Soviet Equipment and Practice. 51
The Contribution of Western Technology and Equipmentto Production 53
Summary and Conclusions. 55

TRANSPORTATION OF OIL AND GAS. 55

Introduction 55
Transportation of Oil and Gas by Pipeline 56
Soviet Oil Pipelines. 57
Gas Pipelines 60
The Role of Western Pipeline Equipment and Technology. 62
Summary and Conclusions. 64

REFINING 64

Introduction 64
The Soviet Oil Refining Industry 64
The Soviet Gas-Processing Industry . . . 67
Western Technology in the Soviet Refining Industry 67
Summary and Conclusions. 68

OFFSHORE 68

Introduction 68
Offshore Exploration and Production . . . 68
The Soviet Offshore Industry 69
The Contribution of Western Offshore Technology 70
Summary and Conclusions. 70

THE PROSPECTS FOR SOVIET OIL PRODUCTION IN 1985. 70

Soviet Oil Reserves. 71
Soviet Oil Production Capabilities 73

THE PROSPECTS FOR SOVIET OIL PRODUCTION IN 1990. 74

THE PROSPECTS FOR SOVIET GAS PRODUCTION, 1985 AND 1990... 75

SUMMARY AND CONCLUSION 76

LIST OF TABLES

Table No. *Page*

2. Russian and Soviet Oil and Gas Production, Selected Years. 20
3. The Growing Importance of West Siberian Oil Production. 20
4. Production of Gas in Tyumen Oblast. 24
5. Oil Production in the Volga-Urals Region 25
6. Oil Production in the Caspian Region 27
7. Gas Production in Central Asia 28
8. Oil Production in Komi 29
9. Natural Gas Production in Komi . . . 29
10. Average Bit Runs 42
11. Drilling for Oil and Gas. 44
12. Waterflooding 52
13. Transport of Oil and Oil Products . . 57
14. Length of Oil and Oil Product Pipelines. 58
15. Diameters and Capacity of Oil Pipelines. 58
16. Length and Diameters of Gas Trunk Pipelines. 60
17. Soviet Oil Production Forecasts, 1985 71
18. Soviet Natural Gas Production Estimates, 1985-90 75

LIST OF FIGURES

Figure No. *Page*

2. Major Petroleum Basins, Oilfields, and Gasfields 21
3. Major Oil Pipelines 59
4. Major Gas Pipelines 61
5. Soviet Oil Refinery Sites. 65

CHAPTER 2

The Soviet Oil and Gas Industry

In 1980, the Soviet Union was both the world's largest producer of oil and its largest gas exporter. It is ironic, therefore, that much of the discussion of Soviet energy that has taken place in the West centered until recently on a debate over the continued viability of Soviet energy independence, at least in the present decade. This debate was occasioned by the 1977 Central Intelligence Agency (CIA) projection that Soviet oil production would peak and begin to decline sharply by the early 1980's. It is by now clear that this outcome is unlikely. The rate of growth of Soviet oil production has slowed markedly, but output does not appear to have peaked. Indeed, the CIA has revised its forecast, pushing back the anticipated decline until after 1985. The focus of interest has now shifted from oil to gas–and from the potential consequences of a Soviet oil shortage to the implications, both for the U.S.S.R. and the West, of an abundance of Soviet gas.

This chapter attempts to elucidate the grounds of past controversies and illuminate present uncertainties. It examines the present condition of, and potential for, the Soviet oil and gas industries, with special emphasis on the impact of the West on oil and gas production. After a brief historical introduction it surveys the U.S.S.R. oil- and gas-producing regions. It then describes the state of each industry sector—exploration, drilling, production, transportation of oil and gas, refining, and offshore activities—including the past and potential contributions of Western equipment and technology. Finally, it summarizes the controversy over the future of Soviet oil production and posits plausible best and worst case estimates of oil and gas output for 1985 and 1990.

INTRODUCTION

The Russian oil industry is one of the world's oldest. When Baku, the historical center of the industry, was ceded to Russia by Persia in 1813, oil was already being produced from shallow hand-dug pits. Development of these sites near the Caspian Sea languished until after 1862, when production began to rise, aided by the introduction of drilling (1869), the end of the state monopoly on production (1872), and an influx of foreign entrepreneurs, such as Robert and Ludwig Nobel (1873). Russian oil production peaked in 1901 at nearly 12 million metric tons per year (mmt/yr) (240,000 barrels per day (bd) or 0.24 million barrels per day (mbd) (see table 2) and then dropped rapidly. This drop was due to a number of factors, including labor unrest surrounding the 1905 revolution.

Although drilling technology was introduced at about the same time in the United States and in Russia, the Russians soon fell behind. In 1901, the Russians relied on wooden drilling tools that could achieve well depths up to 300 ft. In contrast, European concerns using metal drilling technology could drill wells of over 1,800 ft; in 1909, rotary drills in the United States were reaching depths of 2,400 ft.

[1] Historical material is taken from Mashall I. Goldman, *The Enigma of Soviet Petroleum* (London: George Allen & Unwin, 1980); Robert W. Tolf, *The Russian Rockefellers: The Saga of the Nobel Family and the Russian Oil Industry* (Stanford, Calif.: Hoover Institution Press, 1976); William J. Kelly and Tsuneo Kano, "Crude Oil Production in the Russian Empire: 1818-1919," *The Journal of European Economic History*, vol. VI, No. 2, fall 1977, pp. 307-338; and William J. Kelly, "Crisis Management in the Russian Oil Industry: The 1905 Revolution," *The Journal of European Economic History*, forthcoming.

Table 2.— Russian and Soviet Oil and Gas Production, Selected Years
(million tons, billion cubic meters)

	Oil	Gas
1860	0.004	—
1870	0.033	
1880	0.382	—
1890	3.9	—
1901	12	—
1910	11.3	
1920	3.9	—
1930	18.5	—
1940	31.1	3.2
1950	37.9	5.8
1960	147.9	45.3
1970	353.0	198
1975	491.0	289
1980	603.0	435

SOURCE Goldman, op cit., pp 14-15, 22, 23; *Soviet Geography*, April 1981, pp 273, 276, Dienes and Shabad, op cit, p 70

Oil production fell precipitously after the Bolshevik Revolution and the resulting confiscation and nationalization of the oilfields. Soon, however, the new Soviet Government began to open these fields to foreign technology and investment, By 1927, with prodigious Soviet effort and the help of American, French, Japanese, German, and British firms, production surpassed the 1901 level By 1932, with production at 22.4 mmt (0.45 mbd), petroleum exports accounted for 18 percent of Soviet hard currency receipts. It was at this point that foreign involvement was curtailed.

The year 1940 marked the beginning of another temporary drop in Soviet oil production. During the course of World War II, many oilfields were destroyed, and postwar recovery was slow. Indeed, this recovery was only accomplished with a second infusion of imported equipment and technology, technology that helped to create the present modern, nationwide industry.

The first important oil discoveries outside of Baku had been made around 1932 in the Volga-Urals region. The war, as well as a shortage of drilling equipment, delayed further exploration and development in this area, but as the oilfields around Baku peaked and began to decline in the early 1950's, the Soviet industry shifted its emphasis northeastward to the Volga-Urals. By 1955, drilling activities were concentrated there, and the rate of oil production again began to climb sharply.

The pattern has repeated itself. As the Volga-Urals fields peaked in the 1970's, the Soviets were able to offset declining production by bringing new discoveries online, this time in West Siberia. The first discovery in West Siberia was made in 1960. As table 3 shows, by 1970 its fields accounted for almost 10 percent; 6 years later, over one-third; and now more than one-half of total Soviet oil production. It is appropriate, therefore, to begin this chapter's survey of major oil-producing regions with West Siberia.

Table 3.—The Growing Importance of West Siberian Oil Production (million tons)

Year	U.S.S.R.	West Siberia	West Siberia as a share of U.S.S.R. (O/.)
1965 .	242.9	1,0	0.4
1970 .	353.0	31.4	9.8
1975	490.8	148,0	30.2
1976	519.7	181,7	35,0
1977 . . .	545.8	218.0	39.9
1978	571.4	254.0	44.5
1979 .	586	284	48,5
1980[a], . . .	640	315	49,2
1980[b] .	603	312	51.7
1985 (plan)	620-645	385-395	61-62

[a]Original FYP target
[b]Actual production

SOURCE Wilson op. cit. pp. 56 Soviet *Geography* April 1981 p 273

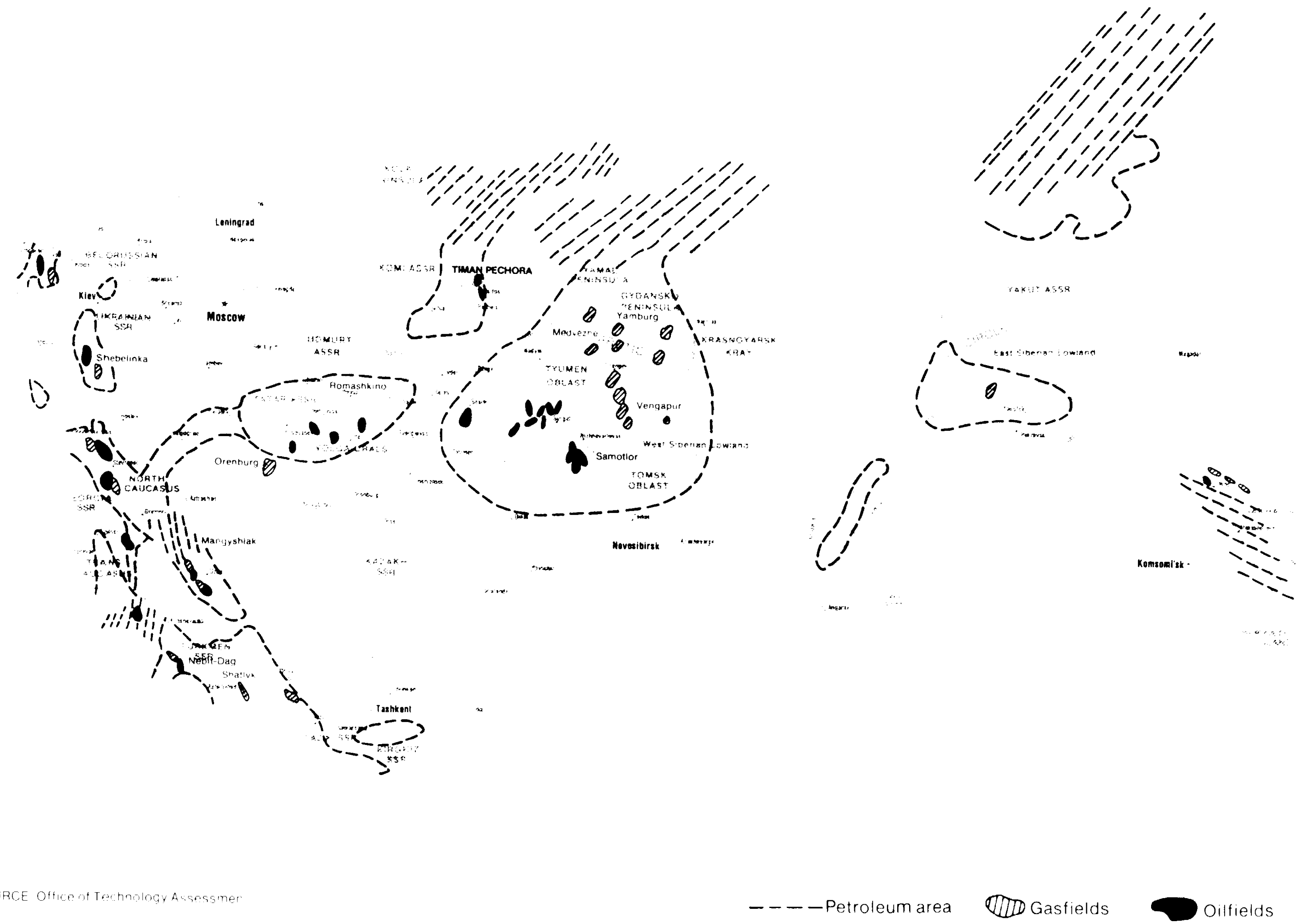
LOCATION OF MAJOR PETROLEUM REGIONS[2]

WEST SIBERIA

The West Siberian lowlands lie between the Ural mountains on the west and the Central Siberian Platform on the east (see fig. 2). The petroleum-producing regions are found in the Tyumen province (oblast) and part of the adjacent Tomsk oblast. This area pre-

Throughout this report, "petroleum" is taken to mean both oil and gas.

Figure 2.—Major Petroleum Basins, Oilfields, and Gasfields



SOURCE Office of Technology Assessment

sents formidable natural obstacles to oil and gas exploration and production. The terrain is extremely flat, and most of the area is a vast swamp, interspersed with sluggish streams and occasional dry ground. The Vasyugan swamp on the left bank of the Middle Ob River alone covers 100,000 square miles (mi^2), equivalent in area to New York, New Jersey, and Pennsylvania combined. Other swamps and bogs abound.

Western Siberia typically has 6 to 8 months each year of below-freezing temperatures. At high water in the Ob system there are 19,000 miles of navigable rivers, but the Ob is blocked for 190 to 210 days per year with ice 30 to 60 inches thick. The shipping season thus lasts only about 5 months. In addition, much of the area is underlain by permanently frozen subsoil (permafrost) that impedes drainage, stunts plant roots, and makes forestry, farming, stock raising, mining, oil drilling, excavation, pipelaying, and most construction activities difficult and expensive,

The map in figure 2 shows few towns of significance in this area; names on Soviet maps often represent mere riverside clearings with a few houses. Large areas are unsettled, virtually inaccessible in summer because of swamps and mosquitoes. In these inhospitable surroundings lies one of the world's largest oil- and gas-producing regions. Here the Soviet Union produced more than one-half of its oil in 1980—312 mmt, about 6.24 mbd—and here too lie the enormous gasfields on which the future of the Soviet gas industry rests.

Oil

Oil was first discovered in West Siberia in 1960 near Shaim on the Konda river, a tributary of the Ob. By 1969, after an intensive exploration effort, 59 fields had been identified in the Middle Ob River region. These included nine large fields (defined as having recoverable reserves of 50 to 100 mmt or 366 million to 733 million barrels (bbl) each); nine giant fields (with recoverable reserves of 100 to 500 mmt or 733 to 3,665 million bbl); and the supergiant Samotlor. "Supergiant" is a designation for fields having recoverable reserves of more than 500 million tons. In this case, the Soviets broke their own self-imposed silence regarding the size of reserves, reporting that Samotlor, the largest oilfield in the U. S. S. R., contains "about 2 billion recoverable tons' (14.7 billion bbl) of oil.'

Soviet planners have concentrated on West Siberian development in an effort to maximize production, and Samotlor has dominated Soviet oil production in the past 5 years. In 1980, Samotlor alone yielded 150 million tons (3 mbd), approximately one-quarter of total oil production for the year. Another way of describing the contribution of this field is through its contribution to incremental output. During the Ninth Five Year Plan (FYP) (1971-75), Samotlor provided over 65 percent[4] of the production increase of West Siberia, and over half of the growth in oil output for the entire U.S.S.R. Much of the controversy over the future of Soviet oil production rests on the question of how long output at Samotlor can be maintained, and whether there is a sufficient number of small deposits to replace it once it does decline. The first billion tons of oil had been recovered from Samotlor by July 1981. At the current rate of production, the field is expected to give out by the late 1980's.

The Soviets are anticipating the inevitable peaking and decline of Samotlor, whenever that may be, by developing a number of smaller West Siberian fields. There is no question that there are many deposits, both in the Ob Valley and in the more remote area of the West Siberian plain, which will be brought into production. One problem with developing such fields, however, is the provision of infrastructure, both to accommodate oilfield workers and to transport the oil itself.

[3] *Sovetskaya Rossiya*, Feb. 28, 1970, quoted in Leslie Dienes and Theodore Shabad, *The Soviet Energy System: Resource Use and Policies* (Washington, D. C.: V. H. Winston & Sons, 1979), p. 58.

[4] Dienes and Shabad give a figure of 66 percent; David Wilson, in *Soviet Oil and Gas to 1990* (London: The Economist Intelligence Unit 1,td, November 1980), p. 9 estimates 73 percent.

Photo credit Oil and Gas Journal

Oil rig near Surgut in West Siberia's Middle Ob region

The pervasive permafrost conditions in Siberia require special, difficult, and expensive construction techniques. For this reason, railroad and road construction has been kept to a minimum. The railroad reached Surgut, for instance, only in 1975, 10 years after the start of oil production there. Hard surfaced roads are largely confined to the area around Surgut and Nizhnevartovsk. It has been estimated that 1 mile of surfaced road in this region costs between 500,000 and 1 million rubles compared to 100,000 to 150,000 rubles in the European part of the U.S.S.R.

The Soviets employ the "work-shift" method in West Siberia; crews are shuttled by helicopter from base cities like Surgut or Nizhnevartovsk to isolated drilling sites where they live in dormitories for the period of their shift.[5] This is not very different from industry practice in the West in difficult areas such as the North Slope, but the obvious disadvantages of this life have required substantial bonuses and incentive schemes to attract workers. Nevertheless, there are still labor shortages and very high rates of labor turnover. As the deposits being worked move farther east, new base cities, or at least permanent settlements, will be required.

Gas

The gasfields of West Siberia extend for over 1,000 miles from the Yamal Peninsula in the north deep into the Tyumen oblast. Production in the area did not begin in any substantial amount until after 1970, by which time pipelines had been constructed to transport the gas. The location of the Tyumen fields is shown in figure 2 while table 4 summarizes production from deposits that are already online. The Tyumen fields are immensely important to the Soviet gas industry. The increase in production of natural gas at Tyumen between 1975 and 1980 (about 120 billion cubic meters (bcm)) amounted to more than 82 percent of the increase for the entire country (146 bcm), and

Table 4.—Production of Gas in Tyumen Oblast (billion cubic meters)

	1975	1979	1980	1981 (plan)	1985 (plan)
Medvezhe	29.9	71	70	70	NA
Vyngapur	NA	13	15	15	NA
Urengoy	NA	26	53	88	250
Others.	3.6	2	2	NA	NA
Casinghead gas.	2.2	11	14	17	NA
Total gas production. . .	35.7	123	156	190	330-370

NA = not available
NOTE Totals may not add due to rounding
SOURCE Soviet Geography April 1981, p 276

1985 plans call for production here to nearly *double.*

Gas extraction in West Siberia began in 1963 with a group of small gas deposits on the left bank of the lower reaches of small gas deposits on the left bank of the lower reaches of the Ob River. Three years later, the world's largest gasfield was discovered at Urengoy. Urengoy is one of several supergiant fields (i.e., fields containing reserves larger than 1 trillion cubic meters) in this region, and it is the focus of development for the present FYP. Other large fields include Medvezhye, which began producing in 1972, and Yamburg, for which the controversial planned pipeline to Western Europe was originally named. The gas for this pipeline, at least initially, will now come from Urengov.

The West Siberian gas industry has been beset with problems that have caused Urengoy to underfill its plan targets. These have nothing to do with the reserves, which make the field the largest single concentration of gas in the world, but rather are the result of inadequate infrastructure. This rests in part on the difficult conditions described in the previous section, exacerbated by the northern location of most of the gasfields, and also in part on the fact that the development of gas has generally lagged behind that of West Siberian oil because alternative sources of supply were already available from Central Asia.[6] But there is also evidence of planning failures in the gas industry.[7]

[5] Ibid , pp. 59-60.

[6] See Jonathan P. Stern, *Soviet Natural Gas Development to 1990* (Lexington, Mass.: Lexington Books, 1980), pp 35-6.

[7] Ibid., pp. 13-14.

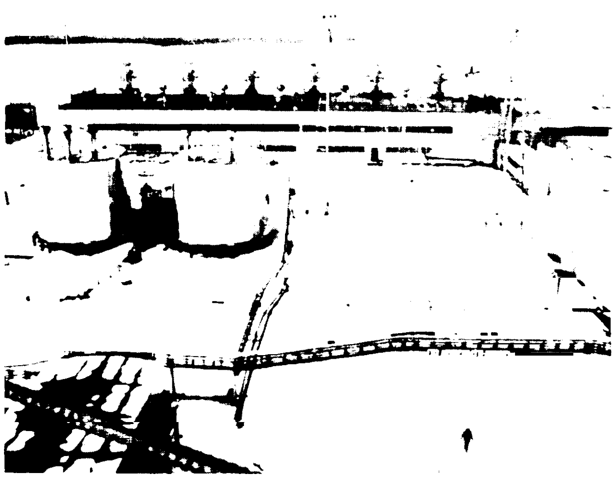


Photo credit *Oil and Gas Journal*

Gas **treatment facility in the Medvezhye field**

One large problem, for instance, has been delays in construction of gas-processing plants. These are necessary to treat the gas before it can be transported, Transportation itself can only be accomplished after the installation of pipelines and the compressor stations that move the gas through the pipe. This sequence has not always been well-planned. Even with the entire infrastructure in place, there are reports of compressor stations remaining idle because gas is being sent in quantities insufficient to justify their operation. In addition, there are large shortfalls in the construction of housing, medical facilities, places of entertainment, etc., for gasfield workers; and poor organization at drilling sites that has led to difficulties in moving rigs from one location to another and to accidents and blowouts. These problems will have to be solved before West Siberia tremendous gas potential is fully realized.

VOLGA-URALS

The Volga-Urals region lies in the far more accessible and temperate European portion of the U. S. S. R., between the Volga River and the western edge of the Ural mountains. Its major petroleum producing areas are found in the Tatar and Bashkir Republics, and Kuybyshev, Perm, and Orenburg oblasts. These provinces together formed the U.S.S.R.'s most important oil-producing region until the late 1970's. Volga-Urals production peaked in 1975 and was exceeded by West Siberia in 1977. It is now in decline (see table 5). But even today, the Volga-Urals accounts for about one-third of Soviet oil production and is the third largest oil-producing province of the world.

The climate of the Volga-Urals is similar to that of the Canadian plains, and the extreme conditions that hamper the extraction and transportation of petroleum in West Siberia do not pertain there. In fact, except for some areas of the Perm oblast, the Volga-Urals deposits are readily accessible by road, rail, the Volga and Kama rivers, and close to major petroleum-using industrial centers. In addition, a large part of the Soviet refining industry is located in the region, although since the decline of the Volga-Urals fields these refineries use oil brought in by pipeline from West Siberia.

Oil

As was noted above, concentration on Volga-Urals oil did not begin until after World War II when development was fostered by the movement of heavy industry into the region. The giant Romashkino field in the Tatar Republic was discovered in 1948. Other large fields were found in Bashkir Republic and in Kuybyshev oblast. Between 1956 and 1958, these three prov-

Table 5.—Oil Production in the Volga-Urals Region
(million tons)

	1975	1976	1977	1978	1979	1980 annual plan
Tatar Republic . .	.103.7	1000	97.8	97.2	85.8	83
Bashkir Republic .	40.3	40.2	40.1	39.6	39.7	38
Kuybyshev . .	34.8	33	31	27	25	25
Perm	22.3	23.5	24	24	24	22
Orenburg . . .	13.9	12.6	12.8	12	12	10
Udmurt Republic .	3.7	4.4	5.5	6.5	7,4	8
Volgograd . . .	NA	NA	NA	NA	NA	NA
Saratov . .	8	8	8	7	7	7
Total	2267	221.7	219.2	213.0	201.0	193

NA = not available

SOURCE Wilson op. cit. p. 15.

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inces became the first, second, and third largest producers in the Soviet Union, a situation that persisted into the late 1970's. Even now, the Volga-Urals is important to Soviet oil industry planners, who hope to slow the region's decline by allocating resources to open new smaller and deeper deposits and by applying tertiary recovery methods in existing deposits.

Gas

Gas production in the Volga-Urals is centered at Orenburg in the Orenburg oblast.[8] Discovered in 1966, Orenburg is of special importance to the Soviet gas industry, for it is the latest supergiant deposit to be located in the more temperate European part of the country. Its gas is therefore more easily accessible to industrial users. But only part of Orenburg's gas goes to domestic consumers. The rest is now being transported to Eastern Europe through the 1,700 mile (2,750 km) Orenburg or "Soyuz" pipeline. This pipeline stretches from Orenburg to the Czechoslovakian border at Uzhgorod where it connects with the existing Brotherhood or "Bratstvo" pipeline system. Orenburg was built as a joint Council for Mutual Economic Assistance (CMEA) project, with East European countries supplying labor and materials in return for eventual repayment in gas deliveries. When it reaches full capacity, the Orenurg-Uzhgorod line is scheduled to carry 28 bcm/yr of gas, nearly all of it to be exported; 15.5 bcm of this will be divided between Czechoslovakia, East Germany, Hungary, and Poland, and the rest sold in Western Europe.[9] Bulgaria and Romania shares are being delivered in another pipeline from the Ukraine.

The advantages of Orenburg's favorable location have to some extent been offset by the technical obstacles posed by the fact that its gas contains both condensate and corrosive sulfur. These must be removed in gas-processing plants before the gas can be transported. There are three processing complexes at Orenburg, two for treatment of gas used domestically and one that processes gas for the pipeline. Production is obviously linked to the capacity of these plants, as well as to the capacities of the pipelines that carry the gas to both domestic and foreign consumers. Construction delays occurred in both of these areas. In addition, housing, transport, and equipment shortages hampered exploration and drilling activities. Meanwhile, Orenburg is providing valuable experience in dealing with sulfurous gas, and reserves explored to date are sufficient to maintain 1979 production rates (48 bcm/yr) until the year 2000.

An additional major source of gas, also sulfurous, has now been discovered southwest of Orenburg at Karachaganak. This field is expected to be developed to replace any decline in Orenburg production.

THE CASPIAN BASIN AND NORTH CAUCASUS

As noted above, the first Russian oil was produced in the Baku district near the Caspian Sea. These sites are now part of an oil-producing region that spans the North Caucasus, Georgia, Azerbaidzhan Republic, Kazakhstan, and part of Turkmen Republic. At Baku, oil is being produced offshore in the Caspian Sea. Together these areas form an oil province of over 1 million km^3, containing hundreds of oilfields.

Oil

The importance of the Caspian basin oilfields has been steadily diminishing. Indeed, many of the older fields, producing since the turn of the century, are now virtually depleted. The Soviets have attempted to stem the decline through offshore development, deeper drilling, and use of water injection and enhanced recovery techniques, but nevertheless, production has continued to fall.[10] Table 6 chronicles this decline during

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[8] See Wilson, op. cit., pp. 21-22; Stern, op cit., p, 31; and Dienes and Shabad, op. cit., pp. 77-79.

[9] Each East European country will receive 2.8 bcm, except Romania which will receive 1.5 bcm.

[10] Wilson, Op. cit., p. 17.

Table 6.—Oil Production in the Caspian Region
(million tons)

	1975	1979	1980a (annual plan)	1980	1985 (plan)
Azerbaidzhan	17.2	14	19.7	14	NA
Kazakhstan	23.9	18	26.9	18.4	23
Turkmen Republic.	156	95	18.6	8	6
Total	56.7	41.5	65.2	40.4	NA

[a]Estimate from Wilson, op. cit., p. 17
NA = not available
SOURCE Soviet *Geography* April 1981 p 273

the last FYP period. The shortfall of 25 mmt (500,000 bd) between the 1980 plan and actual production figures is a significant portion of the shortfall of 37 mmt (743,000 bd) from the original national 1980 plan (640 mmt or 12.8 mbd planned; 603 mmt or 12.1 mbd actual production.) The entire Caspian region produced less than 7 percent of the country's oil in 1980; it is not expected to resume a major producing role.

Gas

The gasfields of the North Caucasus have declined in much the same fashion as the area's oilfields. Two important groups of deposits at Stavropol and Krasnodar began producing in the late 1950's. These fields peaked in 1968, and the rate of depletion since then has been very high. Between 1970 and 1975, output fell by 5 bcm/yr at Stavropol and 16 bcm/yr at Krasnodar. The two deposits combined now produce less than 20 bcm of gas and appear to be declining at an ever-increasing rate. [11]

UKRAINE

Oil

Ukrainian crude oil is of high quality (i.e., it is low in tar, paraffin, and other pollutants and has a high yield of light distillates) and is located close to consumers in the European U.S.S.R. But the Ukraine's oil industry is beset with depleting reserves, new oil being found primarily at great depths and under difficult geologic conditions, " Ukrainian oil production peaked in 1972 at 14.5 mmt (0.291 mbd), and while the Tenth FYP called for a decline to 8.6 mmt (0.173 mbd) by 1980, production was 8.3 mmt (0.167 mbd) in 1979 and 7.7 mmt (0.154 mbd) in 1980, The Ukraine has never contributed more than 4 percent of Soviet oil production, and its importance is not expected to increase.

Gas

In contrast, between 1960 and 1975, the Ukraine was the major Soviet gas-producing region, its output largely sustained by the giant Shebelinka field, which came onstream in 1956 and was supplying 68 percent of Ukrainian gas by 1965. The Ukraine also has a number of smaller deposits. However, these were not able to stave off decline once Shebelinka peaked in 1972. Now, like the North Caucasus, the Ukraine's gas production is in absolute decline, and output declined from 68.7 bcm in 1975 to 51 bcm in 1980, There are indications that the Soviets will continue to invest in the Ukrainian fields in order to maintain production in the accessible west of the country for as long as possible, Western analysts disagree, however, over the potential of the area. On one hand, new deposits have been announced at Shebelinka, in the Black Sea, and in the Dnepropetrovsk oblast.[13] On the other hand, a downturn in economic indicators over the last plan period–e.g., production costs doubled and labor productivity fell–together with the continued declines in production, have led others to conclude that the region will become increasingly less important in the future as rapid declines persist. Indeed, the 1981 annual plan foresees a production decline to 47 bcm.[14]

CENTRAL ASIA

Gas

The Central Asian desert is a gas-, rather than oil-, producing region, with vast fields

[11]Stern, op cit., pp 30-31
Wilson, op cit , p. 23; Dienes and Shabad, op cit , p 53.

[13]Wilson, op. cit., p. 23.
[14]Stern, op. cit., p. 30; *Soviet Geography* (April 1981), p. 276.

lying near the Iran and Afghanistan borders in the Uzbek and Turkmen Republics. Central Asian gas has been important in the U.S.S.R. since the mid-1960's when the giant Gazli deposit in Uzbekistan was brought online. In 1965, Gazli alone produced 12 percent of Soviet gas. Since Gazli peaked in 1971, the region has declined in relative importance, but as table 7 demonstrates, production there has remained stable, largely through the development of sulfurous gas reserves. The sulfur is being recovered at the Mubarek gas-processing complex and the gas then transmitted into a pipeline system that extends from Central Asia to Central Russia. Before the beginning of development of these sulfurous reserves, it was thought that the level of output might not be maintained much longer. '5

Gas production in Turkmenistan rose very rapidly in the early 1970's, but the rate of increase now appears to have leveled off. This republic includes the giant Shatlyk deposit, one of the 10 largest in the world, which alone accounts for nearly one-half of the area's production. Shatlyk is now producing at full capacity, and as table 7 indicates, output for the republic as a whole is increasing slowly. It is expected to rise to over 80 bcm as a result of the development of the newly discovered Dauletabad (Sovetabad) field. " Thus, Central Asian gas may continue to replenish the southern supplies depleted by the exhaustion of the North Caucasus fields. [17]

[15]Stern, op. cit., p. 34; *Soviet Geography* (April 1981), p. 276.

[16]Stern, op. cit., p. 35; *Soviet Geography* (April 1981), p. 279.

[17]Dienes and Shabad, op. cit., p. 84.

Table 7.—Gas Production in Central Asia
(billion cubic meters)

	1975	1979	1980	1981 (annual plan)	1985 (plan)
Uzbek Republic	37.2	37	39	37	—
Turkmen Republic	51.8	70	70.5	69	81-83
Total Central Asia	89.0	107	109.5	106	—

SOURCE: *Soviet Geography*, April 1981, p. 276

KOMI

The Komi Republic lies in the Timan-Pechora region, north of the Volga-Urals, on the edge of the Barents Sea. It is an area of taiga forest and tundra, technically part of the European U. S. S. R., but having a climate similar to that of West Siberia. Nevertheless, this area of 250,000 km^2 lies 1,000 km west of Tyumen and is thus significantly closer than Siberia to centers of energy consumption. Komi is one of the Soviet Union's older oil and gas regions; its first commercial oil was produced in 1930. It is also virtually the only such older region that is not now in decline.

Oil

Komi's first commercial oil was produced near Ukhta in the southwest part of the region, although yields were negligible until the development of three large fields (West Tebuk, Dzhyer, and Pashnya) between 1962 and 1970. This development caused Komi oil production to rise sevenfold between 1960 and 1970, from 0.806 to 5.6 mmt (from 0.016 to 0.113 mbd).

Exploration efforts then shifted northward. There development of two large fields, Usinsk and Vozey, began in 1973, and production continued to rise. Table 8, which shows Komi oil production over the Tenth FYP period, reflects this growth in output. However, Komi failed to meet its 1980 FYP target. The shortfall appears to have been due to such difficulties as early loss of reservoir pressure and infrastructure problems. The latter included construction of a railway branch line, for as in West Siberia, the development of the region is hampered by lack of roads.

While output is continuing to increase in Komi, the long-term prospects for the region seem to rest on exploration activities currently centered further north at the mouth

[18]Komi liquid hydrocarbons include a substantial amount of gas condensate. Oil output data for the region therefore often include condensate. The 1970 figure for oil plus condensate is 7,6 million tons. Ibid,, p.55.

[19]Ibid., pp. 55-6; Wilson, op. cit., p. 22.

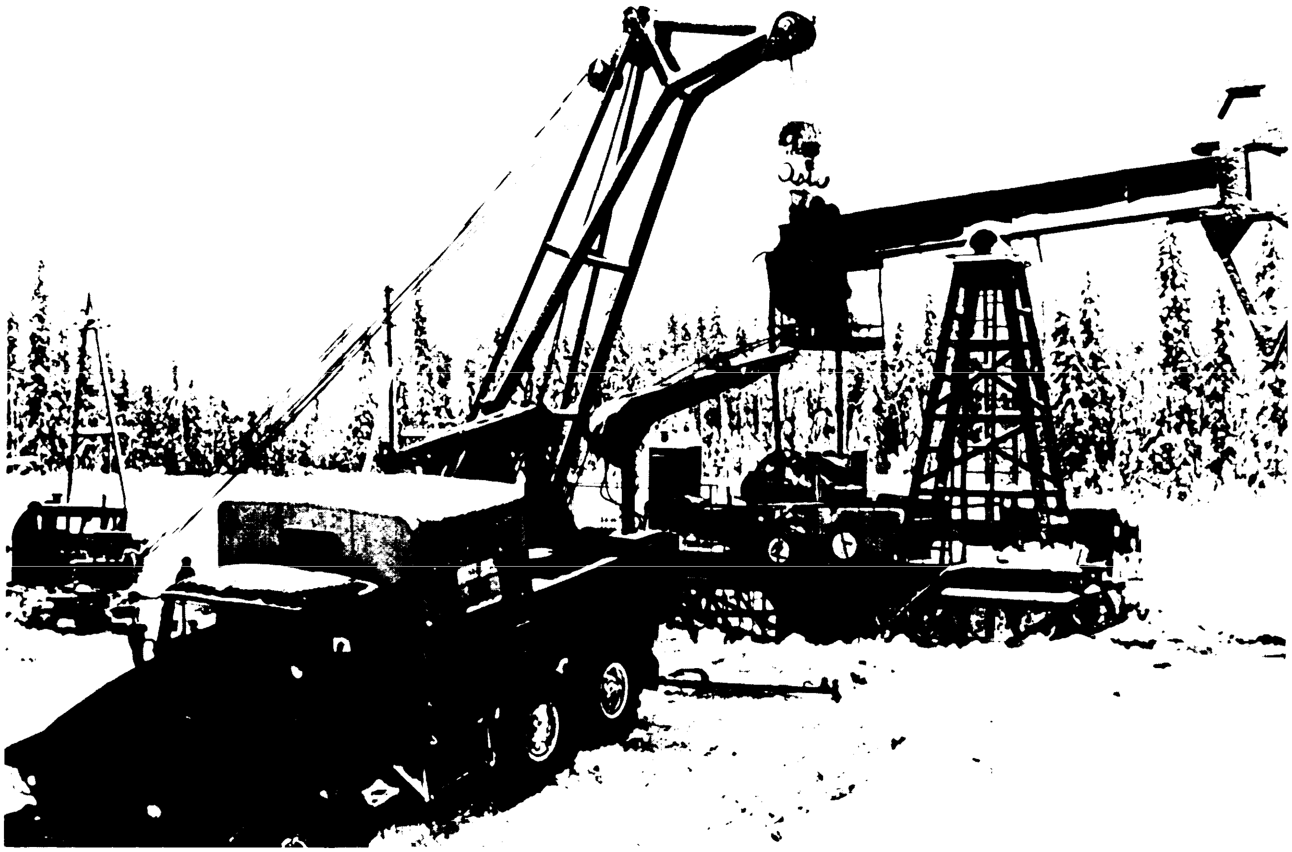

Photo credit: TASS from SOVFOTO

Oilfield equipment installation in the Komitaiga

Table 8.—Oil Production in Komi
(million tons, oil and gas condensate)

1975	11
1979	19
1980	21
1985(plan)	26a

aEstimate

SOURCE Soviet Geography April 1981 p 273

of the Pechora river, and offshore in the Barents Sea. This activity is currently being supported by a settlement of some 20,000 people, but the high expectations of the Soviets may perhaps be evidenced by reported plans for building a new town for 60,000 people in an area presently occupied mainly by tundra-dwelling reindeer herders.[20]

[20] Dienes and Shabad, op. cit., p. 56.

Gas

Komi became an important producer of gas after the giant Vuktyl gas and gas condensate deposit came online in 1968. Vuktyl, which lies 120 miles east of Ukhta on the right bank of the Pechora River, accounts for most of the region's natural gas production. As table 9 shows, this was scheduled to amount to some 22 bcm in 1980, but actual

Table 9.— Natural Gas Production in Komi
(billion cubic meters)

1975	18.5
1976	18.9
1977	18.9
1978	19
1979 (plan)	19
1980 (plan)	22

SOURCE Wilson op cit p 22

output reached only 18 bcm. The outlook is for a gradual decline in the 1980's.

The development of Vuktyl led to the construction of another major gas pipeline, the Northern Lights, which ultimately became a system of pipelines carrying vast flows of gas from West Siberia. The Northern Lights system was carrying 70 bcm in 1981 and is being expanded to a capacity of 90 bcm. It stretches westward across the European U. S. S. R., intersecting with the Moscow-Leningrad line at Torzhok and going on through Minsk to the Czechoslovakian border at Uzhgorod. The 1980 Northern Lights traffic included 18 bcm/yr of gas from Komi (most of it from Vuktyl) and over 50 bcm from West Siberia.[21]

The Komi region is rich in other gas deposits, but aside from the further development of Vuktyl, its future is uncertain. This is due both to the fact that much of Komi's gas lies in very deep reserves, and to the lack of infrastructure in this harsh, hitherto untouched, territory. Soviet long-term plans called for production to rise to 40 bcm by 1990. This suggests that newly discovered fields are expected to be brought onstream, but also that Komi will be depended on for only a fraction of the amount of gas that is slated to come from West Siberia. 22

SAKHALIN

Sakhalin is a Far Eastern island situated between the Sea of Okhotsk and the Sea of Japan. It lies close both to the Pacific coast of Siberia and to the Japanese northern island of Hokkaido. Commercial oil production in Sakhalin began in 1921 when the island was under Japanese military occupation. Onshore production amounted to only about 3 mmt (0.06 mbd) in 1978, and offshore exploration has yet to be completed. The major importance of Sakhalin lies in its potential. Through Soviet-Japanese cooperation, it is hoped that Sakhalin may produce enough oil both to export to Japan and to supply some of the needs of the Soviet Far East, presently calculated at about 15 mmt/yr (0.301 mbd).[23] The Sakhalin project is discussed in detail in chapter 11.

SUMMARY

The center of Soviet oil production has moved progressively eastward over the last century. Once in the European portion of the U.S.S.R.–Baku on the Caspian Sea, and then the Volga-Urals region—the focus of this production now lies in West Siberia. This shift has meant that, increasingly, oil must be extracted far from major population and industrial centers and transported long distances to consumers. Moreover, conditions in West Siberia are harsh, the costs of extracting the oil higher, and erecting the infrastructure necessary to find, produce, and transport it concomitantly more difficult and expensive than in older producing regions. These factors affect the rapidity with which Siberian oil can be exploited. For these reasons, the Soviets continue to devote significant resources to slowing the decline and prolonging the productive life of the more westerly fields, particularly in the Volga-Urals region. A small contribution to this effort to maximize the production of relatively more accessible oil is made by Komi, which is the only producing area in the European part of the U.S.S.R. not yet in decline.

Similarly, the future of Soviet gas production lies in the less hospitable eastern regions. In the case of gas, however, significant contributions to production increases may be expected from the Volga-Urals, i.e., from Orenburg. Some production can still be maintained in older deposits in the Ukraine and North Caucasus, although this is becoming increasingly expensive, and there is disagreement over how long it can continue. In addition, Central Asian gasfields can contribute substantially to the gas available in the southern part of the country.

[21] I bid., p. 86.
"I bid., p. 87.

"Wilson, op. cit., p. 24.

EXPLORATION

Having briefly surveyed the major oil- and gas-producing areas of the U. S. S. R., this chapter now examines the manner in which oil and gas are discovered, produced, and transported in the Soviet Union. For the purposes of this analysis, the oil and gas industry has been divided into six segments or phases—exploration, drilling, production and enhanced recovery, transportation of oil and gas, refining, and offshore activities. Each of these segments will be discussed in terms of current Soviet practice, technological requirements, and the degree to which the U.S.S.R. has in the past or could beneficially in the future utilize Western technology.

INTRODUCTION

In order for oil and gas production to be sustained over the long term, additions must be made to reserves that compensate for the petroleum taken out of the ground. To replace the reserves produced during the Tenth FYP period (1976-80) the U.S.S.R. would have had to add to reserves, both from new finds and additions to existing fields, an additional 2.9 billion tons of oil (21.1 billion bbl). This estimate exceeds estimated gross discoveries during 1971-75 by about 50 percent. ” Yet official emphasis in the U.S.S.R. in the last 15 years appears to have been largely on production from known deposits, rather than on exploration for and preparation of new areas. It has, therefore, been common in the Western literature to find the U.S.S.R. criticized for neglect of exploration efforts.[25] It could be argued that, until relatively recently, any lag in Soviet exploration activities was caused by the fact that discoveries such as Samotlor made extensive exploration efforts unnecessary, at least from a short-term perspective. For the past decade, however, it is more likely that the progress of Soviet oil and gas exploration has been impeded by a general lack of availability y of appropriate equipment.

Exploration for oil and gas in the Soviet Union seems to be handicapped by a lag, not in knowledge, but in its application. The U.S.S.R. has relatively few personnel skilled in advanced exploration techniques, and inadequate stocks of technologically advanced equipment. Some of these problems could certainly be remedied in the short run through purchases of foreign equipment and technology. However, given the leadtimes necessary to develop new fields, it may be too late for such purchases—which might enable the U.S.S.R. to explore at greater depths and in more difficult terrain—to much affect production prospects for the 1980's.

This section describes the methods by which exploration takes place; evaluates, to the degree that this is possible, the Soviet state of the art in these methods; and discusses the past and potential contribution of Western technology in this area. More attention is paid here to exploration for oil than for gas. This is a reflection of the fact that gas reserves in the U.S.S.R. are commonly acknowledged to be more than sufficient to sustain planned increases in production. This is not the case with oil reserves, the present extent and future prospects of which are matters of some controversy.

THE EXPLORATION PROCESS

Exploration for both oil and gas generally takes place in three phases: regional surveys that identify promising geological conditions for the presence of hydrocarbons; detailed geophysical surveys that evaluate specific areas in the regions identified in phase one; and exploratory drilling to test the findings of the first two phases.

Regional Surveys

Regional surveys are conducted in an effort to outline areas that might contain thick

[24]C 1A, "Prospects for Soviet oil [production: A Supplemental Analysis," July 1977, p. 23.

[25](;oldman, op. cit., p. 121 ; Robert W. Campbell, *Trends in the Soviet Oil and Gas Industry* (Baltimore: Johns Hopkins University Press, 19'76), pp. 9-10; CIA, op. cit., pp. 1, 5.

sediments of hydrocarbons in structural traps. This is done with instruments or sensors, usually mounted in aircraft, which measure from the air changes in the magnetic fields and variations in the Earth's gravity. Sometimes, overflights of prospective areas are supplemented by ground-level measurements. Recently, both the United States and the U.S.S.R. have experimented with satellite surveys.

Detailed Surveys

The principle method of conducting a detailed analysis of an area is by seismic survey. Either an explosive or a device that vibrates the Earth is used to generate sound waves, which are reflected and refracted by the underground geological formations. The echoes are detected by seismographs or geophones, and recorded on magnetic tape. The result is a two-dimensional view of the subsurface structures. Seismic surveys produce large quantities of information that must be processed on large computers in order to generate these maps of underground geology, but minicomputers are now used to preprocess the data before it is passed on to a data processing center.

Drilling

Once a promising prospective area is located, the next step is exploratory drilling. Indeed, despite the sophistication of much geophysical seismic work, drilling remains the only means of positively verifying the presence or absence of hydrocarbons in structures. Exploratory drilling utilizes the same technology and equipment as does production drilling, although decisions as to the number, location, and depth of the wells will naturally differ depending on whether or not they are being drilled for exploratory purposes. Drilling technology itself is discussed in a later section of this chapter.

EVALUATION OF EXPLORATION EFFORTS

The success of exploratory activities is determined by additions to reserves–the amount of oil and gas found. In the case of the U. S. S. R., where oil reserves are a state secret, it is obviously difficult to evaluate the adequacy of exploration technology and equipment. The best that can be presented here are some qualitative impressions.

Exploration Technology

The U.S.S.R. is believed to possess adequate domestic capabilities for regional surveys, but its detailed seismic work may be inhibited by equipment that Western observers describe as bulky, difficult to transport, and of comparatively low quality. In general, the U.S.S.R. produces detailed survey equipment inferior in accuracy and capability to Western models. (For example, American experts who have examined Soviet geophone cables have found that they introduce extraneous "noise" into the data, a problem that makes results more difficult to interpret.[26]) These models appear to have been adequate in the past, but as the U.S.S.R. is driven to explore for oil at increasing depths, the need for greater quantities of higher quality seismic equipment will grow. The capabilities of the Soviet seismic equipment manufacturers to meet such a need is uncertain.

In the United States, a shift to the collection of seismic information by digital means began in 1962 and was essentially complete 10 years later (half of the crews had switched by 1968; 80 percent by 1972). In the U. S. S. R., roughly 40 percent of collection work is still done by traditional analog methods. Analog methods provide high-quality results, but these cannot easily be subjected to further processing, and they are far less efficient than digital methods. Consequently, the amount of work that can be done is smaller and the results are much less sophisticated.

As important to the success of detailed survey efforts is the quality and availability of computer facilities. Geophysical exploration is extremely computer intensive, and Soviet planners seem to be aware of the im-

[26] Private communication to OTA.

portance of making available both minicomputers to produce a rough picture of the geology of the area and large computers to further refine it. In each of these areas, the U.S.S.R. remains at least several years behind the West. However, it must be noted that most of the large oil discoveries in the world were made with seismic technology available by 1960. There is, therefore, no necessary correlation between state-of-the-art equipment and the size of potential finds.

Two philosophies for the processing of seismic information have emerged in the United States. In the first, a substantial amount of processing is done in the field at locally based minicomputer-equipped computer centers. The second uses centralized computer centers with large "number-crunching' high-speed (and often state-of-the-art) computers. The former philosophy has been mostly pursued by the independent geophysical contractors in the United States, while a combination of both has been employed by the major or oil companies.

The Soviets have followed both paths. Thus, a small number of field systems utilizing minicomputers began to be introduced in the 1970's. By 1978, the Minister of Oil noted that second- and third-generation processing systems were being introduced, " and 22 systems were to be added by 1980. Some of these systems must be operated by highly skilled crews, which are in short supply. In addition, problems have arisen in coordinating the production and supply of spare parts and services for the minicomputers.

The Soviets clearly wish to increase minicomputer use. A program has been initiated to this end by encouraging the Ministries of Oil and Geology, Minpribor (Ministry of Instrument Making, Automation Equipment, and Control Systems), and the U.S.S.R. Academy of Sciences to work together on minicomputer standardization and production.[28]

The Soviet capability to process digital seismic information using "number-crunchers also lags considerably behind that of the United States. Until the mid-1970's the development of advanced geophysical techniques in the U.S.S.R. was made more difficult by an undeveloped computer base in general: only one high-speed computer model was known to be serially produced.

Although this machine was almost the equivalent of Western computers in speed when it first appeared in 1964, limited peripherals, small core size, and very limited software degraded its performance significantly.[29] The other machines that were available were not well-suited for geophysical processing. For example, programs that take 45 minutes to run on a second-generation Soviet computer would take less than 2 minutes on a 'modestly high-speed U.S. model.") Furthermore, hundreds of the Soviet machines are needed just to process the data from one oilfield.[31] There is evidence that a special processor for geophysical data has been developed, but it is doubtful that it has appeared in any quantities.[32]

Although third-generation Soviet computers started appearing in 1972, the fastest, most powerful models were delayed until the late 1970's. In 1977, there were 18 processing centers for geophysical data in the Ministry of Oil.[33] Financing for computer-

"N. A. Maltsev, "From Well-site to Ministry, " *Ekonomicheskaya gazeta, No. 32,* 1978, p. 15; V. Knayzev, "Gas Under Barkhany, " *Trud,* June 3, 1980, p. 1.

[28] *Pribory i sistemy upravleniya,* No. 3, 1979, pp. 44-45; O. A. Potapov, "The Problem of Processing Large Masses of Geological and Geophysical Data and Ways to Solve It, in S. B. Gurevich, ed., *Holography and Optimal Processing of Information in Geology and Geophysics,* Order of Lenin Physical-Technical Institute imeni A. F. Joffee, Moscow, 1979.

[29] George Rudins, "Soliet Computers: A Historical Survey, " *Soviet Cybernetics Review,* January 1970. pp. 6-44.

[30] *Sotsialisticheskaya industriya,* Mar. 7, 1978, p. 2.

[31] Potapov, op cit.

[32] *Razvedochnaya geofyzyka,* No. 77, 1977, pp. 27-33.

[33] O. M. Rynskiy, "Automation of Economic Planning Calculations—The Most Important Directions in the ASU — Neft !' *Ekonomika neftyanoi promyshlennosty,* 1977.

related expenditures in the Ministry of Geology was substantially increased for 1975-80, but by the late 1970's, work was just beginning on using large computers for geophysical processing.[34] Thus, it is possible that between the two Ministries, the Soviets really only began to do a sizable amount of digital processing using large computers in the past few years.

Activity Levels

Soviet economic planning places heavy emphasis on attaining output targets. The practical consequence of this for oil and gas exploration efforts has been that those ministries charged with exploration—the Ministry of Geology and the Ministries of Oil and Gas–tend to focus on fulfilling their FYP targets, even when such relatively short-term considerations may be at odds with the maximization of oil production over the longest period of time. Those drilling teams and equipment devoted to exploration are unavailable for the drilling of producing wells—wells that yield petroleum that counts toward the fulfillment of output targets. Therefore, it may be more attractive to drill appraisal wells close to already producing regions than exploratory wells in remote areas. Moreover, the fact that drilling targets are expressed in terms of meters drilled, rather than oil or gas found, creates disincentives for deep drilling that is slower and more difficult than drilling a greater number of shallower wells.

At least partly as a consequence of systemic factors such as these, the number of meters drilled in exploratory wells actually declined between 1967 and 1975,[35] from 5.8 million to 5.4 million meters. Whereas in 1964 and 1965 Soviet oil output increased by 13.6 mmt for every million meters drilled, in 1976 this figure fell to 5.6 mmt.[36] This is a reflection of the fact that no giant oil discoveries in the U.S.S.R. have been reported since the early 1970's.

Moreover, drilling targets have been consistently underfulfilled. In West Siberia, for instance, only about 80 percent of the planned volume of exploratory drilling was carried out in 1974, and drillers failed to fulfill their plans in each of the 5 years from 1971 to 1975.[37] During these years, large finds compensated for the level of exploratory effort and further encouraged the devotion of larger shares of drilling efforts to development rather than exploration. Rigs engaged in development drilling are about four times more productive than those used for exploration. This is because depths are shallower; the infrastructure is better; and less time is needed to move between locations.[38]

The Tenth FYP (1976-80) obviously recognized the need to step up exploratory activities. It called for efforts to find additional reserves in Siberia, Central Asia, and Kazakhstan, as well as offshore and in traditional producing areas. Total drilling targets were also raised significantly. In West Siberia alone a more than threefold increase was called for.[39] Given past performance, the likelihood of meeting such a target is at least questionable, but even a 10 percent increase in exploratory drilling would represent a significant investment in exploration activities that have hitherto been stagnant.[40] Moreover, there is evidence that exploration teams have been moving further and further away from the established centers of the industry into more remote areas of Siberia and the Arctic Circle.[41]

[34] Potapol, op. cit.
[35] Campbell, *Trends* ..., op. cit., pp. 10-1 1; see also Goldman, op. cit., p. 122.
[36] Goldman, op. cit., 122.
[37] Wilson, op. cit., p. 45.
[38] CI.4, op. cit., p. 23.
[39] Ibid.
[40] Robert W. Campell, "Implications for the Soviet Economy of Soviet Energy Prospects, *ACES Bulletin*, 20(1), spring, 1978, p. 40.
[41] See Wilson, op. cit., pp. 44-50.

THE CONTRIBUTION OF WESTERN EQUIPMENT AND TECHNOLOGY TO EXPLORATION

The U.S.S.R. has been virtually self-sufficient in regional survey equipment. In the area of detailed survey work, it has purchased geophones from the West, but not in very large numbers. Nor has it ordered the replacement parts for these geophones that U.S. industry experts assert must certainly be required. This leads to the inference that at least this Western equipment may now be inoperable or unreliable.

By far the largest contribution of the West to Soviet exploration activities, however, has been in the area of computers and related software and equipment. In general, the indirect reliance of the Soviets on U.S. computer developments has been large.[42] Oil and gas exploration has benefited both directly and indirectly from this dependence.

The advantage of Western computing equipment is that it can be purchased in complete ready-to-use sets. The Soviets have made major purchases of collection- and processing-related geophysical equipment, from firms, mostly in the United States. The American firm Geosource has completed a $5 million to $6 million deal that included outfitting three complete digital crews with 24 off-the-road exploration vehicles, a portable field recording unit, eight remote processing minicomputer centers, and processors used in conjunction with the minicomputer system.[43] An option for six more crews, including 49 additional vehicles, was exercised by the Soviets as part of a $13 million sale for 1978 delivery.[44] The post-Afghanistan technology embargo has now put further such sales in limbo, and automated display equipment and geophysical equipment, including five more minicomputer systems, sold in 1979 for $9 million[45] have not yet been delivered. Even without this sale, a significant number of the estimated 300 digital collection crews in the U.S.S.R. have been outfitted with equipment supplied, not only by the United States but also by West Germany and France. However, the latter are almost all based on American equipment; Hungarian and East German systems are also available to the U. S. S. R., but these tend to be inferior to, and more costly than, those produced in the West. In addition, the U.S.S.R. has purchased a fully equipped French exploration ship, and has had other ships outfitted in the West.

Through these purchases, the Soviets have acquired advanced Western techniques. According to industry sources, there are as many as 30 to 35 U.S. minicomputer systems in the U.S.S.R. that have been specially designed for geophysical work. These include simple 16-bit dedicated array processors.[46] At least some of the U.S. minicomputer systems were shipped with software packages and Geosource trained 80 Soviet operators in the United States. This firm also installed the systems in the U.S.S.R. and gave extensive field training there.

As a result of these sales the Soviets are in some places using seismic techniques that were current in the United States about 1975. Present practice in the United States has moved far ahead of this level. In the United States array processors are now outfitted with programmable microprocessors that increase throughput by a factor of five. Main and secondary storage sizes have been increased substantially. The Soviets had not as of 1980 mastered multichannel techniques, which enhance the exploration of those deep structures that lack shallower ex-

[42] See Seymour E. Goodman, "Soviet Computing and Technology Transfer: An Overview," *World Politics*, vol. XXXI, No. 4, July, 1979, pp. 539-570; and N. C. Davis and S. E. Goodman, "The Soviet Bloc's Unified System of Computers," *Computing Surveys*, vol. 10, No. 2, June 1978, pp. 93-122.

[43] *Soviet Business and Trade*, May 25, 1977, pp. 1, 3, and Mar. 2, 1977, p. 10.

[44] Ibid., Aug. 3, 1977, p. 1.

[45] Geosource Inc., 1979 Annual Report, p. 5.

[46] An array processor is a computer designed to handle very computer-intensive calculations by simultaneously manipulating large matrices of numbers, and is very useful for seismic applications.

pressions.[47] They only began serial production of their own array processors in 1980.[48] Although geophysical array processor designs may have been available, it is unlikely that a nonmilitary sector could have acquired them.

Again, however, any correlation between state-of-the-art seismic equipment and significant oil production increases has yet to be demonstrated. Thus, although the Western minicomputer systems that have been sold do not represent the state-of-the-art, it is not clear that the latest equipment is vital to the U.S.S.R. On the other hand, the magnitude of these sales implies that U.S. computer technology has played a significant role in aiding the Soviets to collect and process digital seismic data efficiently. This has proven true in the area of large "number-crunchers" as well.

An indirect dependence on U.S. large computer technology is evident in the third-generation Soviet- and East European-made Ryad computers that gradually became available in the 1970's. These are essentially functional duplicates of IBM models. The Soviets pursued this course in order to minimize risk and design decisions, to acquire the ability to tap the great body of software available in the West, and to use Western secondary storage and peripheral devices." But it took the U.S.S.R. almost as long to duplicate these models as it took IBM to develop them. The first, small models did not begin to appear until 1972. Thus, the gradual improvement in Soviet seismic data processing capability between 1972 and 1980 can be equated to that of some of the major U.S. oil companies between 1965 and 1973—with the exception of array processors.

The delivery of large U.S. computers for geophysical processing began in the early 1970's, soon after the 1969 Export Administration Act lifted more stringent export control guidelines.[50] Several large computers were purchased from Xerox in 1973, and between 1975 and 1980 the Soviets purchased at least six major U.S. computers from CDC and IBM. CDC supplied a computer for the Ministry of Geology's All-Union Research Institute; another was to be used for the processing of offshore drilling information on Sakhalin; and two were for processing centers in Irkutsk and Tyumen.[51] Two IBM computers have been sold, one for use in the construction of offshore drilling rigs and the processing of information for offshore exploration, and one to the Ministry of Oil.[52] An export license for the latter sale was held back until IBM agreed to scale down the array processors that were to be included.[53] This also happened with other purchases described above.[54] These computer sales have all included software, supplied by both French and American companies.[55]

The U.S.S.R. has never sent appreciable amounts of seismic data to the West for processing, although it has sent small batches, apparently to test-check its own software. Its reluctance to send data seems to stem from a combination of secrecy, pride, and a reluctance to use hard currency for services.

Although the Soviets have obtained U.S. computers and Western software, and may therefore be able to do some sophisticated processing, it seems that they have so far been unable to implement some of the most advanced algorithms. This is a reflection of a much larger Soviet difficulty in software development, an area in which the U.S.S.R. has been notoriously weak. The reasons for this weakness are largely systemic. The Soviet economy is simply not structured to facilitate—indeed, even to allow—the close

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[47] Ted Agres, "U.S. Builds Soviet War Machine," *Industrial Research and Development*, July 1980 p. 3.

[48] *Soviet Business and Trade*, Aug. 1, 1979, p. 5.

[49] Davis and Goodman, op. cit.

[50] See office of Technology Assessment, *Technology and East-West Trade* (Washington, D. C.: U.S. Government Printing Office, 1979).

[51] *Soviet Business and Trade*, July 21, 1975, p. 2; Mar. 15, 1978, p. 1; June 6, 1979, p. 2.

[52] *Soviet Business and Trade*, Dec. 7, 1977, pp. 1-2,

[53] *Soviet Business and Trade*, Aug. 11, 1979, p. 7.

[54] *Soviet Business and Trade*, June 6, 1979, p. 2.

[55] Soviet *Business and Trade*, Nov. 10, 1976, p. 1; Nov. 8, 1978, p. 3.

and constant interaction between users and suppliers which is necessary to the implementation of appropriate software. Scientists, designers, and theoreticians are unable to communicate directly with systems users. Moreover, these users have little or no incentive to risk even temporary productivity or output declines in order to assimilate innovations.

The software problem is pervasive and has been felt in the seismic exploration area. One Soviet author, for instance, has asserted that "a number of important and necessary algorithms for the processing of geological and geophysical data are often not realized in practice."[56] Many of these applications are based on the use of sophisticated multiple-function array processors and very large capacity disks (in the range of 300 MBytes or more), which have not been made available to the Soviets primarily because of their importance in military applications.

The need for large capacity disks stems from the large size of data sets that are now being collected at high sampling rates. Very thin structures, usually found in small fields, may be missed at lower sampling rates, but it is difficult or impossible to split up the data sets taken at higher rates (such as 0.5 milliseconds) onto separate disks for processing. The Soviets have so far only been able to master the production of small quantities of 100 MByte disks (with oxides from West Germany), but these have been of poor quality. An emerging technology in the United States is acoustic holography (three-dimensional wave analysis), which allows the geophysicist to "see" structures three dimensionally. Large capacity disks are indispensable for this application.

Array processors are used in conjunction with large computers as well as with minicomputers. They are critical for offshore exploration, which yields roughly 50 times the data of onshore operations. Permafrost also presents massive complications and requirements for processing power. Since analog methods are still used extensively in the U. S. S. R., the overall throughput for seismic exploration is much slower than in the United States, and the computing power in use in the United States is still far greater. For example, a single oil company in the United States uses 10 large dedicated mainframes, 30 array processors, and over twenty-five 300 MByte disks. As Soviet hydrocarbons become harder to find, the more advanced computer-related technologies will become more important.

Given the fact that the Soviets have been very slow to introduce digital seismic equipment, the paucity of suitable computers until very recently, and the volume of Western sales, it is clear that Western equipment, especially U.S. computers and associated hardware, has filled an important gap in Soviet ability to process geophysical information. Large U.S. computers are located in all the major oil-producing areas—the Far East, Eastern and Western Siberia, in Baltic and Caspian Sea offshore drilling—as well as in Moscow.

SUMMARY AND CONCLUSIONS

The Soviet Union has expressed its intention to reverse past neglect of exploration activities. In this effort, it will face difficulties associated with the fact that it has insufficient quantities of seismic equipment, that this equipment is not up to Western standards, and that prevailing incentive systems tend to work against the allocation of resources to exploration. These problems will inhibit the U.S.S.R. in its attempts to survey more territory, in harsh terrain, and to prospect for oil at increasing depths. But it is not clear that improved seismic equipment alone would necessarily lead in the end to higher oil production. The number of giant oil discoveries remaining and the environments in which they most likely exist (both subjects of controversy among Western geologists) are at least as important in determining the success of exploration activities as the availability of the technology and equipment to identify them.

[56] Gurevich, op. cit.

The Soviet Union has relied on the West, and particularly on the United States, for assistance in developing the computers and computer-related equipment necessary to sophisticated seismic work. Although the Western equipment in the U.S.S.R. does not represent the state-of-the-art, such equipment has not been necessary in the past to locate major oil deposits. The U.S.S.R. is still seeking Western aid in this area, but it is unlikely that it will feel pressured to turn to the West in the 1980's to the same degree that it did in the previous decade. In the near term, Soviet ability to explore for new reserves is likely to hinge at least as much on the number of field crews it can deploy, the availability of highly skilled personnel, and its ability to assemble integrated sets of equipment for data collection in the field.

In the United States, experience has shown that computer techniques have allowed production declines to slow. In the U.S.S.R. such techniques might improve the efficiency of exploratory activities (i.e., the success rate), and thus, as the decade proceeds, advanced computer systems and software could similarly help to sustain production. Although it appears that the U.S.S.R. is moving ahead with the development of its own systems, systemic problems may delay their development and introduction. If this is the case, there will be significant pressure to acquire such systems from the West, probably toward the end of the decade. The Soviets may seek high-density, fast-transfer secondary memory devices, programmable array processors, integrated sets of equipment for data collection, and information display devices. The prime motivating factor for hardware purchases may be to get working software. If such items are unavailable, and if past practice continues, the U.S.S.R. will likely do without or use what is available, albeit in a suboptimal, more expensive manner, after significant delays.

DRILLING

INTRODUCTION

It is common in the West for energy experts to be critical of drilling practices in the U.S.S.R. It has been asserted that the inferior quality of Soviet-made drilling equipment will hinder progress in drilling unless "quantum improvements" are made; and that weaknesses exist in all elements of Soviet drilling technology and in the organization and supply of drilling operations.[57] In part, these evaluations rest on the fact that the U.S.S.R. has chosen a different–and demonstrably less efficient–technological path in its drilling operations from that pursued in the West, and on the unevenness of Soviet industrial standards and production which creates obstacles for drilling teams.

This section describes the methods by which oil and gas wells are drilled, evaluates the Soviet state-of-the-art in these methods, and discusses the past and potential contribution of Western technology to Soviet drilling. It must be noted that this discussion rests on incomplete and sometimes inconsistent data. Recent information on the annual number of meters drilled or drill bits produced is difficult to obtain from Soviet sources, but it is also surprisingly difficult to acquire similar figures for the United States. The data provided here have been verified to the degree that this was possible, but should not be considered conclusive beyond an indication of orders of magnitude.

THE DRILLING PROCESS

Oil and gas wells are drilled with a bit, i.e., a tool that bites into the earth and progressively deepens the bore hole. In the earliest days of the petroleum industry, hand digging was replaced by a system utilizing a chisel-shaped bit that traveled up and down

[57] C 1A, op. cit., p. 21; Campbell, *Trends:* op. cit., p. 19.

on the end of a rope and simply pounded the well deeper. Today, technology has progressed to the point where sophisticated metals and alloys are used to create a wide array of precision tools, designed specifically for different types of rock and drilling conditions.

Equally important developments have taken place in the other technologies and equipment necessary for drilling. The ropes by which drill bits were raised and lowered in the well have evolved into drill pipe (still sometimes referred to as drill "string") made of high-quality steel; the muddy water that was pumped into the well to cool the bit and help to flush up debris has been replaced by "drilling mud" that is a chemically designed mixture of water and/or finely divided material such as special clays, barites, and chemicals. Drilling rigs—the hoists and derricks from which the drill pipe and bit are suspended and which support, raise and lower them—have developed into large, heavy-duty structures capable of bearing and hoisting weights of several hundred tons. Wooden stakes, inserted into the well to prevent it collapsing, have disappeared in favor of tubular steel casings that are cemented in with special oil-well cement to prevent corrosion and leakage and to reinforce the structure; a safety device called a blowout preventer may be attached to this casing at the surface of the well to prevent sudden explosive escapes of gas or liquid caused by high pressures. Finally, sophisticated electronic "well logging" instruments are now available. These are lowered into the well on cables and measure the density and permeability of the geological structure surrounding the well, allowing geologists to estimate the quantity and recoverability of potential reserves.

In the West, the most commonly used drilling technique employs a rotary drill. This is a system in which both the hollow drill pipe and the bit are rotated at the surface of the well by a rotary table, Drilling mud is pumped down the pipe and out through fluid courses in the bit, and this fluid conveys the rock cuttings to the surface where they can be examined for early traces of oil. With this method, the bit usually remains in the hole until it becomes too dull to be effective. At that point, the drill pipe and bit are drawn up together and the bit replaced. During the drilling process additional lengths of pipe may be added while the bit remains in the ground. A variety of drill bit designs make rotary drilling effective in both soft and hard rock formations.

SOVIET DRILLING EQUIPMENT AND PRACTICE

Turbodrilling

Although the Soviet Union originally employed rotary drilling techniques, it proved unable to produce sufficient quantities of the high-quality pipe necessary to withstand the torque applied in rotary methods. ” Use of low-quality pipe leads to pipe breakage and the consequent loss of drilling time in retrieving the remaining pipe and bit from the borehole. To overcome these problems, the Soviet Union developed the turbodrill.

The turbodrill is a series of multistage turbine sections through which the drilling mud or fluid is passed. The turbine is placed at the end of the drill pipe, just above the bit, and the power required to rotate the turbine is provided by the fluid. The need to turn the entire drill string is thus eliminated, and far less stress or torque is applied to the pipe, which is either not rotated at all or is rotated only very slowly.

The turbodrill is a major Soviet engineering feat, one that was achieved at a time (the late 1940's) that Western engineers were trying and failing to resolve the problems associated with the turbine concept. This system has enabled Soviet drilling teams to dig farther and deeper than would otherwise have been possible given the stress on the drill pipe entailed in the rotary method. The turbodrill works particularly well in soft rock

[58] Campbell, op. cit., p. 21.

formations and is well-suited to directional drilling, a technique which allows the bit to be oriented at the bottom of the borehole in a predetermined direction. Directional drilling has been particularly useful to the Soviets in offshore Caspian drilling.[59] At one time, about 86 percent of Soviet drilling was done by turbodrill; this may now have fallen to about 80 percent.[60]

But the turbodrill is not without drawbacks, and it is responsible for much of the criticism leveled at the performance of the Soviet oil and gas industry. The efficient use of turbodrills requires high capacity rig mud pumps, the best of which are produced in the United States. Soviet mud pumps are greatly inferior to these. More importantly, turbodrills operate at three to four times the speed of rotary drills (120 to 600 rpm v. 30 to 150 rpm), a fact that promotes more rapid wearing of the drill bit, especially in hard rock. Replacing the bit is a time-consuming process, as the bit and drill string must be withdrawn from the ground. As well depths increase, time loss becomes even more of a problem. Thus, drilling in the U.S.S.R. takes longer than elsewhere in the world. Soviet drilling teams are said to devote an average of only about 15 percent of their time to actually drilling; the remainder is spent withdrawing and reinserting the drill string and replacing the drill bit.[61]

Other problems associated with the turbodrill are the fact that it cannot be used under high-stress conditions; that it requires more frequent maintenance when operated in high temperature formations; and that its efficiency deteriorates when it is used with certain drilling muds.[62]

Given these problems, several options are open to the Soviets. A turbodrill could be designed that would operate at lower speeds and withstand higher bit weight; the quality–and hence the longevity–of the drill bits could be improved; or rotary drilling could be substituted, at least for deeper wells. Each of these would entail basic improvements in Soviet drilling equipment and technology, a subject that is discussed in more detail below. However, it must be noted that there is no evidence to suggest that the U.S.S.R. plans a wholesale replacement of turbo with rotary drilling.

Although rotary drilling has been introduced in those areas where local conditions provide a particularly strong rationale (e.g., in areas with deep wells and high temperatures), this has been the exception rather than the rule. Not only do the problems that initially led to the development of the turbodrill persist, but much of the existing stock of ground equipment would have to be replaced to be compatible with rotary drills. Moreover, the U.S.S.R. has a significant amount of pride invested in turbodrilling. In short, it seems more likely that the Soviets will push for incremental improvements in their existing equipment rather than replace it with essentially Western technology.

Drill Bits

Contradictory reports have appeared in the West over both the number and the quality of Soviet domestically produced drill bits. In 1977, the CIA estimated that the U.S.S.R. was producing 1 million rock drill bits annually, compared with only about 400,000 in the entire rest of the world.[63] This may be contrasted with a more recent report that cites Soviet production figures of 421,000 in 1970; 352,000 in 1975; and approximately 400,000 in 1980.[64] Part of the discrepancy here lies in the fact that the CIA figure is for rock bits "of all types, " i.e., those used for other purposes than oil and gas drilling. Similarly, the latter figures are for one type of drill bit only–rolling cutter rock bits. These, it is true, are used in the

[59] V. 1. Mishchevich, "Drilling operations in the U.S.S.R. for 60 Years,"' *Neftyanoye khozyaystvo*, No. 10, 1977, pp. 24-30.
[60] Goldman, op. cit., p. 42.
[61] Ibid., p. 41.
[62] R. W. Campbell, *The Economics of Soviet Oil and Gas* (Baltimore: Johns Hopkins University Press, 1968), pp. 106-114.

[63] CIA, op. cit., p. 26.
[64] Wilson, op. cit., p. 60.

vast majority of Soviet oil and gas drilling—96 percent of development and 88 percent of exploratory drilling; nevertheless the output figure is somewhat understated.

It has been claimed that these output figures may be misleading, not only because the quality of the bits produced is so poor (a matter discussed below), but also because the U.S.S.R. may not produce a sufficient variety of bits to allow the sophisticated matching of drilling equipment to drilling conditions that is standard practice in the West. In this connection, it has been claimed that "a typical Soviet factory produces 255,000 bits a year, but only two models. In the United States, a typical factory produces only 70,000. In part this is because production is frequently interrupted to allow the firm to tool up for the 600 models it offers."[65] If this is meant to imply that only a few types of drilling bits are available in the U. S. S. R., it is clearly misleading. There is evidence that between 1971 and 1975, 35 new types of bit were produced in the Soviet Union, and that during the last FYP period, more than 30 new models were developed, including 20 models of a bit made from ultrahard alloys, designed to drill to depths of 4,000 to 5,000 m and to operate at a faster rate of penetration than conventional rock bits.[66] Whether this variety is sufficient to maximize efficient bit use is another matter, however.

The number of bits or of models available may be less important than the quality of the bits produced. Quality is clearly an issue that has troubled Soviet planners, and may have been one of the chief motives for the import of a facility for the production of tungsten-carbide drill bits from Dresser Industries in the United States (see below). Whereas the majority of drill bits produced and used in the West are "journal bearing," the U.S.S.R. continues to employ an older technology, i.e., most of the bits used are "roller-bearing' models. The chief difference between these two designs is that roller bearings contain a number of small rotating elements, whereas the more technologically advanced journal bearing appears simpler, consisting mainly of two close-fitting parts. Journal bearing bits offer a larger surface area and they tend to be longer lived than roller bearing bits. The fact that the majority of the bits to be produced in the Dresser plant are roller bearing suggests that the U.S.S.R. may find these more suitable for use with the turbodrill.

Soviet efforts to improve the quality of domestically designed drill bits have centered in at least three areas: development of natural and synthetic diamond bit technologies; improvement of roller bearing designs; and work with hard alloy based and coated bits.

Natural diamond bits have been in use in the U.S.S.R. for some 25 years, but their utility has been limited by both economic and technical considerations. Natural diamond bits are costly to produce. In addition, they are prone to failure under the high vibrations that are a byproduct of turbodrilling. On the other hand, diamond bits reportedly last longer than other models, and may therefore be better suited to deep drilling. The U.S.S.R. is now testing synthetic diamond bits that could be produced more cheaply than natural ones.[67]

The Soviet literature also records efforts to improve roller bearing technology. In 1979, the Minister of the Oil Industry reported that Soviet research institutes had developed 122 varieties of new bits suitable for both low- and high-speed drilling, and that 75 of these were being put into production.[68] There are already indications of improved results with such new bits, including

[65] Goldman, op. cit., p. 41
[66] Wilson, op. cit., p. 60.

[67] Campbell, *Trends*, op. cit.; D. Dadshev "An Important Reserve for Deep Drilling," t'\. *shka*, Oct. 20, 1978, p. 2; V. V. Petrov, "The Drillers of Checheno-Ingushetiya in the Struggle for Technical Progress," *Neftyanoye khozyaystvo*, No. 10, 1977, pp. 67-70.
[68] N. A. Maltsev, "New Frontiers of the U.S.S.R. Oil Industry," *Neftyanoye khozyaystvo*, No. 9, 1979, pp. 5-10.

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a report of 20 percent improvement in average meters drilled per bit.[69]

In addition to new designs, the U.S.S.R. is also developing more durable materials for its bits. Since 1977, about 30 percent of all bits produced have had hard alloy teeth in their rock-crushing elements, and as of 1979, factories were reportedly beginning to produce bit parts from steels that had undergone electroslag and vacuum arc remelting.[70] These are processes that remove impurities from the molten metal.

The most promising results have come from bits incorporating new superhard alloys that have a high resistance to wear. Claims for one bit utilizing such an alloy include the assertion that it can replace 40 to 70 conventional or two to three diamond bits, and that individual models have lasted over 1,100 m in production and 500 m in exploratory drilling. These bits are expensive to produce and have been found to be most cost effective at depths of 2,000 to 5,500 m. When used with turbodrills, it is claimed that they can reduce operating costs between 27 and 51 percent, largely because of reductions in downtime. Such bits are reprocessed to recover the alloy.”

In the final analysis, however, the real test of improved bit quality is the number of meters drilled each year in both development (producing) and exploratory wells. Soviet statistics show a marked improvement in drill bit productivity over the past 10 years which, as table 10 indicates, more than doubled between 1970 and 1978. Whether the U.S.S.R. can achieve the extremely ambitious target of raising this productivity a further 2.6 times by 1985 seems more problematic, given past performance. In general, bit productivity has been higher in Western Siberia than in the country as a whole because wells there are drilled into formations that are softer than those encountered elsewhere. However, as depths increase, hard rock is encountered even in these deposits. It is significant, therefore, that bit productivity here has grown in spite of increasing average well depths. In other regions of the U. S. S. R., such productivity declined as wells got deeper.[72] Whether these trends will continue in the face of the probability that new finds in Western Siberia are likely to come at everincreasing depths remains to be seen.

Table 10.—Average Bit Runs (meters per bit)

	1970	1975	1978	1980a	1985a
Development drilling	33.7	54.2	76.1	77.2	198.5[b]
Exploratory drilling . .	19.8	26.6	28.1	33.6	—

[a]Plan.
[b]pledge in *Trud,* June 6.1980

SOURCE Soviet data reported in Wilson, op. clt., p 59

Drilling Mud

Both rotary and turbodrill equipment require lubrication with drilling fluid or mud. It is important to use muds that are chemically appropriate, i.e., which will not react with the underground rock formations in such a way that the formations are damaged or oil and gas zones overlooked. Scientifically designed muds are known in the U. S. S. R., and their production was slated to increase during the Tenth FYP as a number of new compounds became available. However, Soviet practice with respect to the use of these fluids is uneven. Western experts have observed cases of drilling crews simply using water mixed with local clay when proper chemical muds were in short supply. Whether or not this practice is widespread or confined mainly to remote exploration sites is unknown, but it is certain that it can cause damage to subsurface strata. Moreover, the careless reuse of poor mud—apparently a practice more common in the U.S.S.R. than elsewhere in the world—can inhibit the effectiveness of well logging equipment. Used mud, unless properly treated and processed,

[69]M. Abramson and V. Pozdnyakov, “The Series 1 A N Bits Are Also Effective for Tubine Drilling, ” *Neftyanik, No.* 9, 1977, pp. 10-11.
[70]V. 1. Pavlov, K. A. Kuznetsov, and N. P. Umanchik, “oil Industry Machine Building,” *Khimicheskoye i neftyanoye mashionostroyeniye No.* 11, 1977, pp. 18-22; Maltsev, op. cit.
[71]Dadashev, op. cit.; *Pravda Ukrainy*, Jan. 13, 1980, p. 2.
[72]Wilson, op. cit. p. 59.

contains oil, gas, or rock from previously drilled sites, thus distorting the data gathered from the present site.

Drill Pipe

Soviet difficulties in producing adequate quantities of high-quality drill pipe are well-documented in both Western and Soviet literature. At its most general level, this problem is part of a set of difficulties common to the entire Soviet civilian economy: an incentive structure that emphasizes quantity over quality, combined with a complex array of infrastructural problems that leads to shortages of the materials, workers, and equipment necessary to fulfill production targets. The result is often pipe with defective threads and joints that cannot withstand extreme temperatures and fail to protect pipes from corrosion and paraffin buildup.[73] Poor quality pipe can cause the drill string to break, dropping the bit and other parts into the well and requiring time consuming "fishing expeditions' to recover them. Wells then remain idle while replacement parts—which are not always available—are sought.

Soviet drill pipe seems to be adequate for wells down to about 2,500 m, but the weight and stress on the string at greater depths lead to frequent pipe failures. This has obvious implications for the average well depths achievable in the U.S.S.R.–an issue made all the more important by the fact that new finds are likely to be made at deeper levels. There is ample evidence that the Soviets are able to drill very deep wells–8,700 m and greater[74]-and the average depth of wells[75] has been increasing. For development wells the average grew from 1,772 m in 1970 to 1,994 in 1978; and for exploration wells from 1,928 m in 1960 to 2,775 in 1975. The average depth of exploration wells has now stabilized (it was 2,797 in 1978), but it is impossible to determine whether this is the result of an inability to drill deeper or a decision that deeper wells are not necessary. In any case, Soviet ability to provide enough quality equipment (including both bits and pipe) to quickly and efficiently drill a large number of deep wells has been questioned. In 1977, CIA estimated that on average it took Soviet drillers more than a year to drill 3,000 m,[76] while in the West this could be accomplished in one-half to one-quarter of that time.

It is difficult to evaluate these figures. While deep drilling claims a great deal of attention because of its cost and complexity, in 1981 only about 1 percent (some 800) of the wells drilled in the United States will be deeper than 4,840 m. In 1979, the average depth of a United States exploration well was 1,811 m and of a development well 1,361 m. The key question is not the depth at which technology allows one to drill, but rather the depth at which resources will be found. Moreover, most "deep" drilling is for gas–economic oil finds are generally made at shallower depths. Generalizations about the relation of Soviet deep drilling capabilities to oil production prospects should, therefore, be made with extreme care.

Rigs and Hoisting Equipment[77]

The U.S.S.R. has produced about 500 oil drilling rigs per year over the past 30 years, but output has been declining since 1975, from 544 rigs in that year to 505 in 1978. Similarly, the size of the Soviet "rig *park*" has declined. In 1970, 2,083 rigs were operating in the U. S. S. R., 1,124 of them belonging to the Ministry of Oil; in 1978, the total had declined to 1,915, of which 1,013 belonged to the Ministry of Oil. One important determinant of the size of the rig park is the number of rigs retired each year. The average life of a rig in the United States, where older equipment is repaired, is 15 to 20 years. In the U. S. S. R., where scrapping ap-

[73]N. Safyullin, "W'here Metal 'Flies '," *Pravda*, Feb. 28, 1978, p. 2.

[74]See "Transfer of Technology and the Dresser Industries Export Licensing Actions," hearing before the Permanent Subcommittee on Investigations of the Committee on Governmental Affairs, U.S. Senate, Oct. 3, 1978, pp. 173, 178.

[75]Wilson, op. cit., p. 55.

[76]CIA, op. cit., p. 26.

[77]Wilson, op. cit., pp. 55-59. Unless otherwise noted, Soviet data in this section is from this source.

pears to be far more common, the average life of a rig is about 6 years. This does have an advantage. If the entire rig park is replaced nearly twice in every decade, its quality can be rapidly upgraded.

The declining size of the rig park is apparently of some concern to Soviet planners, who have included increases in rig production in the Eleventh FYP. On the other hand, the Soviet Union has consistently exported about a quarter of its domestically produced drilling rigs each year. Presumably, if concern about the number of rigs available for exploratory and development oil and gas drilling were intense, a portion of those designated for export could be diverted. There is no evidence that this is occurring.

Moreover, despite a smaller rig park, the total number of meters drilled has increased over the past 10 years. Table 11 shows selected data which demonstrate this increase in drilling rig productivity. If these figures are accurate, they show a phenomenal rise in such productivity, particularly in contrast to what has been achieved in the United States.

The U.S.S.R. appears to be counting on improving the average size and technical characteristics of the new rigs that are slated to replace those being scrapped. Plans include producing new models for deep drilling adjacent to the Caspian (up to 15,000 m); modifying existing rigs for rotary drilling; and designing rigs especially for "cluster drilling" in West Siberia. Cluster drilling is a process particularly suited to the soft rock conditions of West Siberia. It entails building artificial islands from which clusters of up to 20 inclined wells are drilled in the clay or sand. However, it must be noted that at least some of the "improvements" to Soviet rigs consist of additions to rig design-such as higher horsepower motors for hoisting, improved brakes, and increased diesel engine performance–which are incremental changes to basic rig designs of the 1950's. A more revolutionary change—shifting from traditional block and tackle hoists to a hydraulic hoist system–appears to be stymied by bureaucratic problems.[78]

Table 11 .— Drilling for Oil and Gas (thousand meters)

	Exploration	Development	Total
1950	2,127	2,156	4,283
1960	4,023	3,692	7,715
1970	5,146	6,744	11,890
1975	5,419	9,751	15,170
Drilling by the Ministry of Oil *only*			
1975	2,733	8,927	11,659
1976	2,500	9,600	12,070
1977	2,400	10,400	12,800
1978	2,400	11,700	14,100
1979	2,500	13,000	15,500
1980 plan	2,500	17,000	19,500

SOURCE" Soviet data in Wilson, op cit , p 56

Although both the quality and quantity of rigs are increasing, there is evidence too that the U.S.S.R. has not always achieved an optimum mix of equipment. In 1976, for instance, one drilling association complained that it was oversupplied with rigs designed to drill wells below 5,000 m, but did not have enough lighter rigs for the shallower depths normally required.[79]

One important barrier to increasing drill rig productivity is the time entailed in setting up and tearing down rigs as they move from one exploratory site to another. Thus, the availability of portable or "unitized" rigs is important. The U.S.S.R. has attempted to improve its situation with respect to unitized rigs both by importing them from the West (see below), and by creating its own unitized rigs with new cranes and transport equipment. These rigs can reportedly be assembled by a single crew (as opposed to several different crews of carpenters, earth movers, etc.), are 60 tons lighter than other Soviet , rigs, and can drill to 3,300 m at speeds 33 percent faster than were hitherto achievable. But while experimental modular rigs have been successfully tested, serial pro-

"A. Sherstnev, "Extra-Plan Innovation, "*Sovetskaya Rossiya*, Dec. 11, 1977, p. 2.Courtesy of Battelle Columbus Labs.

79A. P. Gorkov and G. F. Lisovskaya, "Analysis of Estimated Costs of Drilling and Ways of Reducing Them in the 'Ukrneft' Association, " *Ekonomika neftyanoye promyshlennosty, No. 5, 1976,* pp. 7-11. Courtesy of Battelle Columbus Labs.

duction is only just beginning, and it is not clear how long it will take to produce such rigs in significant numbers.

Well Logging Equipment

The poor quality of Soviet well logging has been attributed to two basic problems: the extensive use of the turbodrill, and the lack of quality field instrumentation. The action of the turbodrill is such that it occasionally produces erratic and irregular walls in the borehole. Uneven walls cause the drilling mud to be forced into the resulting cracks and fissures. When probing this type of borehole for hydrocarbon content or permeability, it is difficult to separate the contributions from the mud from the actual geological structure. Soviet domestic well logging instruments in the field are essentially copies of American equipment acquired as part of lend-lease after World War II. Although Soviet research institutes have developed instruments comparable to the Western state-of-the-art, these do not appear to have been tested or put into operation. The result is that the accuracy of available Soviet well logging instruments is generally inferior to that of Western models.

Blowout Preventers

In the United States, blowout preventers are considered basic safety devices, and their use is required by law. In the Soviet Union, they are employed usually only in initial drilling in new regions or where underground conditions (mainly very high pressures) or corrosion are expected to cause problems. Once these initial wells are drilled, the use of blowout preventers is infrequent. Although this equipment may be necessary to cap runaway wells, it does not boost production.

Computers

In the United States, a comprehensive set of computer-based aids is usually used to optimize drilling operations. This consists of both onsite and remote monitoring, including online systems connected to a large central data base for advice on drill bit and mud selection and other parameters, and faster than real-time analysis. Computer-based drilling systems to select correct muds and bits and optimize equipment maintenance schedules can speed up the drilling process and help to eliminate drilling deficiencies—provided that crews have the incentive to do more drilling and have the appropriate range of muds and bits from which to choose. It is not clear that these conditions always pertain in the U.S.S.R.

The available evidence indicates that the degree of onsite Soviet drilling optimization is not very great. Applications are primarily related to data processing and acquisition, which involve calculations of geological formations and conditions, well-angling, and the selection of muds and drill bits.[80] It has been claimed that remote monitoring of drilling paramters is taking place on a "wider and wider" scale in the U.S.S.R.,[81] but the availability of sensing devices is limited, and indeed this practice is relatively new in the United States. The Minister of the Oil Industry in 1978 pointed out that although designs exist, output of "the necessary apparatus has not been organized."[82] There is available a system to monitor and control drilling, and another that predicts drill bit wear on the basis of drill stem torque measurements,[83] but it is impossible to say whether these are in widespread use.

Similarly, there is little indication of the use of computerized well-logging devices. The reservoir modeling routines that exist are unable to handle complicated structures. There is evidence only of a few instances of computers being used for the overall planning of drilling strategies.

[80] Yu. V. Vadetskiy, *The Drilling of Oil and Gas Wells: 4th Edition With Additions and Corrections* (Moscow: Izd. "Nedra" 1978), p. 289.

[81] Ibid., p. 302.

[82] Ibid., p. 303; Maltsev, "From Well-Site ," op. cit., p. 15.

[83] Vadetskiy, op. cit.; and P, M. Chegolin, A. G. Yarusov, and E. N. Ye fimov, *Upravlyayuschiye sistemy i mashiny, No. 4,* July August 1977.

THE CONTRIBUTION OF WESTERN EQUIPMENT AND TECHNOLOGY TO DRILLING

Drill Bits

Although the U.S.S.R. has not purchased a significant number of drill bits from the West, Soviet concern about drill bit quality is obviously reflected in the purchase of a U.S. drill bit manufacturing facility from Dresser Industries. Once fully operational, this plant will produce 100,000 bits each year, 86,000 of which are to be tungsten carbide insert bits (10,000 journal bearing, 74,000 sealed roller bearing, and '2,000 nonsealed roller bearing). In all, Dresser furnished designs for 37 separate bits to be produced in the plant. According to the company, all designs incorporated technology as it existed in Dresser plants at the time the contract was signed (1978). In addition to manufacturing equipment, the sale included product drawings, bills of materials, material specifications, and inplant process and heat treatment specifications for the 37 specific designs.

Soviet motives for acquiring this facility are open to differing interpretations. The decision might indicate that the planners are reasonably satisfied with domestic capabilities to produce more conventional milled tooth bits, but lack the manufacturing capacity for the tungsten carbide designs. On the other hand, once the need for more and better tungsten carbide bits was recognized, a new plant might have been seen as simply the most expeditious way of acquiring additional capabilities.

The bits to be produced in the Dresser plant should operate for long periods at the high rotation speeds of Soviet turbodrills. In fact, it has been estimated that each of these bits will substitute for at least two, and perhaps as many as four, Soviet-made bits. It is a highly speculative exercise to translate this into estimated production increases, but a rough idea of the potential contribution of this technology transfer may be gleaned by assuming that, once the plant is producing at full capacity, and without additional rigs, the new bits allow an increase in meterage drilled of 10 to 20 percent. Assuming that this equates to 10 to 20 percent more new wells with a 30 percent success rate, oil production increases of 3 to 6 percent as a result of this plant are *possible.* (This assumes constant productivity.)

But such increases are by no means certain. Improvements in drill bit quality cannot be translated directly into production increases in isolation from such factors as the incentives provided to drilling teams and the availability and quality of rigs and other equipment. In addition, even if the Dresser plant opens as originally scheduled in 1982, it is not clear that it will achieve the same volume and quality of bits as would be the case in the United States. This problem may be exacerbated by the fact that, as part of the post-Afghanistan technology embargo, the U.S. Government prevented Dresser from providing onsite training of Soviet personnel. (This occurred despite the fact that all licensed equipment had been delivered.) The most that can be said with confidence is that, all other things being equal, the new plant should eventually have measurable impact on Soviet ability to drill more efficiently. Whether this additional drilling capacity could translate into significantly higher production would, however, depend on trends in well productivity y.

Drill Pipe

Recent purchases of drill pipe from Japan, Germany, and France have allowed the Soviets to drill deeper than is generally possible with domestically produced pipe. Western exports of drill pipe are included in more comprehensive categories in trade statistics (see ch. 6), and it is therefore difficult to estimate the magnitude of Soviet drill pipe imports. It is probably safe to assume that this pipe is reserved for deeper wells, which presently account for about 5 to 10 percent of Soviet oil production. The importance of Western pipe will increase if this proportion changes in the future.

Rigs

Aside from rigs used in offshore operations, a subject discussed separately below, the U.S.S.R. is believed to have purchased a sizable number of drilling rigs from Canada during the 1970's, and at least 15 portable rigs from Finland. Soviet emphasis on drilling faster, deeper, and in more locations in the present decade will require additional changes in the composition of the rig park (i.e., the variety and quality of available rigs) as well as increased rig production. It is likely that these demands will lead to continued imports.

Well Logging Equipment

Soviet logging instruments, as Soviet seismic hardware, lag Western equipment both in accuracy and efficiency, i.e., the number of sensors downhole at a given time. The U.S.S.R. has purchased items of this equipment from both U.S. and French firms, but in amounts that do not seem to significantly alter its overall capabilities. Logging operations in those wells supplied with Western equipment may be completed 3 to 10 times faster and with greater accuracy than otherwise, but this does not necessarily contribute to production. In order to significantly increase its overall logging time, the U.S.S.R, would have to purchase enough hardware to equip at least 100 crews and also allow Western technicians in for training and to operate the equipment. Even this number of crews would have difficulty logging the more than 20,000 new wells drilled annually.

Blowout Preventers

The U.S.S.R. has purchased small quantities of American blowout preventers, but probably imports most of this equipment from Romania. U.S. industrial representatives who have examined both Romanian and Soviet-made blowout preventers have found them inferior to those produced in the United States, a situation that may change in the future, as a U.S. firm has sold to Romania a new design for blowout preventers which may improve their quality.

SUMMARY AND CONCLUSIONS

Although Soviet commitment to the turbo—as opposed to rotary—drill makes good sense given the U.S.S.R.'s present manufacturing capabilities, the speed and efficiency of Soviet drilling have been inhibited by this commitment, as well as by the low quality of drill bits and drill pipe, and the size and composition of the rig park. There is no reason to believe that the U.S.S.R. will attempt a wholesale switch to rotary drilling, but it has placed increased emphasis on improving the quality of bits and pipe. In the former case, this has consisted of both stressing domestic design and production of new types of higher quality bits, and more importantly of importing an American-designed facility for the production of large numbers of high-quality bits. In the case of drill pipe, the U.S.S.R. has relied almost entirely on imports from Europe and Japan to compensate for domestic production. Some imports have augmented the Soviet rig park.

In none of these cases does the problem appear to be a lack of scientific or technical knowledge on the part of the Soviet Union. Rather, drilling equipment deficiencies seem to stem from the same systemic problems which pervade all Soviet industries, among them the continued emphasis on quantity over quality of output. The Soviet Union produces drill bits in very large quantities, but there are indications of insufficient variety, and evidence that many bits are so poorly made that they may last one-tenth to one-half as long as Western bits.

Despite these problems, the Soviet Union has managed increases in meterage drilled, drill rig productivity, and in its accomplishments in deep drilling. However, plans for the 1980's call for enormous improvements in each of these areas, improvements at least on the scale of those achieved in the 1970's. Clearly, increased investment is being devoted to the oil and gas sector, but it is impossible to determine how much of this will go into manufacturing drilling equipment. There is no sign of impending basic changes in the incentive system. Thus, given past performance, both in the oil and gas industries and in those industries that manufacture equipment for oil and gas drilling, it is difficult to see how dramatic improvements in production will be accomplished without stepped-up imports of Western drilling equipment.

PRODUCTION

INTRODUCTION

Perhaps even more controversial than Soviet drilling practices and capacities are Soviet oil production techniques. These can differ considerably from those common in the West and have occasioned the charge that in the interest of obtaining maximum shortrun output to achieve plan targets, the Soviets have consistently employed methods that damage their fields and ultimately lead to less oil being recovered. Much of the debate over the future of Soviet oil production, in fact, centers on the practice of waterflooding. Equally, much of the claim for the importance of Western oilfield equipment concerns the provision of Western pumps and other technology for use in fields where substantial waterflooding has taken place.

This section briefly explains the petroleum production process and the role of waterflooding in this process; describes Soviet methods for developing fields, including the level of Soviet domestic production technology; and discusses the past and potential role of the West in this area.

THE PRODUCTION PROCESS[84]

Oil and gas production are affected by the porosity and permeability of the reservoir in which they are found, by the water and gas content of the reservoir, and by the viscosity (i.e., thickness) of the oil. The way in which petroleum deposits must be developed and the extraction techniques applied vary importantly according to these factors. A petroleum reservoir consists of a stratum of porous rock, usually sandstone, limestone, or dolomite, capped by a layer of impervious rock. Oil and gas are stored in the small spaces or pores in the porous layer and contained by the cap rock. Fractures or fissures add to the storage capacity of the reservoir. In order for oil to enter or leave porous rock, there must be free connection between the pores. The ability of the rock to allow the passage of fluids through its interstices depends on the size of the channels which connect the pores, i.e., on permeability. The rate at which petroleum can be extracted from a reservoir depends largely on its permeability, but both porosity and permeability may vary over relatively small areas. Thus, wells located in different parts of the same reservoir may have different producing rates.

The first stage in the process of developing oilfields and gasfields is to drill appraisal wells. These are used to determine the permeability of the rock, the amount of water in the reservoir, the properties of the petroleum, etc. Such information helps to dictate the size of the surface production facilities brought to the field. Actual development of a field may begin before the appraisal process is complete. Development wells are drilled in patterns that reflect the contours of the reservoir: they may be in grid formations, straight lines, or rings. In general, the location of the wells is such as to enhance the producing life of the field. This might mean, for instance, that wells be initially drilled close to water zones so that as oil or gas in the area is depleted they can be turned into water injection wells. Numerous items of

[84] See the British Petroleum Co., Ltd., *Our Industry Petroleum* (London: The British Petroleum Co., Ltd., 1977), pp. 124-136.

equipment are required at the wellhead to "complete' the well. These include a variety of valves, casings, and tubings designed to control the well and the petroleum it is producing.

Oil

Oil that collects in structural traps usually occurs in association with both water and gas. The pores in the reservoir rock were originally occupied by water, which was partially displaced when petroleum migrated into the upper part of the rock. The percentage of remaining water is obviously an important factor in determining the volume of oil in the reservoir, Sometimes the water underlays the entire oil zone. When a considerable body of water underlays the oil in the same sedimentary bed, it is referred to as the "aquifer."

Oil under pressure contains dissolved gas in amounts governed by reservoir pressure and temperature. The oil is "saturated" if it cannot dissolve any more gas at a particular temperature and pressure; it is "undersaturated if it could dissolve more gas under the same conditions. In those cases where there is more gas in the reservoir than the oil is capable of holding in solution, the extra gas, which is lighter than the oil, rises and forms a "gas cap" above the oil accumulation. Moreover, if for any reason the pressure in a saturated oil reservoir is reduced, gas will come out of solution and change the production conditions.

The viscosity of oil can depend on the quantity of gas that it holds in solution. Crude oil in a reservoir can range from very viscous (if it contains little or no dissolved gas) to extremely light and thin (containing large amounts of gas under high pressure). The thinner the oil, the more readily it will flow through the pores and interstices of the rock into the bottom of the well.

In order for this movement of the oil to take place, the pressure under which the oil exists in the reservoir must be greater than the pressure at the bottom of the well. So long as this difference in pressure can be maintained, the oil and its associated dissolved gas will continue to flow into the well hole. The rate at which oil or gas moves towards the borehole depends on the reservoir permeability and, in the case of oil, viscosity.

As the well begins producing, reservoir pressure decreases, and the rate of production will decline unless the pressure can somehow be sustained. There are three natural ways in which reservoir pressure is maintained: hydrodynamics, dissolved gas associated with the oil, and the free gas in the gas cap. These production mechanisms are referred to as "water drive, " "solution gas drive, " and "gas cap drive. " The natural drainage of the oil through the reservoir rock under its own gravity provides a further mechanism, and a combination of any or all of these may operate in the same reservoir. The oil obtained as a result of these natural production mechanisms is known as "primary recovery, " and a field is said to be in the primary phase of recovery so long as there is sufficient pressure left in the reservoir to bring the oil to the bottom of the producing well without outside interference.

At some time in the life of a producing well, primary recovery mechanisms will become insufficient and the reservoir pressure will fall to the point where it can no longer force the oil from the rock into the well. This stage can be reached long before the reservoir is depleted, but it once meant the abandonment of the well. There are now artificial means, known as secondary and tertiary recovery, of maintaining reservoir pressure and forcing more oil out of the pore spaces of the reservoir rock. As much as 50 to 90 percent of the oil in a reservoir may be left in place after the end of the primary recovery phase. Secondary and tertiary recovery techniques now make it technically possible to recover 30 to 90 percent of the oil in a deposit.

Secondary recovery involves the direct displacement of oil with a fluid which is cheaper and easier to obtain than the oil itself. The obvious substances are those that imitate the primary production mechanisms—water and gas. When water is used, the secondary recovery process is known as "waterflooding; when gas is used the process is called "gas drive' or "gas injection. '[85]

Waterflooding is the most successful and extensively used secondary recovery technique—so much so, in fact, that it is now considered an integral part of the development of most fields. Water is introduced under pressure into the reservoir via injection wells. These wells may be located adjacent to producing wells to penetrate the reservoir below the oil/water level in the periphery of the oil zone, or they may be drilled in a line across the reservoir or in a grid pattern. The method chosen usually depends on the type of reservoir and rock and fluid characteristics. In some reservoirs, there is considerable variation in the permeability of the rock, and in these instances the rate of injection must be carefully controlled to avoid trapping and leaving behind large quantities of oil. Similarly, it is important to ensure that the injection water is compatible with the natural reservoir water and that it is free from impurities that might block the pores in the reservoir rock. Filters and forms of chemical treatment may be employed to achieve maximum efficiency in this respect.

Where waterflooding has been employed, it is likely that the reservoir pressure will be so low that mechanical assistance will be required to bring the oil and water to the surface. This is usually accomplished with pumps, the simplest and most common being sucker-rod pumps, which work like plungers. They are run into the well at the bottom of a length of tubing, and powered by a pumping jack at the surface. Far more efficient, especially for deep wells, are electric submersible pumps which, together with their motors and electric cables, are lowered into the well on the tubing through which the oil is to be produced. Electric pumps have a much greater capacity than those of the plunger type and are used when high pumping rates are desired. An alternative to pumps is gas-lift equipment, which injects gas into the oil column in the well bore. This method is preferred where the crude oil contains considerable amounts of sand or suspended solids that could damage mechanical pumps.

More complex and sophisticated variations of these secondary recovery techniques may be applied to achieve an even greater degree of recovery of the oil in the reservoir. Known as "tertiary" recovery, these usually involve the treatment of reservoir rock with chemicals or heat. Research and field testing are being conducted in these techniques, but tertiary recovery is relatively new and is still seeing rather limited commercial applications in the West.

Gas

It is possible to have a free gas accumulation with no underlying oil zone, especially in deeper portions of basins. Sometimes gas is contained in a closed reservoir where there is no water closely associated with it, and is driven out of the pores of the reservoir rock by its own expansion. As gas escapes, the reservoir pressure declines. It is possible to maintain reservoir pressure through water injection, but unlike oil, gas recovery as such is not improved sufficiently by water displacement to justify the expense of this operation. It is preferable, therefore, for the gas to be contained in a reservoir where it is in direct contact with an aquifer possessing a sufficient natural water drive mechanism. The process here is the same as in oil wells—the gas is driven out by the expansion of the aquifer water into the vacated pores, and there is no marked decrease in the reservoir pressure or in the producing capacity of the well. Care must be taken that production rates are not so high as to cause damage from infiltrating water, a consideration which applies equally to oil wells.

"'Some experts would hold that secondary recovery is limited to waterflooding and that the use of gas is a "tertiary' recovery technique. OTA here follows the industry usage as expressed in British Petroleum, op. cit.

SOVIET EQUIPMENT AND PRACTICE

Secondary Recovery: Waterflooding

Gas injection is not an important form of secondary recovery in the Soviet Union,[86] but in 1980 over 85 percent of the oil produced in the U.S.S.R. (v. about 50 percent of the oil in the United States) was extracted with the aid of waterflooding. In West Siberia, 99 percent of all oil is obtained with waterflooding.[87] Soviet oilfields are often injected with water at high pressures from the beginning of their development. The dual effect has been both to raise initial recovery rates and to reduce the number of producing wells required per unit of land. The latter allows the U.S.S.R. to conserve capital and reduce the amount of drilling per ton of oil produced.

There is little doubt that waterflooding produces more oil in the short run, but controversy exists over the degree to which this practice contributes to maximizing the ultimate recovery possible from a given field. Western observers have argued that, depending on the rate of injection and field pressure, water can prematurely break through the oil-bearing formations into the producing wells. The net result is that total output over the life of the field is reduced. Soviet experts, however, contend that waterflooding allows the U.S.S.R. to ultimately recover a much higher percentage of oil in place than has been possible in the West. Soviet ultimate recovery rates of 50 to 60 percent have been claimed, with the average reportedly as high as 40 to 50 percent.[89] This may be compared to a U.S. average in 1977 of 32 to 33 percent.[90]

It may well be that these figures are not directly comparable, and that the U.S.S.R, calculates its ultimate recovery by using a base other than that employed in the West.[91] Moreover, there is evidence in the Soviet technical literature of numerous and increasing problems associated with waterflooding, and indications that at least some ultimate recovery targets have been scaled down.[92] On the other hand, the Soviet Union shows no sign of abandoning its long-held waterflood practices. Indeed, current plans are to raise recovery rates still more, and it has been announced that this will be achieved through more intensive waterflooding, albeit with "improved" methods.[93] With Soviet oil production in mid-1981 still not having peaked, it would appear that this is one area of disagreement in which no final verdict is yet possible.

A similar debate concerns the level of the "water-cut" in the U. S. S. R., i.e., the percentage of water in the oil-water mixture that comes out of producing wells. Table 12 shows Soviet water-cut figures for the past 15 years.

It is clear from table 12 that the average water-cut has been increasing, and that at least between 1965 and 1976 the increase in Western Siberia particularly was precipitous. These figures show that for the U.S.S.R. as a whole in 1980, 57 percent of the total output of producing wells was expected to consist of water. If the 1980 water-cut target of 57 percent were reached, this would mean that in order to produce 603 million tons of oil, over 1,400 million tons of oil and water had to be extracted. Moreover, the water-cut of individual fields can far exceed national or regional averages. There are fields in the Ukraine, for example, in which by 1975 water represented from 60 to nearly 80 percent of total output.[94]

Such figures are difficult to interpret or extrapolate, however. In 1977, CIA attempted a simple extrapolation based on assumed increases in water-cut of, alternatively, 3 and

[86] W. Kelly, H. L. Shaffer, and J. K. Thompson, *Energy Research and Development in the U.S.S.R.* (Battelle Columbus Labs, 1980), pp. IV 14-IV 32., unpublished manuscript.
[87] Wilson, op. cit., p. 75.
[88] CIA, op. cit., p. 13.
[89] Kelly, et al., op. cit., p. IV-30; Wilson, op. cit., p. 78.
[90] CIA, op. cit.

[91] Kelly, et al., op. cit.
[92] Ibid., pp. 13-32; CIA, op. cit., p. 14.
[93] Wilson, op. cit., pp. 78-81,
[94] Kelly, et al., op. cit., p. IV-31,

Table 12.—Waterflooding

	1965	1970	1975	1976	1977	1978	1980a
Average-water-cut . .,	412	43.9	48.2	49.9	50.8	51,8	57.0
Average water-cut, West Siberia ., 1	1	5,0	14,5	15.8	NA	NA	NA
Average water-cut, U.S.S.R. excluding West Siberia, ., ., .,	412	46.2	57.0	59,0	NA	NA	NA

NA = not available
[a]Annual plan target

SOURCE Wilson, op cit p 76

6 percent per year. This exercise yielded projections of average water-cuts of 65 and 80 percent respectively for the U.S.S.R. in 1980. In fact, the 1978 average national water-cut was 51.8 percent and the actual 1980 figure probably somewhere between that and the target of 57 percent.[95] Indeed, projections of this sort are complicated by the fact that the water-cut does not rise regularly for the country as a whole, or even for individual deposits or wells. Large annual increases may be recorded at certain recovery rates, but these may fall to between 1 and 2 percent per year at certain points in the life of a deposit. Nor do the Soviets appear to operate on the basis of a simple or single cutoff point beyond which the water-cut makes further production uneconomic. Eventually, the water-cut may rise to 97 or 98 percent, in which case the cost of pumping fluid will exceed the value of the oil obtained, and the well will be shut down. When the water-cut in an entire field reaches this point, the field may have to be redrilled. (Romashkino has been redrilled four times for this reason). But Soviet experts contend—and U.S. practice has verified–that some deposits can operate for many years with water-cuts of 80 or 90 percent, depending on the value of the oil produced and the costs associated with the waterflooding.

Fluid Life and Pumping Requirements

Regardless of the unresolved issue of the wisdom and propriety of waterflooding, there is general agreement that present Soviet practice entails enormous fluid-lift requirements, and that the higher the water-cut in the future, the greater this problem will become. Both sucker rod and electric submersible pumps are produced and used in the Soviet Union, but the latter have a far greater capacity and are much preferred, especially in Siberia where wells have high water-cuts and therefore high fluid-lift requirements. But electric pumps are in relatively short supply. In 1975, for instance, there were 68,000 producing oil wells in the Soviet Union. Some 54,000 of these were being pumped–9,100 with electric pumps and the rest with sucker rod pumps. In all, the U.S.S.R. had an inventory of about 60,000 of the latter, about 75 percent of which were operational.[96]

The U.S.S.R. has also encountered difficulties with the quality of its domestically produced electric pumps. One problem is pump capacity, which hitherto has been insufficient for use in West Siberia. Many of the wells at Samotlor, for instance, yield 2,000 m^3 or more of fluid (petroleum plus water) a day. Soviet pumps have capacities of only 700 ins/day, although a 1,000 m^3 model has very recently been tested. Another problem is the frequency of equipment breakdowns, particularly in areas with high salt deposition where the average interrepair period lasts 60 days. Improvements in both quantity and quality of electric submersible pumps are apparently being sought in the present FYP period.

Gaslift has not been employed extensively in the U. S. S. R., but there are indications that plans now call for an acceleration in its use, particularly in those areas where sub-

[95]CIA, op. cit., pp. 16-17; Wilson, op. cit., p. 77.

[96]Wilson, op. cit., p. 68.
[97]Ibid., p. 66.

mersible pump capacity has been inadequate. There has been some urgency, for instance, in attempting to transfer gaslift to Samotlor where, as described above, both high salinity and fluid lift requirements make Soviet submersible pumps ineffective. Gaslift has been used in West Siberia for at least 10 years, but it has been introduced slowly and accounts for only a small volume of the fluid raised. Part of the reason may be the high capital cost, particularly of installing the necessary compressor units. If this, rather than inadequacies in the design and quality of Soviet-built equipment, is the primary difficulty, there is a chance that the increases in the price of crude oil scheduled for 1982 may make gaslift more practicable. Meanwhile, the U.S.S.R, has ordered gas-lift equipment from France and is also attempting to improve the quality of its domestically built equipment.[98]

Tertiary Recovery[99]

Tertiary recovery techniques are very expensive and many are still relatively experimental, even in the West. There is evidence of Soviet experimentation with a variety of methods, including steam injection and polymer flooding, and indications that attempts will be made to apply tertiary recovery in older producing regions during the 1980's. The Soviets themselves have reported that, on the basis of experiments in tertiary recovery techniques, a 10 to 15 percent increase in recovery rates can be forecast and "billions of tons" of oil can be reclassified as active reserves. It seems highly unlikely, however, given the Soviet system, that the experiments carried out during the Tenth FYP could affect production significantly for several years at least.

In the long run, there appears to be no serious technical barrier to an expansion in the role of tertiary recovery. Rather, there is an economic barrier in the high cost of tertiary methods. Tertiary recovery must be accorded adequate investment, and economic considerations will influence which methods and geographic sites are developed. Perhaps more important, tertiary recovery results may be affected by the same systemic problems, particularly those stemming from the incentive system, that crop up continually in explanations for Soviet inefficiency. The variety of conditions encountered between and within petroleum fields means that tertiary recovery methods must be chosen and used sparingly and with care. Lack of skilled personnel together with incentives for maximum output over the short term, however, have tended in the past to cause Soviet petroleum industry workers to apply crude and unsuitable techniques in efforts to achieve "quick fixes.

Computers

Computers can be used in oilfield and gasfield operations to monitor wells by signaling when flow rates change, to control the action of pumps, and to optimize enhanced recovery techniques. The increase in production made possible by oilfield automation can be substantial. For example, one oil company in Texas was able to get within 3 bbl of the maximum allowable rate per day using computers, an increase of about 450,000 tons per year. Soviet systems seem to be limited to monitoring flow rates. The largest saving here is in personnel. The Soviet news agency TASS has claimed that by 1980, 85 percent of Soviet oil output would be automated,[100] presumably with this system. However, the head of the Ministry of Oil has noted that the lack of terminals is hindering its operation,[101] and in any case it falls well short of Western standards.

THE CONTRIBUTION OF WESTERN TECHNOLOGY AND EQUIPMENT TO PRODUCTION

Submersible Pumps

The Soviet Union obviously has a substantial domestic capacity for producing

[98] Ibid., pp. 66-68.
[99] See Kelly, et al., op. cit., pp. IV-41-42
[100] *Soviet Business and Trade*, No 12, Nov 9, 1977, p. 8.
[101] Maltsev, op. cit

electric submersible pumps, but since these have lower capacities and require more maintenance than their Western counterparts, it has in the past purchased quantities of pumps from the United States—the only other country in the world where they are manufactured. U.S. pumps lift up to 1,000 tons of fluid per day, and can last up to five times longer than Soviet pumps.

By 1978, the U.S.S.R. had purchased about 1,500 American pumps, with deliveries staggered over several years. Only about 2,000 pumps are produced each year in the United States, and back orders and limited manufacturing capacity had restricted deliveries to the U.S.S.R. to about 30 pumps per month. The CIA has estimated that these American pumps may have enhanced Soviet oil production by as much as 1 mbd.

In retrospect, this figure seems misleading. The U.S.S.R. has purchased *no* submersible pumps since 1978, yet its oil production has not only failed to decline by 1 mbd; it has risen. The American pumps seem to have a lifetime of 3 to 6 months in Soviet service before major overhaul is required. But although the Soviets asked their American suppliers for training in pump repair, the U.S. firms refused. This suggests that, unless the U.S.S.R. has developed unprecedented capabilities in learning to repair foreign equipment with no information from the supplier, the U.S. pumps were probably used until they failed and then put aside. If this is the case, it is likely that no American pumps were still in service by 1979, and the U.S.S.R. must have been able to substitute its own equipment.

This is not to suggest that U.S. pumps were not important to the Soviets or that they might not be so in the future. If pumps could be purchased at previous rates or increased by a factor of two or three *and* if these pumps were replaced or repaired when they failed, the impact on Soviet oil production could be substantial, although difficult to quantify. Estimates by U.S. industry experts show an enormous range–from 8 to 20 percent increases in production.

Gaslift Equipment

Soviet gaslift efforts have been importantly enhanced by the sole gaslift sale reported in the West—a $200 million deal made with two French firms in 1978 for equipment for approximately 2,400 wells, including gas compressors, high-pressure manifolds, and control valves. (Although the French firms were the general contractors for this project, American equipment, built in Ireland, formed part of the package. U.S. computers have also been used for operating the gaslift equipment at the surface.) This equipment has been employed at the high-priority Samotlor where the downhole life of submersible pumps is particularly short. However, this quantity of equipment will equip only about 20 percent of Samotlor's wells, and probably has accounted for some 1 to 3 percent of current production.

Computers

The Soviets have purchased sophisticated automation systems for oilfields and gasfields from the United States and France. Much of this has gone to Western Siberian oilfields (Samotlor and Fedorovsk), including a multimillion dollar multilevel process control system that regulates and optimizes gas-lift operations on several thousand oil wells. Another gas monitoring system was purchased for the Orenburg gasfield. The equipment used in these systems only recently went into production in the Soviet bloc, and considering the leadtimes needed to develop such systems, it is clear that these purchases allowed capabilities far in advance of those that would otherwise have been possible. The Samotlor and Fedorovsk sales are particularly important because those fields are entering critical secondary recovery stages.

These systems may not be necessary if the fields are pumped continuously at maximum possible rates. But if the Soviets door intend to plan oilfields so as to optimize overall recovery rates, automation equipment will be needed. Automated systems for water and gas injection operations will also be in greater demand as more and more fields enter these stages of production and as labor becomes scarce.

The Soviets have recently started producing the computers needed for sophisticated reservoir analysis, i.e., computers with large, fast main memories. Damaged (over-flooded) fields and overestimates of reserves have partially been due to poor reservoir modeling. Future needs will be increased by the number of fields entering secondary and tertiary recovery phases, and by the switch in the late 1980's to fields with more difficult and complex geologies.

Although the U.S.S.R. has been producing all the equipment needed for such multilevel oilfield and gasfield control systems, it does not have much experience in building them, and it may be several years before the Soviets can organize such systems themselves. They may, therefore, continue to turn to the West for such systems over the short term. Over the long term, the U.S.S.R. is unlikely to purchase large computers for reservoir modeling, since it has recently mastered their production. However, purchasing the software may save considerable time and lend new insights into reservoir models, especially since combining very complex geophysical know-how and software is one of the most difficult tasks in the geophysical field. The United States remains the world leader in this technology.

SUMMARY AND CONCLUSIONS

Oilfield development in the Soviet Union employs different techniques than are common in the West. Most importantly, the U.S.S.R. initiates secondary recovery, and particularly waterflooding, at an earlier stage in the producing life of its fields. Although this practice is widely used in the West, the extent to which it is employed in the U.S.S.R. together with documented cases of its misuse have led Western experts to label it potentially damaging to overall extraction prospects. On the other hand, many Soviet petroleum experts continue to believe that extensive waterflooding actually enhances ultimate recovery rates. So long as Soviet oil production continues to rise in fields like Samotlor, which as a high watercut, this debate is unlikely to be resolved.

While it is misleading to generalize about the water-cut rate for the U.S.S.R. as a whole because of important variations between regions and fields, there is no doubt that poor management has led to damage in some fields; or that the fluid-lift requirements occasioned by waterflooding are burdensome. This problem is intensified in the U.S.S.R. because of its poor domestic capability for producing large numbers of high-quality electric submersible pumps for removing the oil and water mixture from wells. Pumps imported from the United States have been important in alleviating this problem, but the U.S.S.R. has demonstrated that it is not entirely dependent on such imports,

TRANSPORTATION OF OIL AND GAS

INTRODUCTION

Once oil and gas are brought to the surface, they must be conveyed to processing facilities and then to refineries, storage, or to ports. In the U. S. S. R., as in the West, this is accomplished by rail, road, water, and pipeline, although the latter has proved to be the most efficient and cost-effective mode of transport. To a large extent, Soviet plans for increased gas production and gas exports rest on the further extension of the gas pipeline system. The length and capacity of Soviet pipeline networks has expanded significantly, an achievement that has been accomplished with extensive imports of Western equipment and technology, particularly large diameter pipe. This section describes the way in which petroleum pipelines function, details Soviet progress in constructing and operating them, and discusses the role of the West in oil and gas transportation.

TRANSPORTATION OF OIL AND GAS BY PIPELINE

Pipelines are generally the most cost effective way of conveying large volumes of petroleum over long distances by land. Although they require a high initial capital investment, in the long run operating and maintenance costs are low, and the cost of pipeline transport drops rapidly with increases in the diameter of the pipe, and therefore the quantity of petroleum that can be transported. A difficulty with pipelines is their inflexibility. Once laid, it is impossible to change their routes, although provision can be made for additions to pipeline capacity.

Pipelines carry oil from the well to field processing centers, and from there to refineries and onward. Sometimes these pipes are lined to protect them from corrosive materials in the petroleum; sometimes they may require insulation or the installation of heating facilities along their route to prevent oil from congealing.

Separate gas pipelines transport gas, which may be independently produced, found in association with crude oil, or produced during the refining process. In the past, associated gas produced in oilfields was often flared off or allowed to escape into the atmosphere. With higher gas prices, this natural gas is now transported to markets.

Important characteristics of the pipe from which oil and gaslines are constructed are

the strength of the material, the technique of manufacture, and the diameter. One improvement in pipe technology has been to achieve strong pipe with thin walls, thus allowing a decrease in production costs. A second has been the introduction of seamless pipe, which avoids the weaknesses introduced by welded seams. Seamless pipe of wide diameter (40 inches and above) is difficult to manufacture, but advances in metallurgical technology have led to the ability to produce long lengths of wide diameter, thin-walled rolled pipe that can withstand high pressures.

Both oil and gas are moved along the pipeline with the aid of mechanical devices–pumps and compressor stations. Oil pipelines may be equipped with any of a variety of pumps—centrifugal, steam turbines, diesel engines, etc.—the appropriateness of which are determined by the volume to be transported, the viscosity of the oil, the pressure required, and the availability of fuel. Pumping stations situated along the route of the pipeline can be maintained manually by mechanical controls, but as distances increase, remote automation becomes more efficient.

Natural gas is pushed through the pipeline by the pressure obtained from compressing the gas. Gas from the pipeline itself is normally used to fuel the compressor engines. Valves are installed every 10 to 30 miles along the pipeline to make it possible to isolate sections for maintenance and repair and to close automatically in response to rapid large drops in pressure. Whereas in a level oil line of constant diameter, pressure will decrease uniformly with distance, in a gas line it decreases according to parabolic law. Pressures are highest at the outlet of a compressor station and drop between them. The efficiency of gas compressors depends on where along the line they are situated. The result is that gas pipeline capacity, unlike that of oil lines, is related to route length as well as pipe diameter. The capacity of a gas pipeline can be increased by adding compressor stations at close (50 to 100 mile) intervals along the route.

SOVIET OIL PIPELINES

West Siberian oil has constituted an increasing share of total Soviet production in the past decade. This has necessitated the construction of major oil pipelines to bring the crude hundreds of miles to refineries and consumers.[102] Nevertheless, rail has remained an important means of transporting oil products in the U.S.S.R. The usual Soviet practice is to use pipelines to carry crude oil from field to refinery and the railroad thereafter. (Truck transport, which is used extensively in the United States, is confined to the distribution of products over relatively short distances to consumers.) This heavy use of rail transport is expensive and inefficient, particularly for the usually short hauls. Product pipelines (i.e., pipelines designed to carry refined products from the refinery to local distribution points) would rapidly pay for themselves, but delays in pipeline construction have meant that the volume of oil and products carried by railroad has continued to grow. In 1979, 35 percent of all oil freight was transported in this manner[103] (see table 13).

Present Soviet policy appears to place priority on phasing out the use of rail for crude oil transport before extending product pipeline capacity. In any event, establishing an extensive products system will require intricate planning, as such a system must serve a variety of distribution points and cope with a number of different products.

[102] This is because the only railway running from the oil-producing region of West Siberia is working at full capacity. Wilson, op. cit., p. 32.
[103] Ibid., p. 25.

Table 13.—Transport of Oil and Oil Products
(million tons)

	1975	1976	1977	1978	1979
Volume of 011 and products transported by:					
Pipeline	499	532	559	589	609a
Rail	389	394	406	412	NA
River	39	38	37	40	NA
Sea	91	101	104	109	NA
Total	1,018	1,065	1,107	1,150	NA

NOTE Totals may not add due to rounding
NA = not available
a Cited in Izvestiya Jan 26 1980
SOURCE Wilson oo. cit., p. 25

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Despite the fact that 1980 plan targets for oil pipeline construction were not met,[104] the length and capacity of the Soviet oil pipeline system have grown extensively over the past 20 years (see table 14). By the end of 1979, there were 67,400 km (about 41,900 miles) of crude oil and product pipeline in the U.S.S.R.

The rate at which additions to oil pipeline capacity can be made depends importantly on the terrain to be covered and the diameter of the pipe being laid. Pipelines are expensive and slow to build in the difficult conditions of West Siberia, where high winds, sand erosion, and swamps inhibit construction. The larger the diameter of the pipe, the higher the capacity of the pipeline, and the U.S.S.R. has placed emphasis on increasing its use of wide diameter pipe. This growth, as well as the corresponding increase in pipeline capacity, is shown in table 15.

The location of major Soviet oil pipelines and their capacities is shown in figure 3. As would be expected, the evolution of this network has been dictated by the movement of the center of Soviet oil production from the Caucasus to the Volga-Urals, and then to West Siberia; and by the location of refineries and export markets. Lines from the Volga-Urals fields, for instance, followed three basic directions before the development of West Siberia:[105] eastward into Siberian refineries at Omsk and Angarsk; westward to Eastern Europe (this is the Friendship pipeline that carries crude oil to refineries in Poland, East Germany, Czechoslovakia, and Hungary; branch lines also serve domestic refineries); and northwestward to refineries in the central and northwest portions of the country.

The onrush of West Siberian oil required large-scale network expansion using increasingly large pipe diameters. West Siberian lines also now follow three basic directions: southeastward into eastern Siberia;[106] southward to Kazakhstan and Central Asia; and southwestward to the European U.S.S.R. In addition, a new pipeline corridor runs due west across the Urals. Construction on a 48 inch, 3,300 km (over 2,000 mile) segment of this line began in 1977. It would appear that this line is intended to handle expected increases in West Siberian production. The first stage (from Surgut to Perm) was completed in 1979 and, despite the difficulties of construction, the entire pipeline was finished

[104] Ibid., p. 26.

[105] Ibid., p. 66.

[106] This line appears to have been planned as the initial link in a system carrying West Siberian oil to the Pacific coast for export to Japan. This plan has been dropped and such oil flows, if and when they exist, will be handled by the Baykal-Amur Mainline (BAM) railway. Dienes and Shabad, op. cit.

Table 14.—Length of Oil and Oil Product Pipelines (thousand kilometers)

	1960	1965	1970	1975	1978	1979	1980 (plan)
Crude	13	22	31	46	NA	NA	NA
Products	4	7	7	10	NA	NA	NA
Total	17	29	37	56	64	67	75

NOTE Totals may not add due to rounding
NA = not available

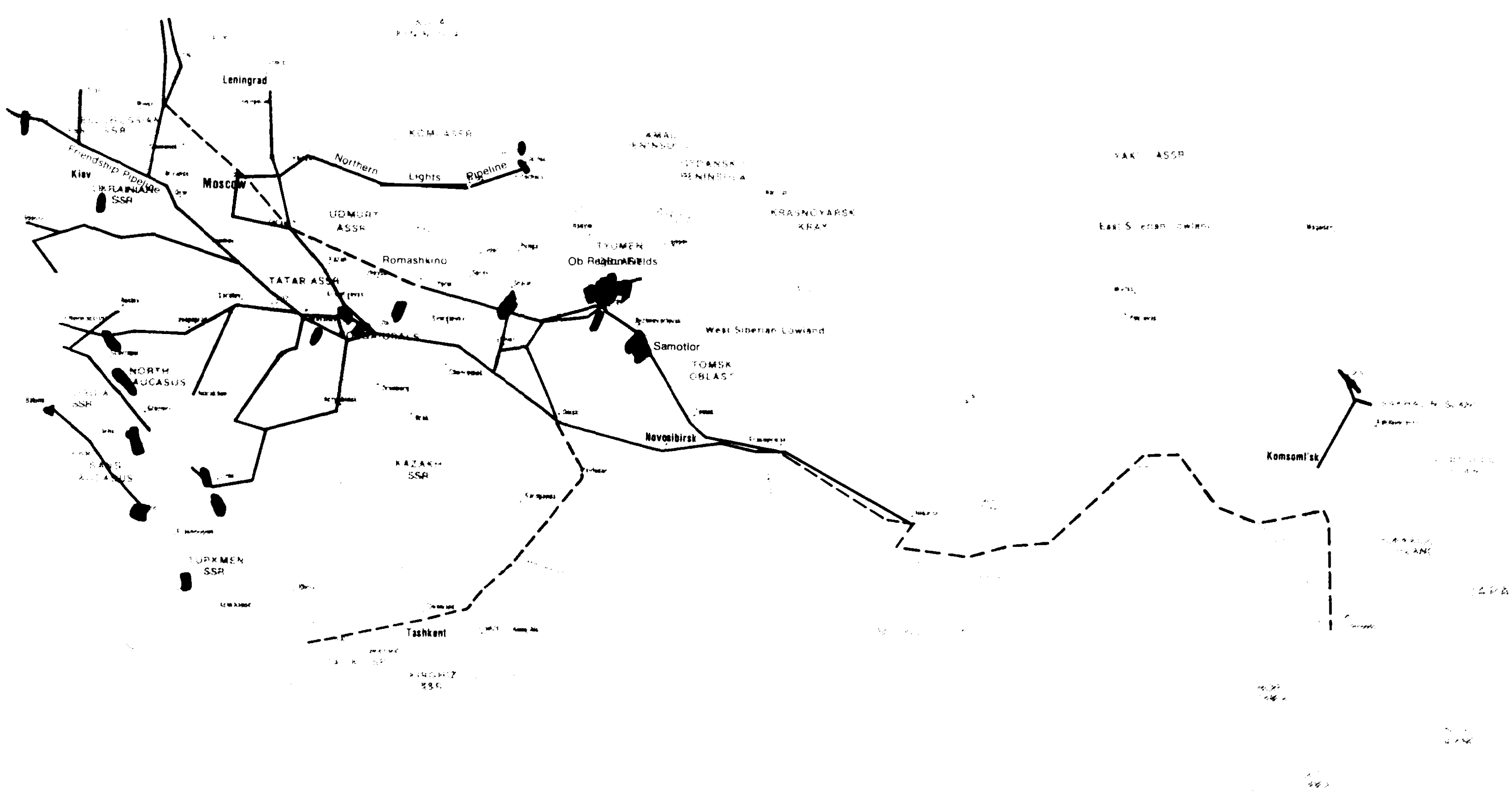
SOURCE Dienes and Shabad op cit p 62. Wilson op cit p 26

Table 15.—Diameters and Capacity of Oil Pipelines

Diameter (inches)	Annual capacity (million tons)	Length of pipelines (thousand kilometers) 1940	1950	1955	1960	1965	1970	1975
Below 20	—	4,1	5.4	75	9.2	9.5	10.8	12.1
20	8	—	—	3.0	6.3	9.9	10,3	15.9
28	17	—	—	—	1.7	6.1	9.5	11.0
32	25	—	—	—	0.05	1.8	2.9	5.9
40	45	—	—	—	—	1.3	39	6.4
48	75	—	—	—	—	—	—	4.9
Total length of pipelines		4.1	5.4	105	17.3	28.6	37.4	56.2

SOURCE Dienes and Shabad op cit p 63

—Major Oil Pipelines



SOURCE Office of Technology Assessment

——— Major pipelines (double and single lines) – – – – Planned ▬ Oilfields in 1981.[107] The completed line will both serve refineries and provide oil for export through the Baltic Sea terminal at Ventspils.

GAS PIPELINES

In 1980, the U.S.S.R. produced 435 bcm of gas and the Eleventh FYP has called for a 50-percent increase in gas production, mostly from West Siberia, in part to support greatly expanded gas exports. The success of these plans will largely rest on the capacities of the pipelines that are required to transport this gas. The existing gas pipeline network grew from about 99,000 km (61,000 miles) in 1975 to about 130,000 km (80,000 miles) in 1980, (see table 16) and has increasingly employed large diameter pipe. Nevertheless, the low capacities of gas pipelines present particular problems. A 48-inch oil pipeline, for instance, can carry 75 mmt of oil each year; a 56-inch gas pipeline can carry only 23 mmt of oil equivalent (23 bcm of gas). Present plans to raise West Siberian gas production, therefore, require enormous increases in the length of the pipeline network. The Eleventh FYP calls for about 40,000 km of new pipeline, an increase of 30 percent, including 25,000 km of 56-inch pipe carrying gas from the Urengoy field.[108]

The Soviet gas network is shown in figure 4. While important lines in this system serve the fields of Central Asia and the giant Orenburg deposit in the Volga-Urals (from which gas is carried to Eastern Europe), the most important part of the network connects the enormous West Siberian fields to consumers. These fields will be supplying most of the increment to production in the next decade.

Three Siberian trunk systems presently carry most of this burden. They are the Northern Lights system, one branch of which runs to the Czech border from whence gas is exported; the Tyumen-Moscow line; and the Tyumen-South Urals system, which may be able to feed Siberian gas to the Caucasus to makeup for the cessation of Iranian gas imports. (A pipeline project that would have supplied Iranian gas to the U.S.S.R. has now been abandoned.) Branch lines from these major systems serve a number of major towns along their route. All of these lines employ 56-inch pipe. An important projected pipeline is the one which will bring additional gas to Western Europe. This is discussed in detail in chapter 12.

Given the fact that pipe with diameters exceeding 56 inches has not been mass-produced anywhere in the world, there are three ways in which the U.S.S.R. might improve its pipeline capacity: cooling the gas to increase its density, raising the pressure of pipelines from the present 75 atmospheres to 100 or 125 atmospheres, and reducing the distance between (and therefore increasing the number of) compressor stations. While research into the technology for the first two

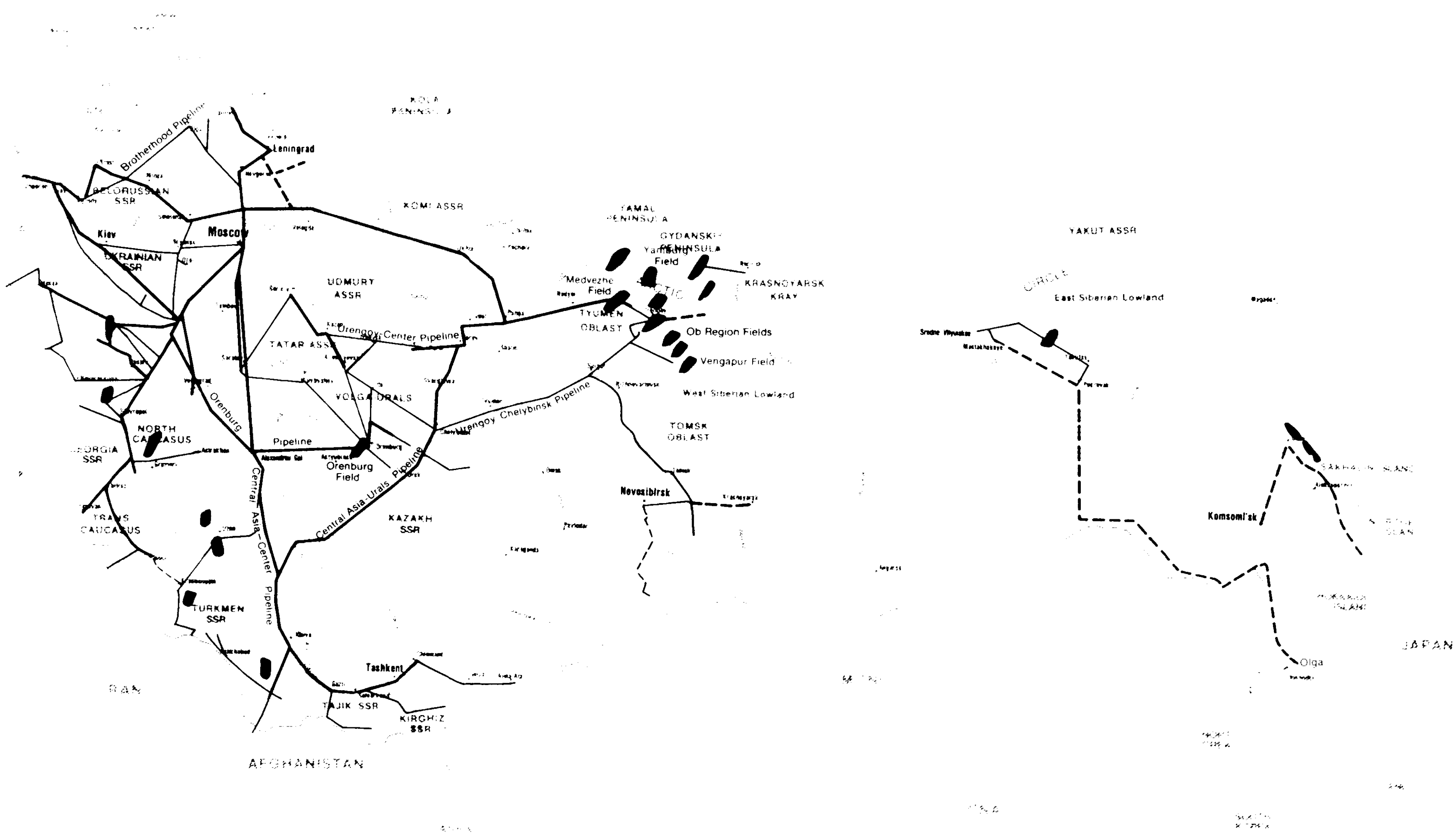
[107] Theodore Shabad, " News Notes," *Soviet Geography*, April 1981, p. 275.
[108] Ibid.

Table 16.—Length and Diameters of Gas Trunk Pipelines

Diameter (inches)	Optimal annual capacity (bcm)	Length of pipelines (thousand of kilometers at year-end)											
		1940	1950	1955	1960	1965	1970	1975	1976	1977	1978	1979	1980 (plan)
< 28		0.33	2.3	4.9	11.8	20.2	29.9	36.2	—	—	—	—	—
28	4.0	—	—	—	6.2	10.6	12.9	16.1	—	—	—	—	—
32	6.2	—	—	—	2.3	4.0	5.0	7.0	—	—	—	—	—
40	8.7	—	—	—	0.7	7.5	15.9	20.6	—	—	—	—	—
48	13.3	—	—	—	—	—	3.8	15.7	—	—	—	—	—
56	20.2	—	—	—	—	—	—	3.6	—	23	—	—	—
Total length of pipelines		0.33	2.3	4.9	21.0	42.3	67.5	99.2	103.5	111.7	117.6	124.4	134.2

SOURCE: Dienes and Shabad, op. cit., p. 83; Wilson op. cit., p. 26; Leslie Dienes, private communication.

Figure 4.—Major Gas Pipelines



SOURCE: Office of Technology Assessmer

M lines (dual or more pipeli —Branch Lines (single pipelines) ----Planned lines Gasfields of these options is ongoing, and cooling technology in gas transportation appears particularly promising, their widespread application does not appear to be imminent. Increasing the number of compressor stations will therefore play the most crucial role in increasing gas pipeline capacity.

Unfortunately, the design and quality of Soviet compressors are poor and construction of compressor stations has chronically lagged behind plan. Moreover, there is apparently an ongoing debate within the U.S.S.R. as to whether or not the distance between compressor stations should indeed be shortened. The argument against such practice is that construction of these stations is highly labor intensive. Reducing their number will shorten construction periods and accelerate the delivery of gas.[109] Whether or not this view will prevail remains to be seen. Should a decision to increase the number of stations be reached, however, it is likely that this is another area in which Western equipment might play an important role.

Other factors inhibiting the construction of West Siberian gas pipelines are labor shortages, the inadequacy of electricity supplies, and shortages of excavating and pipelaying equipment. Delays in the construction of permanent settlements for the large number of workers required to lay gas pipelines have contributed to constant labor turnover. Meanwhile, the North Tyumen region of West Siberia, location of the most important giant gasfields, does not have a permanent electricity supply. Not only does this mean that each compressor station must have its own mobile power unit and the personnel to maintain it, but frequent power failures cause expensive interruptions in compressor operation and can damage compressor units. Finally, pipeline construction is seriously affected by the failure of enterprises producing engineering, excavating, and construction equipment to fulfill their obligations.

It has been asserted that despite these difficulties, Soviet pipelaying work is "fast and efficient."[110] It is difficult to evaluate this statement. Certainly Siberian conditions impose constraints that should affect the success criteria by which any such enormous enterprise is measured. However, the ultimate test will be the extent to which the U.S.S.R. is able to meet its own goals–with or without massive purchases from the West.

THE ROLE OF WESTERN PIPELINE EQUIPMENT AND TECHNOLOGY

Pipe[111]

The Soviets have been heavily dependent on imports of Western pipe of 40 inch and greater diameter, most of which seems to be used in main-line high-pressure transport of natural gas, and on Arctic quality pipe. Comparisons of Soviet domestic pipe production and import figures suggest that, at least through 1975, this dependence exceeded 50 percent and was growing. In 1979, the value of steel pipe imported by the U.S.S.R. rose by 29 percent over 1978.[112]

The Soviet steel industry is capable of producing, 40-, 48-, and 56-inch pipe, and indeed a substantial part of the domestic gas distribution system uses domestic pipe, albeit mostly of small diameter. It would therefore appear that the massive imports are designed to avoid bottlenecks arising from insufficient production capacity and to compensate for the fact that Soviet domestic pipe is of lower quality in yield strength, wall thickness, and general workmanship that that which can be purchased abroad. Soviet

[109] See Robert W. Campbell, "Soviet Technology Imports: The Gas Pipeline Case," The California Seminar on International Security and Foreign Policy, February 1981, pp. 14-20; I. Ia. Furman, "Determining the Comparative Effectiveness of Variants in Designing Gas Transmission Lines," *Gazovaya promyshlennost*, Seriya Ekonomika, organizatsiya i upravlenne v. gazovoy promyshlennosty, No. 4, 1981, pp. 20-21.

[110] ""'~f'ils(~rl, opcit.,pp.29-31.

[111] 'This section is based on Campbell, "Soviet Technology Imports . . .," op. cit., pp. 10-12.

[112] Wilson, op. cit., p 27.

welding practices apparently add to the problem of quality. The U.S.S.R. is attempting to upgrade its pipe manufacturing capabilities. To this end, it has purchased a seamless pipe manufacturing plant from French and German firms. The plant has an annual capacity of 170,000 metric tons (in 1976, Soviet domestic output of 40 inch and larger pipe was 2.6 million tons[113]). In addition, a new pipe-rolling plant destined to produce 56-inch pipe for use at 100 atmospheres is using imported steel plate.

Pumps and Compressors

The U.S.S.R. has purchased pipeline boosters, pumping stations, and gas compressors from the West, but the area in which Western technology appears to have been most important is in compressors for gas pipelines. These do not seem to be produced in adequate quantity and quality in the U.S.S.R. itself. In 1976, the average size of a Soviet turbine-powered centrifugal compressor unit (produced under license from the U.S. Dresser Industries and making up 71 percent of installed gas compression capacity) was slightly over 4 MW. The U.S.S.R, now widely produces units of 5-, 6-, and 10-MW capacity, but ones of 16 and 25 MW, mass-produced routinely in the West, were only scheduled to begin serial production in 1981.[114] The large units needed to increase installed capacity must, therefore, still come almost entirely from the West.

The U.S.S.R. has been importing substantial amounts of gas-turbine-powered compressor equipment since 1973; by 1976, 3,000 MW of such units (about one-third of installed capacity of all types of compressor equipment) had been imported from Austria, Great Britain, Japan, Norway, and the United States.[115] While it is obviously impossible to quantify the net benefits generated by these purchases, one Western expert has estimated that pipe and compressor imports together may well have paid for themselves within 2 years, given the acceleration of gas transport capacity they allowed.[116]

Other Equipment

The U.S.S.R. has purchased American pipeline inspection equipment, but in general has not relied extensively on the West for other material for pipeline cleaning. More important are imports of pipelaying and excavation equipment, particularly that designed for cold climates. Pipelayers have been purchased both from the West and from Eastern Europe, but there are signs that the U.S.S.R, may wish to accelerate such imports for construction of the proposed new pipeline to Western Europe (see ch. 12).

Computers

The U.S.S.R. has the ability to build reasonably advanced computer-based control systems for oil and gas pipelines, but the majority of pipelines probably still employ older, less efficient and more labor-intensive technologies. For instance, even the best Soviet systems do not use microprocessors and minicomputers as they are used in Western state-of-the-art systems. These are connected in a multilevel hierarchy with a central mainframe, and produce greater reliability, quicker response times, and lower labor requirements.

The U.S.S.R. has purchased in excess of $10 million of pipeline-related computer equipment from the West, mostly for pipelines such as Orenburg, for which large amounts of other Western equipment has also been purchased. Announced plans call for the introduction of at least 10 domestically produced oil pipeline automation systems. Such systems could reduce operational mistakes and allow better pipeline maintenance, speedier leak detection, and better overall management of oil and gas flows. If these systems are indeed about to be intro-

[113] Campbell, "Soviet Technology Imports," op. cit., p 12.
[114] Wilson, op. cit., p. 29.
[115] Campbell, "Soviet Technology Imports," op. cit., pp 15, 21.
[116] Ibid., pp. 22-24.

duced, and if delays in the provision of domestic equipment for them occur, the U.S.S.R. may turn to the West for assistance. However, it is not clear if this is a priority area for the acquisition of Western computers or the expenditure of hard currency.

SUMMARY AND CONCLUSIONS

The Soviet oil and gas pipeline system has grown extensively in the past decade. But if the large increases in West Siberian natural gas production so important to Soviet energy plans as a whole are to be realized, further expansion of the gas pipeline network is crucial.

oil and gas pipelines have benefited extensively from Western pipe and compression equipment. Although the U.S.S.R. does manufacture some large diameter pipe and is seeking to upgrade its capabilities in this area, no end to its dependence on Western imports of such pipe is in sight. Similarly, although there are Soviet-made compressors, including some new models with capacities that were hitherto available only in the West, Soviet purchases of such equipment from the West still appear to be cost effective. Indeed, for some time to come, such purchases will probably also be necessary as domestic manufactures remain inadequate in both quality and quantity.

REFINING

INTRODUCTION

Crude oil is not a homogeneous substance. Depending on the nature of the deposit from which it comes, it can consist of a variety of compounds and exhibit a wide range of properties. These properties determine a number of both liquid and gas products which can be produced from the crude in primary distillation. The refineries at which these products are made can employ both primary and secondary processing techniques so that ideally each refinery can produce the optimum product mix for the crude oil which comes to it. Common products are jet, diesel, and residual fuel oil; gasoline; kerosine or paraffin; lubricating oils; and bitumen. During the oil refining process, considerable volumes of gas may also be released. These gases—methane, ethane, propane, and butane—can be used as fuel for the refining process or marketed separately.

Natural gas too is processed both to obtain marketable products and to purify it. Some gases have a high content of natural gas liquids, which can be separated out. In addition many natural gases contain hydrogen sulfide, sometimes in amounts ranging to more than 75 percent. "Sour" gases, i.e., those with high hydrogen sulfide content, are toxic and corrosive, and must be treated before they are used.

Relatively little is known about the Soviet refining industry. The U.S.S.R. issues no statistics on oil refining, and information on throughput—in terms of both product quality, variety, and quantity—must be gathered from indirect sources and based on estimates. This section will briefly summarize major characteristics of this industry.

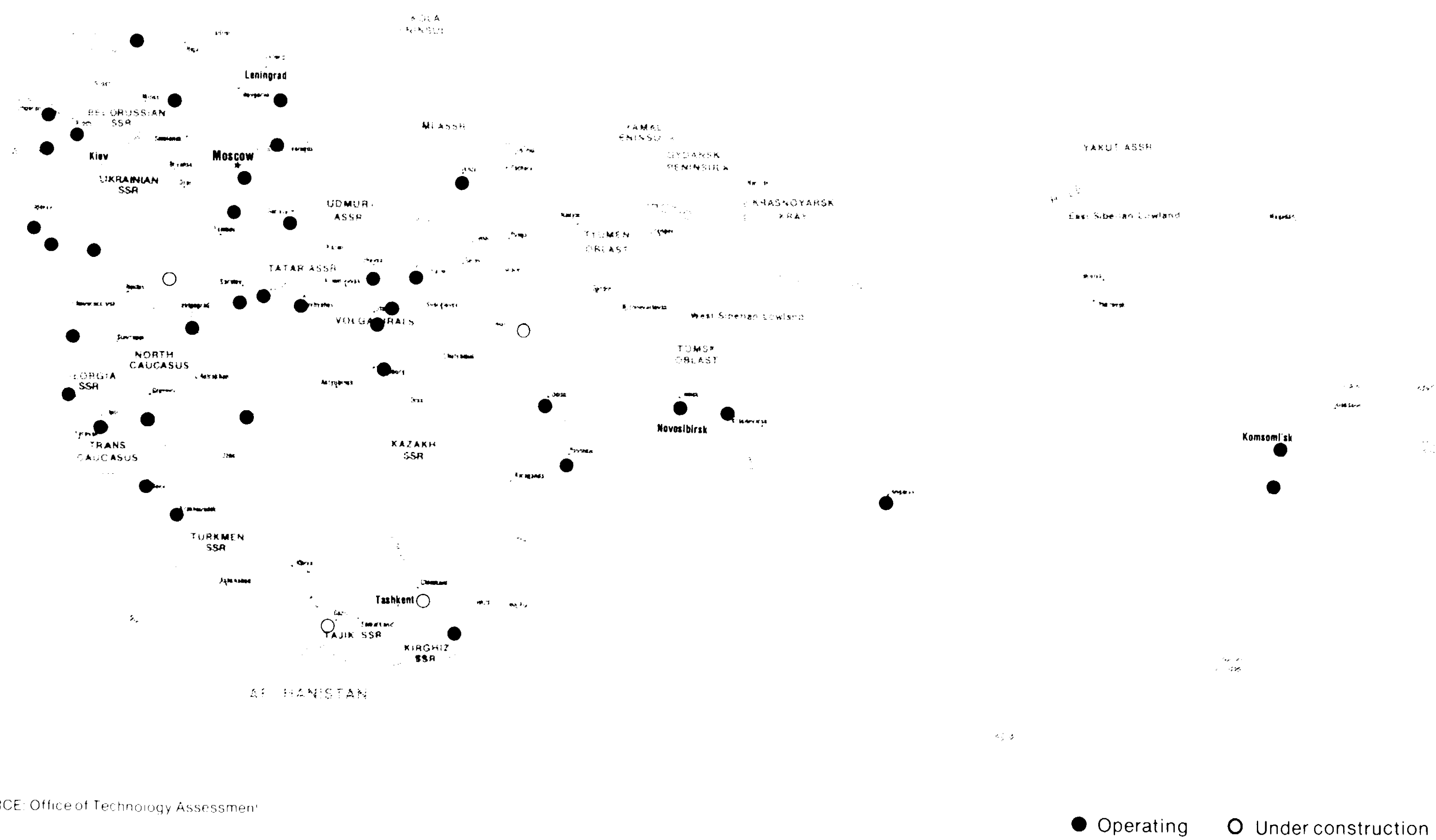
THE SOVIET OIL REFINING INDUSTRY

Major difficulties in the Soviet refining industry have resulted from the geographic distribution and capacity of existing refineries, and from the quality and mix of the refined products produced. There are indications that the U.S.S.R. recognizes and is attempting to remedy these problems, but that much improvement in the refining sector is still necessary.

Figure 5 shows the location of major Soviet refineries. There are some 44 operating refineries in the U.S.S.R.[117] These are

""W'ilson, op. cit., p. 37.

Figure 5. —Soviet Oil Refinery Sites



SOURCE: Office of Technology Assessment

well distributed, with some bias toward the older producing regions-Central Russia, Volga-Urals, North Caucasus, and Azerbaidzhan regions in the western part of the country. One very large refinery is situated in West Siberia. The geographic distribution puts a heavy strain on the overburdened Soviet rail system which, as the previous section indicated, is relied upon for the transport of refined oil products. This fact may have contributed to an apparent change in refinery building policy. While the Soviet predilection has been for expanding refinery capacity by adding to existing sites, there are now plans for the construction of new refineries. Four of these came onstream during the Tenth FYP period in the Ukraine, Belorussia, northeast Kazakhstan, and Lithuania,[118] but plans for others in Central Asia, Eastern Siberia, and southern Kazakhstan have experienced delays.

The quality of Soviet refined products is notoriously poor, the result of inadequate planning and investment in a sector that was ill-prepared to deal with the rapidly increasing volume and variety of the crude oil that began to be produced in the 1950's and 1960's. A large share of refinery output continues to be in the form of residual fuel oil (called "mazut") that is used extensively in electricity generation. One consequence of inadequacy in the refining industry has been an emphasis on the export of crude oil rather than products. Even with the enormous increase in oil prices after 1974, the U.S.S.R. could earn more hard currency from refined product exports. However, export potential is constrained by product quality and product mix.

Nor has the refining industry in the past coped in an altogether optimum fashion with domestic needs. A chronic and pressing problem, for instance, is the large share of heavy fuel oil in the product mix. This is accounted for by the lack of appropriate secondary refining capacity to produce other products. One result is that fuel oil is burned in cases where natural gas would be a more rational and economic fuel. The task facing the U.S.S.R. is to lower the overall share of fuel oil in the product mix and raise that of other products. This will require rationalizing selected refineries through the installation of secondary refining equipment.

The quality as well as the mix of products must also be raised. One example can be found in motor fuels and lubricants. In the past, poor quality automotive products have tended to decrease the efficiency and life span of the machinery and to increase the requirements for repairs and maintenance. The U.S.S.R. has thus made a concerted effort to improve the quality and quantity of such products. In 1970, for instance, the share of high-octane gasoline in total gasoline output was 50 percent; in 1979, this share reached 94 percent.[119] Similarly, the quality of diesel fuel, as measured by its sulfur content, has been improving. In 1965, only 40 percent of Soviet diesel fuel had a sulphur content of 0.5 percent or less. The rate is now over 95 percent, and about 47 percent of Soviet diesel fuel has a sulfur content of less than 0.2 percent. Some sense of the practical consequences of such an improvement may be gleaned from the fact that, according to Soviet calculations, an engine that will run some 57,000 km on diesel fuel with a l-percent sulfur content will last nearly 89,000 km on diesel with 0.2 percent sulfur.[120] In addition, reductions have been made in the losses of oil and oil products during the refining process.

Such improvements have required advances in refining technology and considerable investment in the refining industry. Further alteration and improvement of the refined product mix will require additional large capital expenditures and additional efforts to improve technology. The past and potential contributions of the West in these efforts are discussed below.

[118] Ibid.

[119] Campbell, *Trends . . .* , op. cit., p. 47; Wilson, op. cit., p. 39.

[120] Ibid.

THE SOVIET GAS-PROCESSING INDUSTRY

The associated gas produced with oil, "casinghead gas," can be used in unprocessed form to fuel power stations or it can be processed to separate the liquid petroleum gases. In the past, the U.S.S.R. typically vented or flared this gas. Now, however, efforts are being made to collect and process it. Between 1975 and 1979, production of casinghead gas rose from 29 to 36 bcm, an overall utilization rate of some 69 percent. The Tenth FYP specifically addressed the problem of utilizing the large amounts of casinghead gas being produced (and flared) in West Siberia by planning construction of gas-processing facilities in that region. This work has fallen behind schedule, but the present FYP calls for additional refineries and envisages that by 1985 West Siberian casinghead gas will be fully utilized,

WESTERN TECHNOLOGY IN THE SOVIET REFINING INDUSTRY

The U.S.S.R. has purchased large amounts of oil refining equipment and technology from East Germany and Czechoslovakia, as well as from Japan, France, Italy, and Britain. Western purchases have tended to consist of entire refineries rather than of component parts, and the primary U.S. contribution has been in provision of design and engineering services to Italian and Japanese construction firms (see ch. 6).

To implement planned improvements in refining, the U.S.S.R. will probably require additional Western assistance, although with the exception of computing that might boost efficiency, the technologies involved are not advanced. These include secondary refining techniques such as hydrocracking and catalytic cracking. In the West, microprocessors and minicomputers are used extensively in refinery operations. Although the Soviets use computers in all of their refineries, microprocessors are found only in the largest and most important, and are, con-

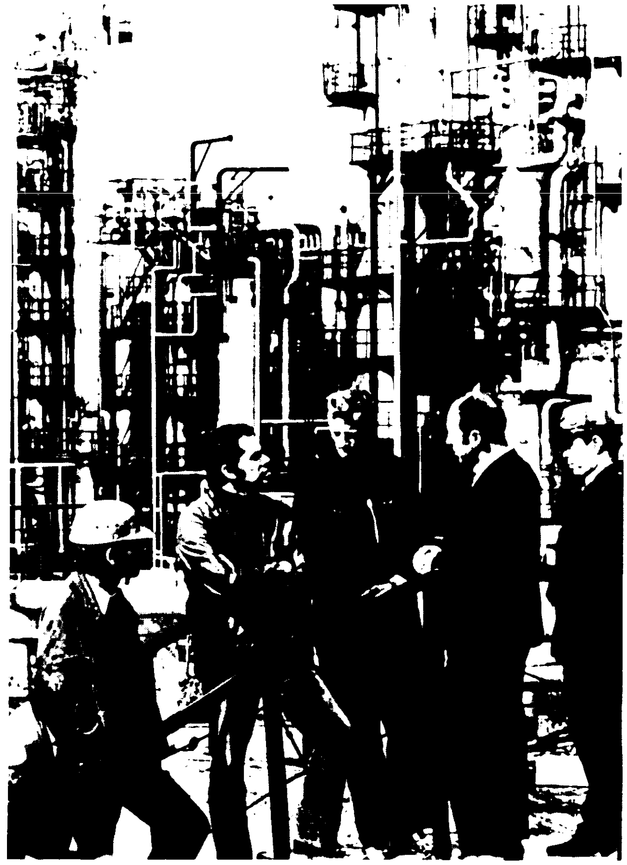


Photo credit TASS from SOVFOTO

French technicians at a French hydrocracking plant in the Bashkir ASSR

servatively speaking, several years behind those used in the West. The need for microprocessor- and minicomputer-based refinery control systems will continue to grow in the U. S. S. R., particularly as the product mix is restructured. So far, the purchase of such systems does not seem to have been accorded high priority, although some minicomputer- and microprocessor-based systems have been included in sales of larger units destined for refineries. The U.S.S.R. has the hardware base to design and implement such systems itself, but it lacks experience in building the software and associated control devices.

It is likely that systemic constraints and incentives will impede the development and introduction of computerized refinery process control systems much more than will problems with the technology. Western purchases may accelerate improvements in efficiency, but from the present signals, it appears that the U.S.S.R. will continue to rely predominantly on domestic developments.

SUMMARY AND CONCLUSIONS

Discussion of the Soviet oil refining industry is inhibited by lack of data, but a few generalizations are possible. Soviet priorities in this sector lie in building more new refineries in West Siberia and the East, near sources of supply and markets. In addition, emphasis is now being placed on improving both the refinery product mix and quality. If past patterns persist, these changes in the refining industry will take place with the aid of infusions of Western technology and equipment, particularly of complete refineries. On the other hand, if oil production does not continue to increase, expansion in refining capacity will not be necessary.

OFFSHORE

INTRODUCTION

The extensive development of offshore oil and gas deposits, i.e., deposits in lakes, seas, and oceans, is a relatively new phenomenon in both the U.S.S.R. and the West. Although it is generally believed that the U.S.S.R. has a promising offshore potential, production from offshore deposits has not yet made a very noticeable impact on overall output.

Most of the equipment and technology employed in the Soviet offshore sector has been either directly purchased from the West or reproduced from Western designs. As new offshore deposits are identified and developed, the need for additional sophisticated offshore equipment will grow. The degree of priority to be accorded offshore development in the Eleventh and Twelfth FYP's is not clear.

This section briefly reviews the techniques and equipment necessary to find, produce, and transport offshore petroleum, surveys the state of Soviet practice in these areas, and describes the past and potential contribution of Western technology to offshore development.

OFFSHORE EXPLORATION AND PRODUCTION

Offshore and onshore exploration of oil involve essential the same processes. An energy source, usually compressed air, is used to generate an impulse capable of penetrating the Earth's crust. As the energy is reflected and refracted by the underlying geological structures, it returns to the surface in the form of echoes that are detected by sensors (hydrophones). Arrays of hydrophones towed behind a seismic survey ship are used to detect the returning echoes. The information is then processed in roughly the same manner as onshore data are processed.

Modern seismic survey ships employ sophisticated computer systems to control the precise timing of the bursts of compressed air and to preprocess the data collected from the hydrophores. Computers, linked with satellite navigation systems, provide a precise fix on the position of the ship. The positioning of the hydrophone arrays is also controlled by the computer.

Offshore exploratory drilling is accomplished using basically the same equipment as onshore, the major difference being the platform on which the drilling equipment is placed. Three major types of movable platforms are presently available—jackups, semisubmersibles and drilling ships.

Jackup rigs generally employ three or four hydraulically operated "legs." The rig is towed to the drilling site where the legs are extended downward to the ocean floor. The entire rig is then raised clear of the water line to permit drilling operations. Modern jackups are currently limited to working in depths no greater than 300 ft.

The semisubmersible rig is a refinement of the jackup. Semisubmersibles are constructed on two or more pontoons on which the rig floats, and either self-powered or towed to the drilling site. Once over the site, the pontoons are partially flooded to provide a stable platform from which to drill. These rigs are either anchored into position or employ a dynamic positioning system. They operate in water depths up to 1,500 ft and can drill to 25,000 ft.

Drill ships represent the state-of-the-art in offshore drilling. The ship is usually of standard design with a drilling rig mounted in the middle of the deck. When the ship is over the drill site, it is either moored with anchors or a dynamic positioning system is employed. A dynamic positioning system uses a series of computer-controlled thrusters in conjunction with a set of sonar beacons placed on the ocean floor to maintain the ship's position over the drill site. A modern dynamically positioned drill ship is capable of exploratory drilling in water depths up to 6,000 ft.

After the exploratory drilling phase is complete, the same well logging process as in onshore wells is used to determine the size of the reservoirs and the possible flow rates. If production is warranted, the reservoir can be developed from an artificial island or a fixed platform production rig, the latter being most common. Once the well is dug and the casing cemented, special subsea wellhead completion equipment is fastened to the casing. This unit is remotely controlled and establishes the rate of production from the well.

Fixed platform rigs differ from exploration rigs in their degree of mobility. These rigs are erected on platforms that have been firmly embedded in the ocean floor. Once the platform is in place, up to 65 development wells may be drilled from the platform using offset directional drilling techniques. Where ice floes make the use of a fixed platform impractical, however, artificial islands may be employed. Artificial islands and fixed platforms are limited to use in water depths of no more than 1,500 ft. Production drilling to greater depths will require new designs such as tension leg platforms or compliant guyed towers. Finally, the petroleum is brought to shore either via pipeline or tanker.

THE SOVIET OFFSHORE INDUSTRY

The offshore regions of the U.S.S.R. offer enormous potential for oil and gas production. It has been estimated that of the 8 million km^2 of total Soviet shelf area, 2.5 million km^2 are promising for the discovery of petroleum. The most attractive regions are the Arctic, Baltic, Black, Caspian, and Okhotsk Seas.[121] Some drilling has taken place in the Sea of Okhotsk off Sakhalin Island (using Japanese equipment; see ch. 11), and in the Black and Baltic Seas, and limited exploration of Arctic waters in the Barents and Kara Seas has begun, but Soviet offshore experience so far has been largely confined to production from shallow waters in the inland Caspian Sea.

Development of the Caspian dates to the 1920's, when earthen causeways were built into the Sea. These were later replaced by fixed pile-supported and trestled platforms, and drilling proceeded from these and from small natural islands. The full potential of the Caspian is only now beginning to be realized, however, as the U.S.S.R. develops the capacity to explore and drill in waters greater than 200 m (600 ft). A major discovery in 1979, the "28th April" deposit, has spurred interest in continuing Caspian exploration and development,[122]

Exploitation of the Caspian, and even more importantly, of the other promising offshore regions is constrained by the status of Soviet deep-water technology. Although the

[121] Campbell, *Trends* . . . , op. cit., pp. 23-44.
[122] Wilson, op. cit., pp. 49-50.

Tenth FYP called for the modernization and augmentation of offshore drilling capacity, this upgrading has not proceeded as rapidly as planned. The Soviet stock of domestic offshore equipment currently consists of seven jackups (three of which are obsolete) and two semisubmersible rigs.[123] The inadequacy of this equipment base is attested to by the extent of Soviet dependence on Western offshore equipment.

THE CONTRIBUTION OF WESTERN OFFSHORE TECHNOLOGY

The U.S.S.R. has purchased or contracted for offshore exploration, drilling, and production equipment from a wide variety of countries, including the United States, France, Holland, Finland, and Japan (see ch. 6). Its own recently acquired ability to build jackups and semisubmersibles is the product of Western technology imports, and it has contracted with a Finnish firm for three dynamically positioned drill ships for use in Arctic waters. These ships are based on a Dutch design, and are being fitted with the latest Western drilling and subsea completion equipment. It is believed that these ships will provide the Soviets with their first deep drilling and subsea completion capabilities.[124]

In addition to purchases of equipment and technology, the U.S.S.R. has entered into joint offshore development projects with other nations. These include the Sakhalin project with Japan, and the Petrobaltic consortium, which at present involves cooperation between the U.S.S.R., Poland, and East Germany in exploring in the Baltic Sea. The consortium is now using a jackup rig built by a Dutch firm and furnished with drilling equipment of U.S. origin.

SUMMARY AND CONCLUSIONS

The U.S.S.R. obviously wishes to expand its offshore activities and capitalize on its great potential. However, its own offshore capabilities are still in their infancy, and purchases of Western equipment and technology will probably continue to be crucial to offshore development in the foreseeable future. Given the fact that exploration in most offshore regions has not even begun, it is difficult to imagine significant offshore production occurring before the end of the present decade.

[123] Ibid., p. 96.

[124] *Directory of Marine Drilling Rigs*, 1980-81.

THE PROSPECTS FOR SOVIET OIL PRODUCTION IN 1985

The prospects for Soviet oil production in the next 5 years have been the subject of controversy ever since CIA's 1977 prediction that Soviet oil output would peak at 550 to 600 mmt (11 to 12 mbd) and then drop sharply to 500 mmt (10 mbd) or less by 1985. The CIA has since revised its estimates, but the fact remains that its original work has largely set the terms for the entire Soviet energy debate, with experts ranged on different sides of what have become the central Soviet energy questions: will oil output peak in the 1980's, and if so, when; can a production plateau be maintained, and if so, how long; if oil output begins to drop, how sharp a decline can be expected?

Leaving aside for the present the issue of whether oil production does indeed constitute the key to the future of the Soviet energy balance (this point is treated below), this section will discuss the prospects for Soviet oil production in 1985 and 1990, identifying for the purposes of this analysis reasonable best and worst case estimates.

Table 17 summarizes recent projections of Soviet oil production. As the table shows, the lower limit is represented by the most re-

Table 17.–Soviet Oil Production Forecasts, 1985 (million metric tons)

Million tons	Date of forecast
1. 500-550	April 1981
2. 560-610	June 1981
3. 600	1979
4. 605-655	1979
5. 612-713	1978
6. 620-645	1980
7. 620-645	August 1981
8. 650-670	1979
9. 700	1980

SOURCES:
1. CIA, as reported in Joseph A. Licari, "Linkages Between Soviet Energy and Growth Prospects for the 1980's," paper presented at the 1981 NATO Economics Directorate Colloquium, Apr. 8-10, 1981. These numbers replace the 1977 estimates of 400 to 500 mmt.
2. OECD, Committee for Energy Policy, "Energy Prospects of the U.S.S.R. and Eastern Europe," June 26, 1981.
3. Robert Ebel, "Energy Demand in the Soviet Bloc and the PRC," June 1979.
4. Leslie Dienes and Theodore Shabad, *The Soviet Energy System* (Washington, D.C.: V. H. Winston, 1979), table 53, p. 252.
5. Herbert L. Sawyer, "The Soviet Energy Sector: Problems and Prospects," Harvard University, January 1978, quoted in George W. Hoffman, "Energy Projections—Oil, Natural Gas and Coal in the U.S.S.R. and Eastern Europe, *Energy Policy, pp. 232-241*.
6. Soviet Eleventh FYP target.
7. U.S. Defense Intelligence Agency, "Allocation of Resources in the Soviet Union and China—1981." Statement of Maj. Gen. Richard X. Larkin before the Joint Economic Committee, Subcommittee on International Trade, Finance, and Security Economics, Sept. 3 1981.
8. Jeremy Russell, Shell Oil.
9. David Wilson, *Soviet Oil and Gas to 1980*, Economist Intelligence Unit Special Report No. 90. This report was published just after the Soviet plan target was released. In a foreword, the author reasserts his belief that oil production of 700 mmt is achievable and attributes the lower Soviet plan to an apparent decision to divert resources from oil to gas production. EIU's 1990 target of 750 mmt, which is discussed below, is not disclaimed.

cent forecast of the CIA and the upper by a publication from the British Economist Intelligence Unit (EIU). The U.S.S.R. own Eleventh FYP figures fall between. Using this universe, OTA has posited best and worst case scenarios for Soviet oil production in 1985 of 645 and 550 mmt (12.9 and 11 mbd) respectively. These are not predictions. Rather, OTA has selected plausible high and low output figures that can be used to illuminate the energy problems and opportunities facing the U.S.S.R. The basis for these scenarios can best be understood through an examination of the assumptions and reasoning behind the differing forecasts shown here. The following sections, therefore, compare the arguments bolstering the table's high and low estimates–700 mmt (14 mbd) and 500 to 550 mmt (10 to 11 mbd).

Differing estimates of future Soviet oil production have been based on two separate but related sets of arguments. one concerns Soviet oil reserves; the other the state of Soviet oil production practice and technology. Seemingly irreconcilable differences between diverging forecasts can be traced to different assumptions and expectations with respect to each of these.

SOVIET OIL RESERVES

Introduction

Oil production over any given period of time obviously depends in part upon the quality, quantity, and accessibility of the resources in the ground, Reserves are the portion of this resource base that has been identified. They are important in determining both cumulative production and annual rates of output. Unless the rate of additions to reserves keeps pace with or exceeds the rate of production, output cannot remain stable indefinitely or rise over long periods.

Discussion of oil reserves anywhere in the world can be confusing, first because the standards of classification and definition employed by analysts are not always identical; and second, because the concept of a reserve is meaningful only within the context of some standard of economic feasibility. This means that as economic conditions or available technology change, amounts of oil ascribed to different reserve categories will change. This complex situation is compounded in discussions of the U.S.S.R. both because the Soviet system of reserve classification and nomenclature is very different from that employed in the West, and because Soviet oil reserve information is an official state secret. Western analysts must, therefore, calculate their estimates of Soviet reserves from intermittent and sometimes inconsistent bits of information. It is hardly surprising that analysts working from different data bases should arrive at differing conclusions.

In sum, two major points *must* be stressed. First, estimates of reserves are not static. As additional research, exploration, and development drilling proceed, reserves in any category may be redesignated to higher or lower classifications. Second, given the variety and subtlety of reserve classification systems, extreme care must be taken in interpreting differing reserve estimates. It is important to ascertain the definitions and other assumptions upon which such estimates are based.

The U.S. and Soviet Systems of Classification

Briefly, two different nomenclatures are employed in the United States. According to the American Petroleum Institute, reserves may be either measured, inferred, or indicated. These are referred to as proved, probable, or possible by the U.S. Geologic Survey. In both cases, categorization is by two sets of criteria, the degree of geological assurance that the oil exists, and the economic feasibility of producing it.

Soviet categories–A, B, C_1, C_2, D_1, and D_2— are also broken out according to the degree of exploration and appraisal drilling that has been carried out and some inexplicit criteria of economic recoverability. Only in the most general sense can Soviet reserve categories-be made to correspond to those used in the West. Indeed, Western analysts have disagreed over the relations between the two classification systems.

Low and High Soviet Reserve Estimates

The CIA and EIU figures for Soviet oil reserves for the most part form the lower and upper limits of the estimates that have appeared in the West. While the CIA has estimated approximately 4.1 bmt (30 billion bbl) of what it calls "proven" reserves, the EIU study gives a range of 14 to 15 bmt (102 to 110 billion bbl) of what it calls "proven and probable" reserves. Only one reserve figure has slightly exceeded EIU's–16 bmt (120 billion bbl), published by the Swedish group Petrostudies.[125] On closer examination, these figures appear to be based on different nomenclatures, different standards of comparability between Western and Soviet definitions, and different evaluations of the abilities of the Soviet oil industry.

The CIA produced a figure for proved reserves that it believes represents a realistic estimate of economically recoverable oil given present technology. It must be noted that this definition yields a conservative estimate. Nor is CIA sanguine about Soviet prospects for additional to reserves. To replace the oil produced between 1976 and 1980, the U.S.S.R. would have had to have found 2.9 bmt (21 billion bbl). According to CIA, this amount exceeded gross discoveries during 1971-75 by roughly 50 percent.[126] Reversing the decline in discovery rates would require increasing exploratory drilling to what CIA believes to be an unlikely extent. The best hope for reserve additions in the 1980's in this analysis, therefore, becomes luck—new finds of giant or supergiant fields near enough to existing infrastructure to allow their quick development.

At the opposite end of the spectrum, EIU does not believe that the present Soviet oil reserve situation is a constraint on near- and medium-term production. The EIU study adopts the same vocabulary as the CIA—"proved," and "probable' '-but it offers no explanation of the meanings assigned to these words or how they are correlated to Soviet categories.

Conclusions

The basis on which these high and low reserve estimates rest is in large part that of subjective judgments about the level of technology, the production costs, and the amount of time necessary to exploit deposits of oil in different stages of development and exploration. CIA, given its own evaluation of Soviet petroleum technology, has applied very strict criteria to its estimate. EIU appears to be far more sanguine about the ability of the Soviets to recover more oil from their existing fields and to develop new fields

[125] Petrostudies has received widespread publicity for forecasts of Soviet oil reserve and production potential far in excess of those found elsewhere. Most Soviet energy experts regard Petrostudies' claims as so sweeping as to be highly unreliable.

[126] CIA, "Prospects . ," p. 23.

within the time frame of current planning periods. This difference in outlook and interpretation is also reflected in the two assessments of other aspects of Soviet oil industry practice.

SOVIET OIL PRODUCTION CAPABILITIES

In addition to its low estimation of Soviet ability to make sufficient additions to reserves to support increased production in the absence of new giant discoveries, CIA's analysis of the prospects for Soviet oil output rely heavily on its evaluation of Soviet production practices and its expectations that the U.S.S.R. would be unable to significantly improve these by 1985 or 1990. The EIU study on the other hand is optimistic about Soviet ability to meet plans to improve its oil industry performance and technology. Among the most important areas of disagreement between the two analyses are waterflooding and other enhanced recovery techniques, drilling, and equipment manufacture.

CIA appears to have departed from some aspects of its original 1977 treatment of waterflooding which, as noted above, presented an overly simplistic—and therefore misleading—picture of the magnitude, trends, and consequences of this practice. But the overall judgment would seem to remain: The U.S.S.R. has engaged in a basically short-sighted policy of overexploiting its largest deposits through a method that can lead to sharp production declines once a field has been exhausted. Should this occur at Samotlor, the consequences for the entire Soviet oil industry would be immense—particularly since new finds do not appear to have been keeping pace with the rate of production. Moreover, emphasis on maximum production has led to concentration on development drilling over exploratory drilling. CIA doubts the Soviet's ability to achieve the increases in both of these activities necessary to improve the discovery rate and to continue to increase production. This judgment rests in turn on doubts over the availability of Soviet drilling crews and the quality and quantity of Soviet drilling equipment—including bits, pipe, and rigs—which can be produced during the present plan period. Nor does CIA believe that Western equipment and technology can be imported in sufficient quantities and utilized efficiently enough to make up for these lacks.

The EIU analysis takes precisely the opposite tack. Although it notes past cases of underfulfillment of oil industry targets, it emphasizes those areas in which the U.S.S.R. has made progress (in number of meters drilled, for instance) in the past 5 years. More significantly, it reports Soviet Eleventh FYP targets and development plans–for number of drilling crews, number of new exploratory and development wells to be drilled, drill crew productivity, average new well yield, production of more and/or better bits, drill pipe and rigs, utilization of sophisticated tertiary recovery techniques—and forms its assessment of the future of the industry on the assumption that these will be fulfilled.

These "pessimistic" and "optimistic" assessments of Soviet oil production prospects therefore rest in large part on judgments of Soviet ability to greatly improve on a wide variety of oil industry parameters in the next 5 years. Past patterns of plan underfulfillment, poor performance in a number of areas (equipment quality, drill rig and crew productivity, for example), and above all the inefficiencies and obstacles introduced by the nature of the Soviet economy and incentive system, all tend to advise caution in counting too heavily on fundamental changes in likely Soviet achievements, On the other hand, improvements have been made in a number of areas, and there is enough evidence of increased investment in the oil industry to suppose that such improvements will continue.

The Soviets' own Eleventh FYP reflects diminished expectations for oil production. Its upper limit of 645 mmt (12.9 mbd) is, after all, only slightly higher than the

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original underfulfilled 1980 target of 640 mmt. Moreover, the average annual rates of growth envisaged in the plan are substantially lower than the rate of 1.9 percent achieved between 1979 and 1980. Whether the new target is more the reflection of a deliberate investment decision to grant lower priority to oil in favor of gas (and possibly nuclear power development) or more a response to Soviet recognition that greater oil production would be unachievable in the absence of giant new finds, it is impossible to tell. In any case, those who before the plan targets were revealed believed that gains to as high as 700 mmt by 1985 were technically achievable are unlikely to abandon that view.

OTA has chosen the Soviet Union's own target of 645 mmt for its best case scenario. Such an outcome seems achievable if a number of things go well for the U. S. S. R., including new finds, improvements in domestic manufacturing capacities, improvements in oil industry productivity, and continued—if not greater-imports of Western equipment to compensate for domestic shortfalls and inadequacies. The CIA projection is a plausible worst case, given the opposite set of expectations about Soviet domestic accomplishments and the continuation of present relatively modest levels of Western imports. However, the likeliest outcome is probably somewhere between 550 and 645 mmt— i.e., for the next 5 years, the U.S.S.R. through increased effort and investment in its oil industry may well be able to hold production fairly stable at 1980 rates.

THE PROSPECTS FOR SOVIET OIL PRODUCTION IN 1990

The variables affecting possible Soviet oil production in the latter part of the decade are numerous and complex, and the exercise even of selecting plausible best and worst cases for analytic purposes is highly speculative. Here too, the universe of responsible estimates that have appeared in the West are bounded by CIA and EIU, CIA projecting a fall to about 350 to 450 mmt (7 to 9 mbd) and EIU an increase to 750 mmt (15 mbd). The central question once again is whether production will fall, rise, or remain stable. Assuming no new giant finds in the immediate future, no massive infusions of Western equipment, and no hands-on assistance in offshore development, OTA believes that projections that see Soviet oil production rising significantly between 1985 and 1990 are excessively optimistic. A more realistic best case assumes that output could be held stable at 1985 levels or slightly below. A plausible worst case would see an absolute decline in production, although perhaps not as serious as that envisaged by CIA. However, it must be emphasized that the difficulties that the U.S.S.R. will probably still be experiencing in 1990 may not be permanent. As the U.S.S.R. develops capabilities to explore and exploit its offshore and East Siberian resources, oil production eventually could begin to rise once more. This at least is the expectation of both the U.S. Defense Intelligence Agency and the U.N.'s Economic Commission for Europe.[127]

[127] U.S. Defense Intelligence Agency, "Allocation of Resources in the Soviet Union and China— 1981. Statement of Maj. Gen. Richard X. Larkin before the Joint Economic Committee, Subcommittee on International Trade, Finance, and Security Economics, Sept. 3, 1981.

THE PROSPECTS FOR SOVIET GAS PRODUCTION, 1985 AND 1990

The attention surrounding the Soviet oil production controversy has until recently obscured the significance of gas in the Soviet energy future. That significance should not be underestimated. Gas has been called the "ace in Soviet energy plans . . . a critical cushion for the uncertainties faced by the planners with respect to other sources of (energy) supply."[128] Indeed, the key question for Soviet energy availability in the present decade may not be whether oil production is about to decline, but rather whether the U.S.S.R. can exploit its tremendous gas reserves quickly enough for gas to become the critical fuel in the CMEA energy balance. While it is important that gas not be regarded as the U.S.S.R.'s easy energy panacea–as this chapter has pointed out, gas development faces numerous obstacles—discussion of the prospects for gas production to 1990 is essential to understanding the opportunities confronting the Soviet Union during this period. This section discusses the range of **estimates** of Soviet gas production in 1985 and 1990 and, as with oil, posits OTA's best and worst case scenarios.

Soviet proven natural gas reserves are enormous. This fact is uncontroversial. In 1980, these were variously estimated in the West at 25 to 33 trillion cubic meters (tcm), some 40 percent of the world's proven reserves.[129] The U.S.S.R.'s own **estimate is some** 39 tcm. This is the thermal equivalent of 31.6 billion tons or 231.6 billion bbl of oil. These orders of magnitude have not been disputed, and the size of the proven reserve base alone is enough to support many years of substantially increased production. Indeed, Soviet gas reserves are equivalent in magnitude to Saudi Arabian oil reserves.

Constraints on gas output, therefore, rest not on resources, but on the ability of the gas industry to deliver its product to consumers in the U.S.S.R. and in Eastern and Western Europe. Specifically, these constraints concern the ability of the U.S.S.R. to substantially increase its gas pipeline network—and this in turn entails obtaining quantities of large diameter pipe and compressor stations—and to provide adequate infrastructure for the industry and its workers. These problems are exacerbated by the fact that the bulk of the U.S.S.R.'s established reserve base lies in West Siberia.

The Eleventh FYP calls for increasing gas output from its 1980 level of 435 bcm to 600 to 640 bcm by 1985, and Soviet projections supplied to the Secretariat of the United Nations Economic Commission for Europe for 1990 are 710 to 820 bcm. These and the range of production estimates that have appeared in the West are summarized in table 18. As this table shows, there is very little disagreement over these figures. For 1985, it seems reasonable to adopt the range in the Soviet plan as worst and best cases. Actual production will probably fall in between. The

Table 18.—Soviet Natural Gas Production Estimates, 1985-90 (bcm/mbdoe)

	1985 (bcm)	1985 (mbdoe)	1990 (bcm)	1990 (mbdoe)
1.	605	9.9	750	12.3
2.	600	9.8	700	11.5
3.	660	10.8	—	—
4.	600	9.8	750	12,3
5.	598-647	9.8-10.6	–	—
6.	600	9.8	765-785	12.5 -12.9
7.	600-640	9.8-10.5	710-820	11.6-13.4

SOURCES:
1 Leslie Dienes and Theodore Shabad, The Soviet *Energy System* (Washington. D C V H Winston, 1979), table 53 p 252
2 CIA, as reported in Joseph A Licari, Linkages Between Soviet Energy and Growth Prospects for the 1980's, paper presented at the 1981 NATO Economics Directorate Colloquium, Apr. 810, 1981
3 Herbert L Sawyer, "The Soviet Energy Sector Problems and Prospects, " Harvard University, January 1978, quoted in George W Hoffman "Energy Projections—Oil, Natural Gas and Coal in the U S S R and Eastern Europe, *Energy Policy, pp 232-241*
4 David *Wilson Soviet Oil and Gas to 1980* Economist Intelligence Unit Special Report No 90
5 "Situation et Perspectives du Bilan Energetique des Pays de L'Est," *Le Courier des Pays de L 'Est. No* 216, March 1978, median and low hypotheses only
6 Jonathan P Stern, *Soviet Natural Gas Development to 1990* (Lexington, Mass Lexington Books, 1980), table 151, p 178
7 Soviet Eleventh FYP and projections submitted to the Secretariat of the U N Economic Commission for Euro De

[128] Dienes and Shabad, op. cit., **p.** 287.
[129] Stern, op cit., **pp.** 22-3; Wilson, op cit., **p 44**

situation for 1990 is more complex. Gas production in the 1980's will be determined, above all, by the level of Western exports of pipe and compressors available to the U. S. S. R., and a worst case should posit little or no Western assistance. OTA has, therefore, chosen as its worst case assumption production of about 665 bcm. This level of output is approximately halfway between the high case for 1985 and the low end of the Soviets' own 1990 projection. OTA's best case for 1990 is 765 bcm, the midpoint of the Soviet range. The midpoint, rather than the upper end of the target was chosen in the face of the extraordinary magnitude of the Soviet range.

SUMMARY AND CONCLUSION

The heart of the Soviet oil and gas industry is now firmly established in West Siberia. Despite the harsh climate, difficult terrain, and the remoteness of this region, the U.S.S.R. has over the past 10 years built an extensive petroleum industry there, In 1980 West Siberia accounted for over half of oil and nearly 36 percent of gas output. While there is general agreement that the prospects for gas are bright, the continued viability of the oil sector, as well as the ability of the U.S.S.R. to remain the world's foremost oil producer and a net oil exporter, has recently been the subject of controversy in the West.

This controversy was initiated by a 1977 CIA report that contended that Soviet oil production would drop precipitously to as low as 400 mmt (8 mbd) by 1985, occasioning the possibility that the CMEA as a bloc or even the U.S.S.R. itself would have to import oil. CIA has now raised its estimates and has clarified its position on CMEA oil imports, i.e., it does not foresee the U.S.S.R. itself buying oil on world markets although it still contends that the CMEA as a bloc would be in a net deficit position. In fact, CIA's basic argument has changed little: it believes that in the absence of new major finds, Soviet oil output will peak and decline sharply before the end of the decade.

CIA production estimates are the lowest to appear in the West. Others have projected substantial increases in Soviet oil production in the present decade. These judgments appear to be based on a different interpretation of the available Soviet reserve data, different evaluations of Soviet oil industry practice, and a higher estimation than CIA's of the ability of the U.S.S.R. to overcome its own institutional problems in improving a variety of industry parameters.

OTA's own survey of the state of Soviet oil equipment and technology has shown that, while the U.S.S.R. has selectively utilized Western imports in a number of areas, it produces large quantities of most of the items it needs. For the most part the Soviet difficulty is not that it lacks the know-how to provide for itself, but that the structure of its economy and its incentive system are such that it has difficulty producing sufficient quantities of high-quality equipment. Items purchased from the West are usually of higher standard than those that can be produced at home, and this reinforces their ability to compensate for domestic shortfalls. In addition, there are three areas in which the West probably can make contributions to the Soviet state-of-the art. These are computers, associated software, and integrated equipment sets for oil exploration; offshore technology, still in its infancy in the U. S. S. R.; and high capacity submersible pumps.

Soviet oil industry performance as measured in equipment productivity and number and depth of new wells is improving, and Western equipment must clearly have contributed to these improvements, although such contributions are impossible to quantify. There is every sign that the U.S.S.R. would like to continue to benefit from Western help, but it does not appear to be ready to depart from past practice and import massive volumes of equipment or request hands-on assistance.

OTA believes that CIA's estimates may be taken as a worst case outcome for Soviet oil production, but that it is also possible that the Soviets could achieve their own target for 1985 of 645 mmt (12.9 mbd), which would represent a modest increase over 1980 production of 603 mmt. Likelier than either of these extremes, however, is that production will remain about stable. This assumes no major changes in Western export or Soviet import policy, and no major new discoveries of oil.

Gas production is far less controversial. Here the proven reserve base is immense and production is constrained mainly by the lack of pipelines to carry the gas to consumers. Western large diameter pipe and pipeline compressors have made dramatic contributions in the past, and there is every indication that continuation of such imports will be crucial throughout the decade. The Soviets' own plan targets of 600 to 640 bcm gas production in 1985 (equivalent to 9.8 to 10.5 mbd of oil, up from 435 bcm in 1980) seem to bound plausible worst and best outcomes in this sector. By 1990, production could exceed 750 bcm (12.3 mbd of oil equivalent), contingent on continued infusions of Western pipe and pipeline equipment.

While these large increases in Soviet gas production will not signify the end of the U.S.S.R.'s near- and medium-term energy problems, gas can certainly help to compensate—both in domestic consumption and in export—for oil production that has leveled off or even slightly declined.