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The Role of Western Equipment in Soviet Oil and Gas Development

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The Role of Western Equipment in Soviet Oil and Gas Development

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formation available of 15 July 1984 as used in this report.

The USSR has achieved its present status as the world's leading producer of crude oil and natural gas largely through the use of domestically manufactured equipment. It has turned to the West for selected high-quality and advanced state-of-the-art equipment and technology to obtain higher operating performance and reliable service, as well as to overcome shortages of key items. In recent years the Soviets have undertaken a program to enhance both the quality and quantity of equipment manufactured domestically, and this effort will continue into the 1990s. Thus far, however, the inefficiencies of the Soviet economic system have hindered both the production of high-quality petroleum equipment and the efficient use of advanced techniques and equipment acquired from the West

During the 1970s the USSR purchased some $5 billion worth of Western oil and gas equipment. The impact of these imports was larger than their share in total Soviet oil and gas equipment supply would suggest, however, because the imported equipment was used to cover shortages in the USSR's own supplies or to cope with particularly difficult technical problems. Especially important among these acquisitions were:

- A turnkey plant to produce high-quality drill bits (from the United States).
- Gas-lift equipment for two major oilfields in West Siberia (from France, with key components from the United States).
- An assembly yard for producing offshore drilling platforms (from France).
- Large-diameter line pipe, pipelayers, and turbine compressors for the gas pipeline network (from West Germany, Italy, France, and the United States).
- Equipment and chemical plants for enhanced oil recovery (EOR) projects (from the United States, France, Italy, and West Germany)

The US embargo imposed in late 1981 on delivery of oil and gas equipment and technology to the USSR introduced some chaos into planning and supplying the Siberia–to–Western Europe gas export pipeline project. At the same time, the action appears to have spurred the Soviets to complete pipelaying earlier than originally scheduled and to accelerate development of domestically manufactured gas turbines of 16-megawatt (MW) and 25-MW capacity. Moreover, the sanctions were not supported by US allies, and the Soviets obtained necessary equipment and supplies—albeit with some delays—from Western Europe and Japan. Some of the equipment so obtained—notably heavy-duty pipelayers—would otherwise have been exported from the United States. The Soviets have indicated their intention to continue favoring non-US suppliers of petroleum industry goods and services

Secret
SOV 84-10153X
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We expect that the increasing capability of the Soviet gas turbine industry will lead to reduced dependence on imports of Western turbines and compressors for future gas pipeline construction. A less ambitious pace of pipeline construction during 1986-90, combined with some realization of Soviet plans to increase domestic production of high-pressure large-diameter pipe, will tend to diminish the need for pipe imports. Moscow, however, will undoubtedly be mindful of the potential political influence that West European steel producers could bring to bear in their countries at a time when additional purchases of Soviet gas are under consideration. Accordingly, the USSR will almost certainly continue to purchase substantial amounts of West European pipe

During the remainder of the 1980s, the cost and speed of certain other phases of Soviet energy development will depend substantially on the level of imports of Western oil and gas equipment and know-how. The need for high-quality, high-capacity electric submersible pumps to cope with increasing water cuts and lower well flow rates—coupled with the inability of Soviet industry to supply those units—will cause Moscow to continue seeking them from US firms (at present the sole suppliers). Despite frequent statements that they intend to avoid procurement involving equipment or licensing of US origin, the Soviets have been active in procuring such equipment (directly or through a third-country supplier). In addition to submersible pumps, they particularly want specialized US equipment for sour gas wells. Any current US monopoly on the supply of these items will not last indefinitely. Other Western suppliers could develop the capacity to provide such technology to the USSR in 18 to 36 months. Other Western equipment and technology needed by the Soviets include special inhibitor chemicals and technology to deal with the ravages of corrosion (now widespread in the oil and gas fields of the USSR) and catalytic cracking units for refining a greater percentage of gasoline and other light petroleum products from a barrel of oil

Soviet dependence on imports of Western equipment and technology will probably increase as exploration and development shift to deeper and more complex onshore and offshore deposits, especially as exploitation of the deep sulfurous petroleum deposits in the Pre-Caspian Depression and Central Asia proceeds. Exploration and development of Arctic offshore deposits in the Barents and Kara Seas will surely require large amounts of Western equipment and technology. The pace of Arctic offshore development will depend on the degree to which the Soviets are willing to permit major Western firms to man and manage operations and, possibly, on the availability of Western financing of project costs measured in tens of billions of dollars.

Contents

The Role of Western Equipment in Soviet Oil and Gas Development (U)

Introduction

The USSR produces most of its own petroleum equipment, but domestic manufacturers have been unable to meet the rising demand of the oil and gas industries for more and better equipment. The lack of adequate amounts of high-quality equipment has hampered efforts in several areas of the petroleum industry, including drilling and production in West Siberia and the enhanced oil recovery program.[1]

In the late 1970s, the Soviets showed increasing awareness of the difficult problems confronting their oil industry—rapidly rising drilling requirements, increasing need for fluid-lift equipment, and a decline in the quality of oil reserves at new fields. Efforts were undertaken to expand and improve domestic equipment manufacturing capabilities with indigenous and imported technology, as well as to import a wide variety of equipment to support the oil and gas development programs.

This paper examines the importance of technology transfer from the West to the Soviet oil and gas industries in the 1970s and early 1980s and discusses the impact of Western sanctions. The implications for petroleum development later in the 1980s are discussed against the backdrop of likely Soviet progress in domestic technology and manufacturing capability.

Availability and Adequacy of Domestic Equipment

The USSR is one of the world's major producers of petroleum equipment. Nonetheless, equipment shortages have constrained oil production for at least a decade. The existence and extent of the shortages are confirmed by [ ] reported that in the late 1970s domestic equipment supply was adequate to meet only 70 to 80 percent of the oil industry's needs. Shortfalls—both qualitative and quantitative—in equipment supply continue to threaten fulfillment of production goals in the oil industry.[2] In December 1983, for example, a Supreme Soviet committee on energy censured the enterprises responsible for production of oil industry equipment, referring specifically to shortages of drilling and production equipment in West Siberia.

The ongoing inadequacy of equipment supply reflects, in part, the poor quality of metallurgy, fabrication, and quality control in the manufacture of Soviet petroleum equipment. Press reports are rife with complaints about the poor quality of domestic oil and gas field equipment, especially drill pipe, casing, drill bits, drilling rigs, and submersible pumps.

Plants located in and around Baku in the Azerbaijan SSR produce about 70 percent of the oil and gas field equipment used in the USSR.[3] This area, located on the western shore of the Caspian Sea, was one of the country's earliest oil-producing regions, and the petroleum equipment industry arose there. Although the center of oil-producing activity shifted to the Volga-Urals region in the 1950s and 1960s and then to West Siberia, production of most of the oilfield equipment has remained centered around Baku. With increasing emphasis on the development of oil and gas deposits in West Siberia, the need for special steels and equipment to withstand the rigors of arctic service continues to grow. However, the plants responsible for manufacturing such steel and equipment are not meeting the qualitative or quantitative requirements,

[1] Soviet oil production rose at an average annual rate of 7 percent during 1961-81, but averaged less than 1 percent in 1982-83. The decline in output reported for October 1983 through March 1984 reflects serious production problems in West Siberia. In contrast, Soviet production of natural gas—which rose dramatically at an average annual rate of nearly 12 percent during 1961-83—shows every prospect for large annual increases to continue through the 1980s.

Soviet statistics on total oil production include both crude oil and gas condensate. The Gas Ministry is responsible for all offshore production—oil as well as gas. Gas Ministry oil output thus includes offshore oil output, as well as gas condensate produced at gasfields.

[2] As a result of shortages, the Soviets have increasingly turned to Western suppliers (see discussion of reliance on Western equipment and technology, pages 8-12).

[3] In many plants, petroleum equipment is produced along with other equipment; more than 70 plants throughout the USSR contribute to the overall output of oil and gas industry equipment.

. . . A Riddle Wrapped in a Mystery Inside an Enigma . . .

That the USSR is the world's largest producer of crude oil (12.35 million barrels per day in the second quarter of 1984) is no mystery. But how it succeeds in this is somewhat of an enigma. The Soviets themselves implicitly raise the question. The 7 July 1984 issue of Sotsialisticheskaya industriya, *for example, reported on the proceedings of a roundtable conference in Baku, attended by representatives of the oil and gas ministries, Gosplan, the Tyumen' oil and gas organization, the Azerbaijan Republic oil and gas industry, and various scientific, engineering, and construction organizations. The immensity of the problems facing the Soviet oil industry (and, inferentially, the consequent high cost to the economy) is suggested by the newspaper's report of the session:*

- *Although Tyumen' production of oil "will continue to grow," its extraction will increasingly require modern pumping techniques and equipment and a "fundamentally different approach" to the exploitation of the fields.*
- *Ambitious development plans—including tripling of the number of wells—will boost the demand for rig equipment, well pumps, and maintenance and repair equipment and services.*
- *Even present demands for drilling equipment are not being met; shortages of rig equipment range up to 50 percent, and only 30 to 50 percent of the demand for well-repair equipment is being met.*
- *Oil industry machine-building plants have outmoded equipment and lack automated machinery; there is a severe lag in new plant construction and upgrading of existing facilities.*
- *Up to one-third of the wellhead and pressure-control devices delivered have serious manufacturing defects.*
- *Demand for better equipment has driven the oilfield operators to establish their own machine-building sections.*
- *Development and application of new technology take too long; for example, a new, much more efficient pump was first tested in 1970, but production is not scheduled until 1986. Streamlining of decisionmaking and approval procedures is essential.*

In the face of these and other handicaps, the Soviets have been able to maintain output by using their traditional tactic of massive infusion of capital and labor. From 1975 to 1982 the share of the increment in industrial investment allocated to the oil sector rose from 13 percent to 43 percent, and the labor force of the Oil Ministry increased by an estimated 30 percent, compared with about 10 percent for industry as a whole.

even though efforts are being made to rebuild, re-equip, and expand existing facilities. Major plants producing oil and gas equipment are listed in the appendix.

The Soviet oil and gas industries obtain some equipment from Eastern Europe. Romania has supplied small quantities of deep drilling rigs; blowout preventers, Christmas trees, and other wellhead equipment; and drill pipe, pumps, and pump rods. The other East European countries have provided a variety of equipment, including specialized oil refinery equipment from East Germany and Czechoslovakia. Although the acquisition of equipment from Eastern Europe supplements domestic production qualitatively as well as quantitatively, it does not satisfy the need for the higher technology, higher quality equipment available from Western manufacturers.

Exploration Equipment

Soviet geologists use a wide array of techniques in their exploration effort—satellite imagery to locate promising areas, regional and localized seismic surveys, geochemical mapping, and well logging. However, progress in exploration is impeded by technological limitations in several key areas. For example, Soviet technology in magnetometers and gravity meters lags considerably that available in the West. Efficient performance of regional surveys requires the highly sophisticated sensing technology embodied in these instruments, as well as advanced data-processing capability. Rather primitive domestic seismic hardware and software force the Soviets to rely on techniques that can identify large geologic structures but which lack the resolution to identify smaller, more subtle traps. Soviet seismic techniques also yield poor results below 3,000 meters, hampering deep explorations.

Although the Soviets employ common-depth-point (CDP) profiling methods, as well as "weight dropping" and "vibration" wave-propagation techniques in lieu of explosives, they generally lack the computers and sophisticated software to process seismic data into usable, high-resolution form. Remote areas, such as East Siberia and the offshore Arctic, will be difficult to explore without vastly improved geophysical surveying equipment and technology. During 1983, for example, various domestic manufacturers of geophysical equipment were chastised in the Soviet press for continuing to supply outdated equipment and technology and for not expanding capacity to meet the needs of the petroleum industry

Drilling Equipment

Soviet drillers have received heavy criticism for contributing to the sharply declining rate of growth in Soviet oil production. The major problem in drilling centers on the poor quality and inadequate quantity of drilling equipment—rigs, drill pipe, tool joints, bits, and blowout preventers—combined with poor execution in the field. The restraining influence of drilling problems on oil production is compounded by sharply rising drilling requirements stemming from increasing well depths, decreasing new well flow rates, and increasing depletion. The average well depth is increasing while new well flow rates are decreasing Also, the USSR's lack of high-quality drill pipe (capable of withstanding the stresses of the more efficient rotary drilling) forces drillers to rely principally on turbodrills, which become less efficient as well depths increase. Although the turbodrill is a noteworthy Soviet development, it is much more limited than rotary drilling for exploration and development of deep deposits at varying depths under the high-stress conditions that are increasingly being encountered

Turbodrilling

In turbodrilling, the drill pipe itself does not rotate and transmit torque to the drill bit as in rotary drilling. Only the lower section of the downhole motor and bit rotate during turbodrilling operations. Elimination of torque on the drill string permits the Soviets to sidestep many of the problems associated with the use of domestically manufactured low-quality, heavy drill pipe and tool joints (which could not be used in rotary drilling). Higher axial loading by the heavier drill pipe and faster rotation of the bit also increase the turbodrill's rate of penetration initially. In addition, a stationary drill string is less apt to experience drill string failure and twist offs.

Two characteristics of the turbodrill tend to reduce the productivity of drilling operations when it is employed. First, the turbodrill's high rate of bit rotation leads to increased abrasion of the cutting surfaces and often, in turn, to more frequent bit replacement—a time-consuming operation. Secondly, maintaining the rotational speed of the bit at increasing depths requires a reduction of the weight on the bit and thus results in a lower rate of penetration

The USSR produces about 500 to 600 oil and gas drilling rigs annually (see table 1). Most of these rigs are manufactured at two plants in the Volga-Urals region—the Uralmash Plant in Sverdlovsk and the Barrikady Plant in Volgograd. A new drilling rig plant built near Sverdlovsk could raise Soviet production to as much as 800 rigs per year. The average service life of a Soviet rig is about six years, compared with about 15 to 20 years for rigs built in the West.

Table 1
USSR: Production of Petroleum Equipment [a]

	Deep-Well Pumps (*thousand units*)	Turbodrills (*sections*)	Drilling Rigs for Development and Deep Exploration Drilling (*complete units*)	Refinery Equipment	
				Thousand Tons	Million Rubles
1970	77.0	6,562	480	127	92
1971	81.0	7,384	497	139	NA
1972	81.0	7,694	512	157	NA
1973	82.0	8,103	516	159	NA
1974	85.0	9,328	483	172	NA
1975	85.1	9,780	544	171	123
1976	86.1	9,354	511	164	151
1977	83.2	9,700	503	171	170
1978	95.0	9,016	505	180	183
1979	95.0	8,976	473	188	195
1980	91.6	9,270	521	184	201
1981	95.0	9,459	541	NA	209
1982	96.0	9,291	558	NA	210

[a] *Narodnoye khozyaystvo SSSR 1982 g.*, p. 156, *v 1980 g.*, p. 167; *v 1975 g.*, p. 261.

There are chronic complaints from the oil industry that the rigs currently available are too heavy, immobile, and inadequate; especially lacking are compact portable rigs for use in northern climates. Rig shortages have been reported, particularly in West Siberia, where the planned doubling of drilling from 1980 to 1985 will be difficult to achieve without a major increase in drilling brigade productivity, a greater supply of high-quality rigs, and improved availability of skilled drilling crews.[4]

Soviet drill pipe performs adequately when drilling relatively shallow wells (less than 2,000 meters deep) with the turbodrill, but in deeper drilling where rotary rigs are used, the poor-quality steel used in Soviet drill pipe often fails. Problems related to the quality and quantity of drill pipe and casing produced in domestic plants are sporadically cited in the Soviet press. In 1980, for example, a news account indicated that 4 to 6 percent of the casing delivered to well sites was unusable. Insufficient quantities of drill pipe and casing were listed as factors causing the underfulfillment of West Siberian drilling targets in 1979 and 1980.

Widespread use of the turbodrill in the USSR has been effective in the shallow, hard rock formations in the Volga-Urals basin and for directional drilling from cluster-drilling pads in West Siberia. The addition of a second mud pump on West Siberian rigs improved turbodrill performance and extended its reach to depths of 2,500 meters (from about 1,800 meters in much of the Volga-Urals region).

[4] [ ]

Attempts are being made to improve the turbodrill by adding more sections to the hydraulic turbine (to maintain torque while reducing the turbine speed), increasing pump pressure, and installing better antifriction bearings. At the present time, the USSR produces more than 9,000 turbodrill sections annually. Such a production rate implies that most of these units wear out rapidly, generally lasting less than one year

The quality and performance of drill bits produced in the USSR improved during the 1970s and early 1980s, but Soviet bits are only one-quarter or less as efficient as bits of comparable design made in the West. However, with the newly built turnkey drill bit plant at Kuybyshev[ ] operating at its design capacity of 100,000 bits annually, the average quality of Soviet bits will be improved markedly. (See pages 9-10 for details of this technology transfer.) The Soviets reportedly produce over 500,000 bits of all types annually, an amount roughly 1.3 times the total non-Communist output

Production Equipment

Artificial Lift. As oil wells age and flow rates decline because of low reservoir pressure or high water cuts (percentage of water in the oil-water mixture produced from an oil well), artificial-lift equipment—rod-and-beam (sucker-rod) pumps, submersible pumps, or gas-lift units—is installed to maintain or increase oil production by lifting greater volumes of fluid.[3] As of 1 January 1980, 86 percent of the 82,500 producing oil wells were being worked by artificial lift—51,600 by rod-and-beam pumps, 17,200 by electric submersible pumps, and 2,300 by gas lift. During 1971-79, Soviet production of rod-and-beam pumps rose by nearly 50 percent, and in 1980 these pumps were used in 62 percent of all producing wells. The rod-and-beam pumps, which do not embody high technology, have the worst service record of all the artificial-lift equipment produced in the USSR. They have an average service life of only 90 days compared with 350 days for those produced in the United States. Breakage of pump rods, poor sleeve bearings, and sleeve misalignments are the main causes of rod-pump malfunctions.

The output of submersible pumps in the USSR more than trebled during 1971-79, from 2,200 to about 7,000. As of 1980, about one-fifth of all producing wells in the USSR used submersible pumps, and these wells accounted for about one-third of total oil output. The quality of the Soviet-made pumps, however, is far inferior to those manufactured in the United States. Their capacity—a maximum of about 1,200 barrels per day (b/d) for the largest Soviet units—is less than half that of units purchased from the United States during the 1970s and is inadequate for many of the high-yield wells in West Siberia. Although Soviet plants are attempting to improve the capacity and quality of the pumps, the Soviet press continues to criticize their quality. This suggests that the Soviets will continue to seek high-quality, high-capacity submersible pumps from the United States—at present the sole supplier

The USSR produces a small amount of gas-lift equipment. Because of the high frequency of repairs on pumping equipment, some Soviet petroleum officials have become more interested in the use of the gas-lift process for producing oil. In 1969, Western compressor-pressured gas-lift equipment was installed for the first time at the Pravdinsk oilfield in West Siberia. As a result of experience with this equipment, the Soviets installed their own compressorless gas-lift equipment at the Uzen' field in Kazakhstan and at the supergiant Samotlor field in West Siberia, using high-pressure gas available at each of these oilfields. In 1980, less than 3 percent of the total producing wells in the USSR were using the gas-lift process

[3] Rod-and-beam pumps are used for low-productivity oil wells, and high-capacity electric, centrifugal submersible pumps are used to lift large volumes of fluid. Gas lift is a process that artificially increases the flow of fluids from a well by continuous injection of gas into the well bore at relatively high pressure. Essentially, gas lift is a low-maintenance alternative to high-capacity submersible pumps, although the initial equipment and installation costs are higher.

[ ]

The initial capital investment for most gas-lift systems is higher than that for pumping units because of the need for gas pipelines, infrastructural equipment, and—in most cases—compressors. However, maintenance costs are much lower for gas-lift wells; wire line tools and special workover rigs permit rapid workover of wells with minimum downtime, resulting in the use of as few as one-tenth the number of personnel to maintain the wells

High-Pressure, High-Temperature, Corrosion-Resistant Equipment. As production of oil and gas from deep reservoirs (below 2,500-meter depths) increases, so does the need for high-pressure, corrosion-resistant downhole and surface equipment that the Soviets are currently unable to produce. Special heat-and-corrosion-resistant metals, alloys, seals, threads, and fittings are used to withstand the severe operating conditions encountered in sour gas deposits at Orenburg and at the Astrakhan', Karachaganak, and Tenghiz fields in the Pre-Caspian Depression. In the latter fields, as much as half of the gas produced consists of hydrogen sulfide (H_2S) and carbon dioxide (CO_2). Even trace amounts of these contaminants, when combined with the salts in water, cause stress cracking of the metal used in oil and gas well equipment. Corrosion has become a major problem at Samotlor, the Soviet Union's largest oilfield, where H_2S has severely damaged all of the wells and flow lines in the oilfield gathering system, as well as the waterflood pressure maintenance system. At the present time, therefore, special inhibitor technology and corrosion-resistant, high-pressure equipment must be obtained from the West

Enhanced Oil Recovery (EOR).[4] The EOR program in the USSR was not given priority until 1976, although the importance of increasing oil recovery from existing fields had been recognized since the early 1960s. The optimism and confidence expressed for this program by high-level Soviet officials has not been realized. As of 1982, the commercial output of oil obtained by EOR techniques was only about 60,000 b/d, or about 0.5 percent of total oil production

The Soviets have experimented with EOR programs in many fields, emphasizing thermal and chemical applications. However, difficulties have been caused by limited domestic production capabilities, as well as by technical and administrative ineptitude. Soviet industry has not been able to build the steam generators needed for thermal recovery or to produce sufficient amounts of surfactants or polymers for chemical and polymer flood operations.[5] Moreover, management and financial problems have plagued the Soviet EOR program. Most notably, the Deputy Minister of the Petroleum Industry in charge of enhanced recovery projects was fired in 1981 for falsifying data and for gross waste of EOR materials. Since this scandal was made public, the Soviets have postponed several EOR projects, citing both management and technical difficulties, as well as high costs

Offshore Technology and Equipment

The USSR is looking to its offshore areas to provide future production of oil and natural gas. Soviet and Western geologists believe these areas have significant oil and gas potential. To date, however, production of oil and gas from offshore deposits—primarily from shallow-water and near-shore fields in the Caspian Sea—accounts for less than 2 percent of national output for either fuel.

Soviet capabilities for offshore operations are much further behind the state of the art than those for any other phase of the petroleum industry. Although the USSR is attempting to upgrade offshore technology by strengthening domestic manufacturing capabilities for producing equipment such as rigs, platforms, and subsea production equipment, the high-technology requirements have forced the Soviets to acquire modern equipment from Western suppliers or reproduce equipment of Western design. As new offshore deposits are located and developed—probably in deeper water and under more difficult climatic conditions—the need for additional sophisticated equipment and know-how will rise sharply.[6]

[4] Enhanced oil recovery (EOR) refers to recovery of oil from a petroleum reservoir beyond that economically recoverable by conventional primary methods (using natural reservoir energy) and secondary methods (artificial maintenance of reservoir energy and artificial lift). EOR employs physical, chemical, or thermal means to alter the forces that hold the oil in place in the reservoir rock

[5] Polymers, organic compounds characterized by a large-chain molecule formed by thousands of repeating blocks called monomers, are added to injected water to increase its efficiency as a front to drive oil toward producing wells. Surfactants, essentially detergents that affect the interfacial tension between oil and water, are used to facilitate the flow of oil out of the rock pores.

[6] Further details of operating offshore equipment obtained from the West and cooperative offshore ventures with Western firms are given on pages 11-12 and 1[illegible]

Pipelines

In the USSR, pipeline transportation accounts for all of the gas, about 90 percent of crude oil, and 10 to 15 percent of petroleum products transported. Most of the Soviet oil pipeline network is relatively new, having expanded from about 17,000 kilometers (km) in 1960 to almost 73,000 km by the end of 1982. Nearly 80 percent of the larger diameter—1,020- and 1,220-millimeter (mm)—oil pipeline network was laid from 1970 to 1982

The Soviet oil pipeline industry is largely self-sufficient; there is no required equipment that cannot be produced from domestic sources. The Soviets do import, on a selective basis, pipelayers, bulldozers, surge control valves, and insulating materials to speed construction and to improve the operational capacity and service life of their pipelines. Soviet pipeline construction techniques and pipe manufacturing technology are inferior to those in the West. Pipe welding and insulation are frequently of poor quality, pipeline deterioration often occurs more rapidly than expected, and corrosion takes a heavy toll on pipeline facilities. The Soviets are already having to replace sections of some relatively new oil pipelines.

The increased emphasis on natural gas pipeline construction dating from the late 1970s (the length of the gas transmission pipeline system was 144,000 km at the end of 1982), made the USSR more heavily dependent on Western large-diameter (1,420-mm) line pipe, pipelayers, ball valves, controls, and—to a lesser degree—turbine/compressor sets.

To date, the bulk of domestically produced large-diameter line pipe is unsuited for high-pressure natural gas transmission service, especially in the arctic regions where the largest producing fields are located. The Soviets are just beginning to successfully use domestically manufactured steel to produce large-diameter pipe for high-pressure service, a multilayered pipe manufactured in short sections. Imported Western steel plate is now being manufactured into 1,420-mm line pipe, but annual output of this pipe is less than 1 million tons

[ ]

Most Soviet gas pipelines have been equipped with domestically manufactured turbines and compressors. Until recently, however, the units produced were too limited in capacity or inadequate in quality to perform efficiently on 1,420-mm pipelines.

Moscow has an ongoing program aimed at improving the quality and capacity of domestically manufactured pipe-handling and pipelaying equipment. Until recently, heavy-duty pipelayers had to be imported from the United States or Japan to handle 1,420-mm-diameter pipe efficiently. However, a new, more powerful and stable pipelayer (TG-502), designed for laying 1,220-mm and 1,420-mm pipe, was put into series production in 1980, and some 400 to 500 units were to have been produced in 1983

A priority program to develop high-capacity turbine compressor sets for the gas pipeline network has been under way since the December 1981 US embargo. Serial production of a 16-megawatt (MW) industrial gas turbine (GTN-16) began in 1982, and prototypes of a 25-MW unit (GTN-25) were undergoing testing in 1982-83 with some 14 units targeted for production in 1983. Although the Soviets claim that the GTN-25 turbine is on a par with Western industrial 25-MW turbines, the new Soviet unit has not been adequately field-tested and [ ] the Soviet press have reported negatively on many aspects of its development. Given the USSR's poor track record in the design and production of heavy-duty industrial gas turbines, it is unlikely that it could quickly bring newly developed equipment (GTN-16 and GTN-25) to a high level of reliability and efficiency. Moscow is, however, undertaking—apparently with some success—a program of converting retired NK-8 turbofan aircraft engines into mechanical-drive turbines, thereby increasing the availability of 16-MW turbines for gas pipeline service.

Oil Refining

The USSR produces the bulk of its own refining equipment in numerous petroleum and chemical machine-building plants throughout the country. Imports, however, have served to supplement domestic supplies. Standard 120,000-b/d-capacity pipe stills manufactured in East Germany are being used to increase primary distillation capacity at existing refineries, as well as to provide the first primary distillation capacity at several new refineries. Catalytic reforming and hydrogen treating units imported from Czechoslovakia since the mid-1970s are being used to upgrade the quality of light products. During the past several years, Western firms have delivered several catalytic reformers to upgrade motor gasoline quality, as well as calciners to produce high-quality petroleum coke. The only known hydrocracker in operation in the Soviet Union is a Western-built unit installed at the Ufa refinery in the mid-1970s. Soviet attempts to copy this unit at the Omsk refinery and expand its capacity have not been successful to date

Planned expansion of secondary refining capacity to reduce the yield of heavy products and raise the yield of high-quality light products is lagging badly. The program calls for the extensive installation of modern catalytic cracking, delayed coking, hydrocracking, hydrodesulfurization, catalytic reforming, and hydrogen-treating processes. We do not believe that the Soviets have the domestic manufacturing capacity to produce all of the units required. The Soviet program for building catalytic cracking units has been stalled for some time, but there is now some indication that technical difficulties are being overcome. Even with successful implementation of new designs, however, the domestic producers will be unable to construct the substantial number of units required to improve light-product supply during the remainder of the decade. Negotiations with Western firms to provide such equipment have been reported, but no firm contracts have been awarded.

Gas Processing

Construction of gas-processing facilities has taken a growing share of total gas industry investment in the USSR since the mid-1970s. The Soviets are able to provide nearly all of the primary processing equipment for these facilities in the West Siberian region, where low-sulfur gas is being produced in increasing volume. However, secondary- and tertiary-stage processing equipment needed for propane-butane and ethane separation, as well as sulfur removal equipment at the sour gas deposits of Orenburg, Astrakhan', Tenghiz, and Central Asia, must be obtained from the West

Reliance on Western Equipment and Technology

The Soviets have in the past compensated for petroleum equipment shortcomings or met needs for particularly difficult operations by importing from the West. During the 1970s, the USSR ordered or bought about $2 billion worth of Western oil equipment, which was only a small share of its total equipment needs. More than 18 million tons of large-diameter pipe have been imported since 1968, together with ball valves and a substantial number of turbine compressor sets for expansion of the high-capacity pipeline network supplying gas for domestic use and export to Western countries. The value of imported Western equipment used on the gas pipeline system during the 1970s approximated $3 billion. These imports of Western equipment had an impact far out of proportion to their cost, however, because the imported equipment enabled the USSR to cover critical shortages in its own supplies or to cope with particularly difficult technical problems.

Major Soviet purchases of petroleum equipment and technology from the West during the 1970s included the following:

- High-capacity electric centrifugal submersible pumps, gas-lift equipment, well-completion units, drill pipe, steam generators, seismic equipment, and pipeline equipment (especially line pipe, pipelayers, and compressors).
- Plants to produce key equipment—such as [ ] drill bit plant at Kuybyshev.
- Equipment for the yards at Baku and Astrakhan' that assemble offshore drilling and production platforms.

Exploration Equipment

The USSR has made major purchases of collection and process-related geophysical equipment from Western firms. In 1976, for example, [ ] completed a $6 million deal that included outfitting three complete digital exploration crews with 24 special-purpose off-the-road vehicles, a portable field recording unit, eight remote-processing minicomputer systems, and associated processors. In 1978, a $13 million sale was completed [redacted] to equip six more digital crews. A significant number of the estimated 300 digital exploration crews in the USSR have been supplied with equipment from West Germany and France in addition to that from the United States.[10]

According to [redacted] sources, as many as 30 to 35 US minicomputer systems specifically designed for geophysical work have been delivered to the USSR. Some of these systems were shipped with software packages, and Geosource trained 80 Soviet operators in the United States. This company also installed the systems in the USSR and gave extensive on-site field training. Soviets have also purchased a fully equipped ship for offshore exploration and have had several of their own ships outfitted in the West for exploratory operations.

Soviet well-logging instruments lag Western equipment both in accuracy and efficiency. One factor that constrains the efficiency of the Soviet instrumentation is the relatively small number of sensors downhole at a given time. New exploratory and development wells measured with Western equipment may be completed much more efficiently and with greater accuracy than wells logged with domestic equipment.[11] In most cases, this would have a positive effect on oil and gas production.

The USSR has purchased well-logging equipment from US and French firms, but not in amounts that substantially enhance the Soviet petroleum industry's overall capabilities. To improve logging operations appreciably, the USSR would have to buy enough Western hardware to equip at least 100 crews and also allow Western technicians on site to operate the equipment and train Soviet workers. Moreover, Soviet drilling-fluid technology would have to improve to reduce borehole contamination, which can block off many hidden oil- and gas-bearing zones.

Drilling Equipment

Moscow recognizes the importance of high-quality drill pipe and tool joints for its deep-drilling program, both onshore and offshore.[12] Purchase of high-quality drill pipe and tool joints from US, Japanese, and West European firms in recent years has allowed the Soviets to drill deep wells that now account for 5 to 10 percent of oil production and perhaps 20 percent of natural gas output.

[redacted] luring the past year, the USSR obtained about 3,400 tons of drill pipe from the Brazilian subsidiary of a US firm. The Soviets claim that drill pipe orders for an unspecified future period should average 6,000 to 10,000 tons per year. We believe that much of this pipe is to be used for offshore drilling operations. Discussions have been held since the late 1970s with Western suppliers for the purchase of a turnkey plant to manufacture high-quality drill pipe. [redacted]

During the 1970s, the USSR purchased a number of drilling rigs from Western suppliers, including at least 15 portable land rigs from Finland. Although rigs imported from the West represent only a small share of the total number of rigs available in the Soviet Union for use on land, they comprise a much more significant share—about one-third—of the emerging offshore drilling-rig park.

[10] Congress of the United States, Office of Technology Assessment, *Technology and Soviet Energy Availability*, 1981, p. 35

[11] Well logging entails the lowering of sonic, nuclear, or electrical measuring instruments into the borehole to test formations. Data are then recorded on porosity, permeability, fluid content, types of fluids, and the sequence and composition of the formations and the depths at which they occur

[12] Soviet press reports indicate that domestic steel fabrication plants continue to encounter problems in producing seamless tubular steel—drill pipe, tubing, and casing—in the quantity and quality needed in oil and gas field operations. Leakproof threaded tool joints and pipe connections are no less important than drill pipe casing and tubing in severe service.

Although the USSR has not purchased a large number of drill bits from the West, Soviet concern about drill bit quality was demonstrated in the purchase of a turnkey drill bit plant from [redacted] in 1978. This plant, located at Kuybyshev, is designed to produce 100,000 bits annually, 86,000 of which will have tungsten-carbide inserts and sealed-journal bearings. These US-designed bits should operate for long periods at the high rotational speed of Soviet turbodrills. Each currently being produced at Kuybyshev should replace two to four bits of domestic design produced at other Soviet plants. The new bits should also reduce downtime for bit replacement, thereby increasing rig productivity and reducing the need for rapid expansion of the rig park. [redacted] drill bit production at the [redacted] plant reached an annual rate of 100,000 units—the plant's design capacity—as of early 1984. Quality control problems persist, however, resulting in reduced penetration capability and shorter service life for the bits produced. More Western equipment has been ordered to deal with aspects of the quality problem, but other aspects probably stem from the inability of [redacted] to have provided all of the necessary technical training. Although superior to other Soviet-made bits, the new Kuybyshev bits have had a life of only 50 to 60 hours, about one-third that of comparable bits manufactured in the United States

The potential contribution of this US technology in terms of increased oil production is difficult to measure in isolation from such factors as the quality of drilling rigs and well-completion equipment and the incentives provided to drilling crews. However, we estimate that improved bit life resulting from use of the Kuybyshev bits could facilitate a 5-percent increase in drilling meterage with no increase in the number of rigs. Such an increase in drilling meterage could result in raising gross oil output by about 70,000 to 90,000 b/d.[u]

[u] Assuming an average well depth of 2,400 meters in the mid-1980s, the new bits could result in the drilling of 440 additional development wells annually. If, as is the case now, 15 to 20 percent of the additional wells are injection wells, the new bits could account for 350 to 375 additional producing wells. By the mid-1980s, the average well yield is likely to be 200 to 250 b/d. Thus, yield per well times number of additional wells would provide about 70,000 to 90,000 b/d of additional oil

Production Equipment

Approximately 1,200 high-capacity electric centrifugal submersible pumps were purchased from US firms during the 1970s. These pumps had a total nominal capacity of 3 million b/d of fluid (an average of 2,500 b/d per unit). Most of these pumps probably were used in wells where the water cut was about 50 percent and could be in operation for three to six months before a major overhaul was required. Therefore, depending on the length of repair, these US pumps could have accounted for a range of 500,000 to 1 million b/d of oil production annually during the latter half of the 1970s

After several years during which changing US export control policy clashed with Soviet interest in obtaining more pumps, a $40 million Soviet order for an estimated 400 US-made submersible pumps was approved for export in January 1984. In late March 1984 [redacted] the Soviets requested price quotations on four types of high-capacity submersible pumps from a US manufacturer.

By the early-to-mid-1970s, US compressor-pressured gas-lift equipment may have accounted for a 20-percent increase in annual oil output at the Pravdinsk field, as well as a 10-percent rise in the oil recovery rate.

In 1978 the Soviets undertook to expand gas-lift operations in West Siberia. A French firm (Technip) contracted to install compressor-type gas-lift equipment—gas compressors, manifolds, valves, and controls—in 1,800 wells at Samotlor; similar equipment was purchased for 600 wells at the Fedorovo field. Currently the Samotlor project is at least three years behind schedule because of construction delays. The Fedorovo project is nearing completion but has also been delayed and is experiencing operating problems. If installed on schedule, the gas-lift equipment could have provided some 200,000 to 300,000 b/d of additional oil output beyond that otherwise expected from these fields. However, because of the delay, the window of opportunity for the most effective use of this equipment may have been missed: the water cut at Samotlor exceeded 50 percent in 1983 and is now higher than optimal for this mode of extraction. In the interim, the Soviets have admitted they are trying to copy the US gas-lift valves.

During the past six years, the USSR has entered into negotiations and has signed contracts with a number of Western firms for the supply of equipment, chemicals, and plants to produce CO_2 and surfactants for EOR. In the fall of 1977, an Italian firm, [redacted] was awarded a $24.5 million contract to build a plant for the annual production of 250,000 tons of surfactants. The plant was to have been completed by 1980, but no reports of its operational status are available. Two CO_2 liquefaction plants, valued at $38 million, were ordered from a West German firm [redacted] to support miscible flooding operations. One such plant with a capacity of 1 million tons per year was built near Tol'yatti for a miscible flood project at the supergiant Romashkino oilfield. The second plant, with a capacity of 400,000 tons annually, was to have been installed at Kemerovo in West Siberia, but no confirmation of its completion is available.

[redacted] the USSR purchased 15 high-capacity steam generators from a US firm in March 1978 for use in thermal EOR projects in five old oil-producing areas. None of these generators were placed in operation before mid-1980 because of the lack of competent Soviet personnel. In 1981 the Soviet [redacted] appropriated $81 million for purchasing US steam-injection equipment to increase oil production by 110,000 b/d in the Baku region and by 125,000 b/d at the Uzen' field in Mangyshlak. However, this equipment was not acquired because of the US embargo on sales of oilfield equipment in 1981 [redacted] efforts were under way in 1983 to obtain equipment for an EOR operation at the Uzen' oilfield at a cost of approximately $180 million. Other equipment has been obtained for an EOR project in Komi ASSR. Soviet petroleum officials have admitted that future purchases of steam generators would have to be made on a turnkey basis, because Soviet petroleum engineers and technicians have not been able to properly install and use equipment purchased from the West.

Western equipment and technology are indispensable for processing of gas streams containing high percentages of natural gas liquids that are contaminated with H_2S and CO_2. As the Soviets prepare to exploit new sour gas deposits such as Astrakhan', Karachaganak, and Tenghiz in the Pre-Caspian Depression, they are conducting negotiations with Western firms to provide specialized well-completion equipment, field gathering lines and manifold systems, gas plants, and sulfur-extraction equipment and technology.

Offshore Equipment and Technology

Most of the modern equipment and technology employed in Soviet offshore oil and gas exploration and production has been either purchased from the West or reproduced from technology supplied by Western firms. The Soviets have built five jack-up rigs copied from a Western-built unit imported in 1967. Their first semisubmersible rig was built in Finland with a US firm as contractor. It was completed in 1980 and placed in operation in the Caspian Sea early in 1982. Three more copies of this semisubmersible rig have been built at a French-equipped assembly yard at Astrakhan' and are now operating in the Caspian Sea. Finland has recently completed the delivery of three drillships to the USSR; two of these ships have conducted exploratory work in the Barents Sea, and the third operated southwest of Sakhalin in the fall of 1983 and is now off the coast of Vietnam. A joint agreement is currently being sought with Western firms for development of Barents Sea petroleum deposits. Large-scale development in the Barents Sea could be a multibillion-dollar undertaking involving massive infusions of Western technology and equipment.

At Vyborg, northwest of Leningrad, the Soviets have completed one semisubmersible offshore platform and currently are building two more. However, Finnish technical experts indicate that this yard is incapable of building rigs that are up to international standards because of a lack of technical personnel. The Finns believe that the Soviets will seek Western assistance to rehabilitate their rig-building program. Moreover, [redacted] the Soviets will need

Western-manufactured equipment—high-pressure blowout preventers, motion-compensation devices, and drilling and production control systems—for their offshore rigs

In addition to purchasing offshore equipment and technology, the USSR is conducting a cooperative venture with several Japanese firms to explore the offshore area around Sakhalin. The Soviets purchased one Western jack-up drilling platform (the Okha) and have ordered a second (the Ekhabi), which is being built in Singapore. They have leased geophysical survey vessels from Japanese and other Western suppliers and are negotiating with Western consortiums to provide production platforms for use in the Chayvo and Odoptu offshore oil and gas fields at the northeast tip of Sakhalin. However, commercial oil or gas production is not expected from this area before the late 1980s. The USSR also is a partner in a consortium (Petrobaltic) with Poland and East Germany to explore for oil and gas deposits in the Baltic Sea. This consortium is using a jack-up rig built by a Dutch firm and furnished with drilling equipment supplied by a US company.

Pipeline Construction and Equipment

Since the early 1960s, imported large-diameter line pipe has played a key role in Soviet construction of gas, and some oil, pipelines. During the 1960s, the USSR imported about 2.8 million tons of pipe, almost all 1,020 to 1,220 mm in diameter. Imports accounted for about 40 percent of total Soviet pipe supply for oil and gas pipeline construction during this period. During the 1970s, the Soviets began to expand their transcontinental gas pipeline network with 1,420-mm pipelines, but they were unable to produce high-quality steel plate for the manufacture of high-pressure line pipe. Thus, they were dependent on the West, primarily Japan and West Germany, for 1,420-mm pipe, as well as for steel plate for a small amount of 1,420-mm pipe produced by Soviet pipe mills. During 1971-80, total Soviet pipe imports amounted to an estimated 15 million tons, of which about 10 million tons were 1,420 mm in diameter

As the Soviets expanded the large-diameter gas pipeline network, domestic capacity to produce suitable turbine compressors was inadequate to meet demands. As a result, the USSR was forced to rely on US and West European firms to supply gas turbines and spare parts for a substantial number of compressor stations." During the 1970s, the West supplied approximately 300 gas turbines with capacities from 10 to 25 MW. The total installed capacity of Western turbine compressor units accounted for about 15 percent of total Soviet operating compressor capacity in the early 1980s.

On the recently built 1,420-mm gas export pipeline from the Urengoy gasfield to the Soviet export terminal at Uzhgorod, the USSR originally contracted with Western firms to install 120 25-MW and five 10-MW heavy-duty industrial gas turbines of US design. Because of the US embargo, however, the USSR decided to equip some of the compressor stations with Soviet turbines. The Soviets announced that as many as 22 of the 40 gas pipeline compressor stations would be equipped with Soviet turbines. However, US-designed 25-MW gas turbines are being installed at 14 of 20 compressor stations

The Impact of Sanctions

In December 1981, following the declaration of martial law in Poland, President Reagan embargoed exports of gas- and oil-related equipment to the USSR. Licensing controls were expanded to cover oil and gas refining and transmission equipment in addition to exploration and production equipment and technology. This action was aimed at stopping or retarding construction of the controversial gas export pipeline to Western Europe. In November 1982, the President removed controls for oil and gas transmission and processing equipment, thus reverting to the status in existence before December 1981—license review with a presumption for approval. In return for this action, the European allies of the United States agreed to cooperate in undertaking a number of multilateral studies designed to explore opportunities for increased Western economic and energy security.

The US sanctions have had both adverse and positive effects from the Soviet viewpoint. Adversely, oil production problems were exacerbated because Moscow could not acquire US high-capacity electric submersible pumps during the year of the sanctions. Lack of direct access to US high-pressure, corrosion-resistant blowout preventers and other oilfield equipment probably slowed exploration of new oil and gas fields north of the Caspian Sea. The embargo-retarded delivery of Western gas turbines and compressors for the gas export pipeline led the Soviets to install still unproven domestic gas turbines at several compressor stations. These changes in plans and the added confusion may set back the schedule for operation of the pipeline at full capacity, but it will not impair Moscow's ability to deliver the gas called for in existing contracts with West European purchasers on schedule. In fact, the pipelaying phase of construction on the export line was finished in record time—about 18 to 20 months. The US embargo was circumvented by [redacted] firms that delivered heavy-duty pipelayers and [redacted] supplied turbine compressor sets embodying US components and technology.

The embargo highlighted to Soviet leaders their country's vulnerability to sanctions and stimulated decisions to accelerate improvement of some domestic manufacturing capabilities. As a result, the USSR has made progress in manufacturing large gas turbines for gas pipeline service and heavy-duty pipelayers, increased quantities of large-diameter pipe, and improved the quality of modern exploration and production equipment. Moreover, the Soviets have been successful in contracting with non-US Western suppliers to obtain much of the equipment and technology they need

Soviet Reaction

The Soviets reacted to the embargo defiantly. They mounted a highly publicized campaign to build the gas export pipeline, touted as a top-priority project, ahead of schedule. When the US embargo was lifted in November 1982, the Soviet campaign continued, as Moscow was evidently determined not to be vulnerable to direct or indirect influence exerted by the United States. Completion of the gas export pipeline in record time was paralleled by the efforts of Soviet industry to accelerate the introduction of large pipelayers and large gas turbines for pipeline service. This response entailed some diversion of manpower and facilities, as well as disruption of planning and production of other goods, but the Soviet leadership was willing to pay the price.

The attitude of high-level Soviet officials regarding trade with the United States for petroleum equipment and technology has hardened in recent years because of the embargoes imposed since 1978. [redacted] stated in 1983 that there is no official Soviet policy against purchase of US petroleum equipment, but because of recent US policies it is unlikely that the USSR will purchase much US equipment in the future, especially if comparable equipment is available elsewhere. Moreover, he claimed that the Soviet Union would demand from US suppliers convincing documentary evidence of their ability to deliver the equipment.

[redacted] questioned the ability of US suppliers to guarantee that they will be able to honor contractual agreements to supply petroleum equipment and services to the USSR in the face of any future political action by the US Government. He stated that, without sanctity of contract, the Soviets would favor the purchase of West European, Canadian, or Japanese equipment over that from the United States whenever possible.

Despite the official Soviet reaction that the US embargo had not been effective, [redacted] high-level Soviet petroleum industry officials [redacted] 1983 [redacted] indicated that the sanctions had caused considerable disruption and delay in some energy construction programs [redacted]

Alternative Western Suppliers

[redacted] Available statistics on Soviet orders for Western oil and gas equipment reveal that the volume peaked sharply in 1981, when large orders were signed for the purchase of line pipe and equipment for construction of the Siberia-to-Western Europe gas pipeline. About $4.3 billion worth of orders were recorded in 1981, $1.3 billion in 1982, and only $825 million for 1983

Soviet oil and gas industry officials have been active in recent months searching for non-US Western suppliers capable of manufacturing US-designed equipment for onshore and offshore operations. Much of this effort has focused on acquiring state-of-the-art geophysical surveying vessels, deep-drilling and producing systems, and components for such systems—mostly related to exploration and development of Barents Sea oil deposits. The USSR is now seeking credits to finance the purchase of equipment in these categories

[redacted]

" Premium threads, used to connect sections of downhole tubing in a well, incorporate specially designed seals. They are considered essential to prevent leakage, especially in sour gas application

Initiatives in COCOM

An ad hoc group in COCOM was established in early 1983 to identify and consider the case for controlling high-technology items (equipment, materials, and technical data not now controlled), including those with oil and gas applications. The United States proposed a list of 21 oil and gas equipment and technology items deemed to meet the COCOM strategic criteria—that is, items having significant actual or potential military use by the USSR. (These items are summarized in 11 categories in table 2.) Bilateral discussions were held with most of our COCOM partners

The other COCOM nations were not completely persuaded by the US proposals and have not agreed to control all the items. If the proposed list were used by the United States as a basis for unilateral national security controls, firms that produce the included items could be denied US licenses even if COCOM refuses to include these items on its control list. But US leverage on the Soviet Union in the area of oil and gas equipment is limited and continually diminishing. US firms still have a unique contribution to make in providing certain specialized items of equipment—such as high-capacity submersible pumps—but even in these areas other Western countries could gear up to supply these items within a few years. Moreover, any reapplication of export controls or proposed COCOM initiative on technology that has no clearly identifiable direct military application is unlikely to be supported by US allies

The Role of Technology Transfer During 1984-90

The Soviet oil and gas industries have raised the level of domestic technology and equipment in use during the past few years, and steady improvements are likely over the remainder of the decade. However, as the USSR seeks to discover and develop new onshore and offshore oil and gas deposits, it will encounter

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Table 2
Strategic Oil and Gas Equipment
Proposed for COCOM Controls

Item	Application	Non-COCOM Availability	Potential Military Significance
Deep, submersible, high-pressure pumps with a capacity of at least 135 tons per day of fluid at depths greater than 600 meters (IL-1131)	Secondary oil recovery (to handle increasing volumes of water produced with oil)	None; could be developed in about two years	Nuclear propulsion systems (pressurized water reactors) on submarines, strategic underground petroleum storage sites.
Geophysical/seismic survey vessels including geophysical hardware and software systems (IL-1416), including positioning and navigation systems	Offshore oil and gas exploration	None for onboard high-technology equipment	Antisubmarine warfare; electronic countermeasures; detection and identification systems; improved command, control, attack, and evasion capabilities.
Navigation, direction-finding, radar, and airborne communications equipment (IL-1501), including satellite navigation equipment	Offshore oil and gas exploration	None	Targeting; reconnaissance; support of submarine-launched ballistic missile systems; antisubmarine warfare.
Acoustic and/or ultrasonic systems or equipment specially designed for locating underwater or subterranean objects	Oil and gas exploration (onshore and offshore)	None for offshore positioning equipment; none for side-scan sonar equipment; and Sweden for subbottom profiling equipment	Submarine navigation; underwater detection systems; antisubmarine warfare; weapons guidance systems; surveillance and fire-control systems.
Gravity meters and components thereof with an accuracy of 0.1 milligal (IL-1595)	Oil and gas exploration (onshore and offshore)	Sweden	Military inertial-guidance systems and mapping for land, sea, and air weapons systems.
Corrosion-resistant oil- and gas-producing equipment capable of operating in corrosive environments containing more than 10 parts per million hydrogen sulfide and carbon dioxide (IL-1100 NI)	Exploitation of sour gas/oil deposits	Argentina, Austria, Brazil, Mexico, Sweden, and Venezuela have limited capability to supply some of this equipment that is based on COCOM technology	Military applications requiring special materials, processing, and manufacturing techniques, and/or metallurgy for rocket and jet engines and new weapon systems where metal fatigue, failure, and wear are critical.
High-pressure/high-temperature oil- and gas-producing equipment capable of operating at pressures exceeding 350 atmospheres and at temperatures above 93°C (IL-1100 NI)	Exploitation of deep oil and gas deposits	Argentina, Austria, Brazil, Mexico, Sweden, and Venezuela have limited capability to supply some of this equipment that is based on COCOM technology	Military applications requiring special processing and manufacturing techniques, and/or metallurgy for rocket and jet engines and new weapon systems where metal fatigue, failure, and wear are critical.
Deep-well drilling rigs and systems capable of operating below 3,000-meter depths (IL-1500 NI)	Exploitation of deep oil and gas deposits	None for complete systems; Austria, Brazil, Finland, Mexico, Singapore, Sweden, and Switzerland have limited capability for some equipment items based on COCOM technology; USSR and Romania make systems of inferior quality	Manufacture of deep submersible vehicles; underground nuclear testing monitoring, and sampling; development of new weapon systems.
Magneto-telluric systems (IL-1500 NI)	Oil and gas exploration (onshore and offshore)	None at present in West; USSR (low quality)	Antisubmarine warfare; low-frequency communications systems.
Well-logging equipment and related computer hardware and software (IL-1500 NI)	Evaluation of oil and gas discoveries, especially deep deposits	None for complete systems; Austria, Hungary, USSR, Romania, Sweden, and Taiwan have limited capability to produce some items of inferior quality	Airborne electronic countermeasures; avionics; naval systems; antisubmarine warfare; underground nuclear testing; weapon systems.
Mud-logging equipment and technology and related computer hardware and software (IL-1500 NI)	Deep-drilling operations under high-pressure, high-temperature, and corrosive conditions	Very limited in terms of computer hardware and software	Airborne electronic countermeasures; avionics; naval systems; antisubmarine warfare (nonacoustic detection).

deeper and more complex geologic conditions—often in highly corrosive environments, under high pressure and temperature. These conditions will pose a substantial challenge to the equipment manufacturing sector, which thus far has been unable to meet domestic demand for high-quality petroleum drilling and producing equipment or advanced state-of-the-art production techniques and systems.

Moscow will continue to purchase Western oil and gas technology and know-how into the 1990s, especially that for finding and developing deep, less accessible onshore and offshore reserves. We believe future purchases will cluster into 10 broad categories:

- Oil and gas exploration equipment.
- Deep-well drilling equipment and technology.
- Fluid-lift and oil-treatment equipment.
- Offshore drilling and production platforms and related systems.
- Computers and automated control technology and equipment.
- Specialized corrosion-resistant drilling and production equipment for high-pressure, high-temperature service.
- Enhanced oil recovery technology and equipment.
- Gas pipeline equipment.
- Secondary oil-refining equipment.
- Gas-processing equipment.

The Soviets probably will continue to pursue approaches other than outright purchase for acquiring Western technology. They regularly collect information on Western-developed technology and equipment through open and covert means. They also use joint-development projects such as the Sakhalin offshore exploration and development agreement with Japan to obtain Western know-how and equipment—and these projects have the added benefit of not requiring large up-front payments of hard currency. Moscow is currently pursuing a joint oil and gas exploration and development scheme for the Barents Sea. For these joint projects to achieve success, however, the Soviets will have to overcome their past reluctance to grant foreign firms access to geologic and field data

The effect on oil and gas output of purchases from abroad and improvements in domestic technology will ultimately depend on the ability of the Soviets to assimilate and apply them on a timely basis. The

Barents Sea Development

In the expectation of major long-term benefits, the USSR views the development of Barents Sea hydrocarbon deposits as a high-priority project. Any oil found there in the near future is not likely to be available for domestic use or for export—even with significant Western help—until well into the 1990s. Because of the huge gas reserves available onshore in West Siberia, gas discoveries in the Barents Sea are unlikely to be developed before the year 2000. (Soviet officials admit that a Barents Sea oil development project will take 10 to 15 years for maximum rates of production to be realized.) The eventual cost of developing a large discovery (for example, the size of that at Prudhoe Bay on Alaska's northern coast) could easily amount to $25 billion, depending on its size, distance from shore, water depth, reservoir depths, and ice conditions

In 1983 the Soviets signed an agreement with a consortium of seven Norwegian firms to provide a general work plan for exploration and development of oil and gas deposits in the Barents Sea. This $135,000 study detailed the technical assistance the USSR will require to explore an area covering about one-third of the central Barents Sea. In May 1984, a Deputy Minister of Foreign Trade, Vladimir Sushkov, declared that the Soviets have begun negotiations with Norway for offshore equipment purchases that could amount to $10-11 billion. He also has called for US and Canadian cooperation for development of the offshore oil potential in the Barents Sea. Moreover, he claimed that Japanese and West European firms were no longer restrained by US licensing policies in offshore oil exploration and development equipment and were actively seeking contracts with the USSR for delivery of such equipment and technology track record, however, as elsewhere in Soviet civilian industries, has been poor.[4] Soviet research institutes and key industrial ministries have frequently acquired state-of-the-art knowledge and have closely studied and tried to copy Western techniques and equipment. But the timely application of this knowledge and equipment in large-scale field projects has been difficult, primarily because of systemic constraints—a dysfunctional incentive and reward system and a reluctance on the part of managers to take necessary risks. The Soviets recognize these problems and have made some preliminary attempts at solving them. However, we do not expect the kind of fundamental changes that would allow the effective assimilation of new and improved technologies on a timely basis or on a scale that would dramatically raise efficiency and productivity in the oil and gas industries.

For at least the remainder of the 1980s, the bulk of Soviet oil and gas production will continue to come from large, relatively shallow deposits that pose few serious technical obstacles to exploitation. An increasing share of output will, however, originate from deeper deposits in more complex geologic environments, where—in the absence of unexpected progress in Soviet manufacturing capabilities—Western equipment will be needed.

The denial of Western equipment would require the Soviets to allocate much more investment to industries manufacturing oil and gas equipment and would make energy production more difficult and costly. Aside from the investment impact, it would produce ripple effects in the economy, but these could be minor and, in any event, difficult to quantify. The effort that was rallied to complete the laying of the gas export pipeline ahead of schedule is only one indication of Soviet willingness to devote resources to what Moscow considers high-priority projects. Moreover, the capabilities of not only Soviet industry but also of other potential suppliers of oil and gas equipment outside the circle of traditional Western suppliers such as Mexico, Brazil, and Singapore are improving rapidly. The developing capabilities of these suppliers may limit the duration of impact of a future embargo to the 18 to 36 months needed to bring non-US facilities into production of desired items.

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Appendix

USSR: Selected Petroleum Equipment Plants

Table A-1
Regional Summary of Listed Plants

	Number of Plants
Total	90
A. Belorussia and the Ukraine	16
Belorussian SSR	1
Ukrainian SSR	15
B. Caucasus regions	25
Azerbaijan SSR	19
Georgian SSR	2
Dagestan ASSR	1
Rostov Oblast	3
C. North and Central regions	14
Gor'kiy Oblast	2
Kursk Oblast	1
Leningrad Oblast	6
Moscow Oblast	3
Orel Oblast	1
Tula Oblast	1
D. Volga-Urals regions	26
Bashkir ASSR	1
Tatar ASSR	5
Udmurt ASSR	2
Astrakhan' Oblast	1
Chelyabinsk Oblast	1
Kuybyshev Oblast	1
Perm' Oblast	3
Saratov Oblast	1
Sverdlovsk Oblast	8
Volgograd Oblast	3
E. Kazakh and Central Asian regions	5
Kazakh SSR	1
Tajik SSR	1
Turkmen SSR	3
F. Siberia and the Far East	4
Altay Kray	1
Tyumen' Oblast	1
Chita Oblast	1
Khabarovsk Kray	1

Table A-2
Tubular Goods and Large-Diameter Pipe

Plant and General Location	Major Products	Output Details/New Construction
A. Belorussia and the Ukraine		
Novomoskovsk Pipe Plant (Novomoskovsk, Ukrainian SSR)	1,020-mm-diameter pipe	Estimated 1985 production—180,000 tons.
Dneprodzerzhinsk Pipe Plant (Dneprodzerzhinsk, Ukrainian SSR)	Drill pipe and casing	
Khartsyzsk Pipe Plant (Khartsyzsk, Ukrainian SSR)	1,020-, 1,220-, 1,420-mm-diameter pipe	Longitudinal-weld gas pipeline pipe; estimated 1985 production—820,000 tons.
Libknekht Pipe Plant (Dnepropetrovsk, Ukrainian SSR)	Drill pipe; casing	
Zhdanov Pipe Plant–Ilich Works (Zhdanov, Ukranian SSR)	Drill pipe and casing, spiral-weld 1,020-mm-diameter pipe	Estimated 1985 large-diameter output—60,000 tons.
B. Caucasus regions		
Rustavi Metallurgical Plant (Rustavi, Georgian SSR)	Casing	
Azerbaijan Pipe Plant *imeni* V. I. Lenin (Sumgait, Azerbaijan SSR)	Drill pipe	
Taganrog Metallurgical Plant (Taganrog, Rostov Oblast)	Casing and drill pipe	
C. North and Central regions		
Vyksa Pipe Plant (Vyksa, Gor'kiy Oblast)	Multilayer 1,420-mm-diameter pipe	Estimated 1985 production—500,000 tons.
D. Volga-Urals regions		
Uralmash Metallurgical Plant (Sverdlovsk, Sverdlovsk Oblast)		
Al'met'yevsk Spiral Seam Pipe Plant (Al'met'yevsk, Tatar ASSR)		
Kamensk-Ural Metallurgical Plant (Sverdlovsk, Sverdlovsk Oblast)		
Severskiy Pipe Plant (near Sverdlovsk, Sverdlovsk Oblast)		
Chelyabinsk Pipe Plant (Chelyabinsk, Chelyabinsk Oblast)	1,020-, 1,220-mm-diameter pipe; casing	Produced about one-fifth of total pipe output in 1970. Plant began producing casing in 1980 (70,000 tons a year) Estimated 1985 large-diameter pipe production—700,000 tons.
Volzhskiy Plant (Volgograd, Volgograd Oblast)	1,020-, 1,220-, 1,420-mm-diameter pipe	Estimated 1985 production—450,000 tons.

Table A-3
Heavy-Duty and Aeroderivative Mechanical-Drive Gas Turbines for Large-Diameter Gas Pipeline Service

Plant and Location	Function
A. Belorussia and the Ukraine	
Sumy Machine Construction Plant (Sumy, Ukrainian SSR)	Produces pipeline compressor associated with 16- and 6-MW aeroderivative turbines.
C. North and Central regions	
Nevskiy Machine-Building Plant (Leningrad, Leningrad Oblast)	Assembles gas generator for 25- and 10-MW industrial gas turbines.
Leningrad Turbine-Blade Plant (LZTL) (Leningrad, Leningrad Oblast)	Produces turbine blades for all types of industrial gas turbines.
Leningrad Metals Plant (LMZ) (Leningrad, Leningrad Oblast)	Produces power turbine for 25-MW industrial gas turbine and associated pipeline compressors.
Leningrad Gas Turbine Plant (Leningrad, Leningrad Oblast)	Administratively connected to LMZ but primarily manufactures large turbines for power generation.
D. Volga-Urals regions	
Kazan' Aircraft Engine Plant (Kazan', Tatar ASSR)	Converts aircraft engine to gas generator for 16-MW aeroderivative.
Sverdlovsk Turbomotor Plant (Sverdlovsk, Sverdlovsk Oblast)	Produces 16-MW industrial gas turbines.
F. Siberia and the Far East	
Khabarovsk Machine Construction Plant (Khabarovsk, Khabarovsk Kray)	Produces 10-MW industrial gas turbines.

Table A-4
Other Equipment for Exploitation of
Oil and Gas Resources

Plant and General Location	Major Products	Output Details/New Construction
A. Belorussia and the Ukraine		
Drogobych Machine-Building Plant (Drogobych, Ukrainian SSR)	Rock bits	
Khar'khov Electrical Machinery Plant (Khar'kov, Ukrainian SSR)	Electric downhole motors, electrodrills, possibly electric centrifugal pumps	
Poltava Diamond Instrument Plant (Poltava, Ukrainian SSR)	Diamond drill bits	Uses "Slavutich" alloy for synthetic diamonds.
Oil Drilling Equipment Repair Plant (Kalush, Ukrainian SSR)	Special packers	
Kiev Instrument Plant (Kiev, Ukrainian SSR)	Well-logging units	
Kiev Armature Plant (Kiev, Ukrainian SSR)	Valves	
Frunze Plant (Sumy, Ukrainian SSR)	Piston compressors	
Sumy Pump Works (Sumy, Ukrainian SSR)	Oil-pumping units	
Mash Zavod (Chernovtsy, Ukrainian SSR)	Refinery equipment—oil pumps, compressors, heat exchangers	
Minsk Electric Engineering Plant (Minsk, Belorussian SSR)	Cathodic protection equipment for pipelines	
B. Caucasus regions		
Baku Instrument Plant (Baku, Azerbaijan SSR)	Various types of instruments for petroleum and chemical industries; tongs for servicing sucker rods; geophysical equipment; instruments for testing drilling muds and cement	Put into operation in 1960; expanded in the late 1970s.
Bakinskiy Rabochiy Machine-Building Plant (Baku, Azerbaijan SSR)	A large variety of drilling, production, and refining equipment, such as pumping jacks, various types of pumps, drilling equipment; heat exchangers, oil separators, and other refinery equipment; well-servicing equipment	One of the largest Soviet equipment plants; new shop to produce rod pumps ("oil well pumps") built in 1978.
Petrov Engineering Works (Baku, Azerbaijan SSR)	Mobile offshore drilling and production platforms	
Bol'shevik Machine-Building Plant (Baku, Azerbaijan SSR)	Rock bits, fishing, and other miscellaneous well-servicing equipment; specializes in soft formation coring and drilling bits	In operation since about 1900.
Dimitrov Machine-Building Plant (Baku, Azerbaijan SSR)	Tongs, high-pressure valves, well-servicing equipment	
Kirov Drilling Instrument Plant (Baku, Azerbaijan SSR)	Drill bits of many types, tool joints, wellhead equipment	Founded in 1929 as a repair plant; production of bits and tool joints began after World War II. The largest Soviet producer of tool joints (approximately 500,000 per year).

Table A-4 (continued)

Plant and General Location	Major Products	Output Details/New Construction
Dzerzhinskiy Machine-Building Plant (Baku, Azerbaijan SSR)	Multiple-completion equipment, rod pumps, gas-lift valves	The major Soviet producer of rod pumps expanded capacity during 1976-80. Plan to build 135,000 pumps per year and repair up to 35,000 per year. In 1980 plan started production of bushingless rod pumps.
Iosif Kasimov Machine-Building Plant (Baku, Azerbaijan SSR)	Wide variety of oilfield equipment, drilling-mud units, well-servicing equipment, well-logging units	Capacity of plant was expanded during 1976-80.
Krasnyy Proletariy Machine-Building and Repair Plant (Baku, Azerbaijan SSR)	Valves and other types of fittings, spare parts for drilling equipment, and oilfield equipment repair	
Pervogo Maya Machine-Building Plant (Baku, Azerbaijan SSR)	Plant repairs and overhauls, drilling equipment	
Lieutenant Shmidt Machine-Building Plant (Baku, Azerbaijan SSR)	Christmas trees, wellhead equipment (including wellhead equipment for cold climate and corrosive environments), portable rigs, rig equipment	This is the oldest Soviet oilfield equipment plant and one of the largest. Capacity was expanded during 1976-80; during 1981-85 plant is to begin production of well-servicing units.
Buniat Sardov Machine-Building Plant (Baku, Azerbaijan SSR)	Drilling rigs, well-repair units	New steel foundry was built during 1976-80.
Kishly Machine-Building Plant *Imeni* Narimanov (Baku, Azerbaijan SSR)	Turbodrills, pumping jacks, drilling equipment	Capacity was expanded during 1976-80.
Volodarskiy Machine-Building Plant (Baku, Azerbaijan SSR)	Drilling, well-repair, and well-logging equipment	Major supplier of drilling tongs.
October Revolution Machine-Building Plant (Baku, Azerbaijan SSR)	Metal structure for offshore drilling; miscellaneous drilling equipment	
Petr Montin Petroleum Equipment Plant (Baku, Azerbaijan SSR)	Valves, multiple-completion equipment, wellhead equipment, valves and fittings for refinery equipment	
Krasnyy Molot Machine-Building Plant (Groznyy, Dagestan ASSR	Refining equipment, well-servicing equipment	Wellhead production shop planned as of 1977.
Kutaisi Electrical Machinery (Kutaisi, Georgian SSR)	Electrodrills, electric centrifugal pumps	
Krasnyy Kotel'shchik Production Association (Taganrog, Rostov Oblast)	Steam generators for enhanced oil recovery	The major Soviet producer of these generators.
Kalinin Pilot Plant (Baku, Azerbaijan SSR)	Automation and remote control devices for pipelines and storage	
Azinmash (Baku, Azerbaijan SSR)	Circulating swivels; well-logging units	
Petroleum Equipment Plant (Novocherkassk, Rostov Oblast)	Well-servicing units; vibrating drilling machines for exploratory drilling	
C. North and Central regions		
Borets Machine-Building Plant (Moscow, Moscow Oblast)	Electric centrifugal pumps, compressors	The plant's pumps are used for oil production, water injection, and in the oil refining industry.

Table A-4
Other Equipment for Exploitation of (continued)
Oil and Gas Resources

Plant and General Location	Major Products	Output Details/New Construction
Moscow Hard Alloys Combine (Moscow, Moscow Oblast)	Diamond drill bits	
Mytishchi Instrument Making Plant (Mytishchi, Moscow Oblast)	Portable truck-mounted exploration equipment	
Geomash Plant (Shchigri, Kursk Oblast)	Unit for installing masts for well repair	
Livgidromash Association (Livny, Orel Oblast)	Electric centrifugal pumps	Reportedly began production in 1980.
Nevskiy Machine-Building Plant (Leningrad, Leningrad Oblast)	Antiflare devices, gas turbines, compressors, drill rigs	
Tyazhpromarmatura Plant (Aleksin, Tula Oblast)	1,420-mm-diameter ball valves, (for pressures up to 75 atmosphere)	
Vyborg Rig Assembly Plant (Vyborg, Leningrad Oblast)	Offshore drilling rigs	
Krasnoye Sormovo Machine-Building Plant (Gor'kiy, Gor'kiy Oblast)	Elevators and possibly other well-servicing equipment	
D. Volga-Urals regions		
Astrakhan' Rig Assembly Plant (Astrakhan', Astrakhan' Oblast)	Offshore drilling rigs	
Ishimbay Machine-Building Plant (Ishimbay, Bashkir ASSR)	Instruments for winding cable, fishing tools, other well-servicing equipment	
Kuybyshev Machine-Building Plant (Kuybyshev, Kuybyshev Oblast)	Rock bits, tool joints	This plant currently is the largest Soviet drill bit plant. The [redacted] bit plant is an addition to the existing plant.
Kungor Machine-Building Plant (Perm', Perm' Oblast)	Turbodrills and turbodrill components; portable rigs, miscellaneous oilfield equipment	Largest producer of turbodrills.
Pavlov Machine-Building Plant (Perm', Perm' Oblast)	Turbodrills and turbodrill components	
Ocher Machine-Building Plant (Perm', Perm' Oblast)	Pipelayers	
Dzerzhinskiy Petroleum Equipment Plant (Sarapul, Udmurt ASSR)	Rock bits, deep-well pumps	Drill stem tester shop is to be operational by 1985 (capacity of 500 per year). Bit production is limited.
Saratov Plant (Saratov, Saratov Oblast)	Rock bits, pressure regulating valves for storage tanks	
Ural Heavy-Machine-Building Plant (Sverdlovsk, Sverdlovsk Oblast)	Drilling rigs	Largest Soviet rig manufacturer, especially for drilling below 2,500 meters.
Verkhnyaya Pyshma Drilling Rig Plant (Verkhnyaya Pyshma, near Sverdlovsk, Sverdlovsk Oblast)	Drilling rigs	Built in 1981.
Verkhniye-Serginsk Machine-Building Plant (Verkhniye Sergi, Sverdlovsk Oblast)	Drill bits	A major drill bit producer.
Barrikady Machine-Building Plant (Volgograd, Volgograd Oblast)	Medium- and heavy-drill rigs	The Barrikady and Uralmash plants together produce most Soviet drilling rigs.
Petrov Machine-Building Plant (Volgograd, Volgograd Oblast)	Various types of refining equipment: pumps, heat exchangers, cracking units, coking chambers, storage tanks	

Table A-4 (continued)

Plant and General Location	Major Products	Output Details/New Construction
Nefteavtomatika Association (Bugulma, Tatar ASSR)	Well-logging units	To be expanded to build automated oilfield units for oil treatment.
Izhevsk Oil Machine-Building Plant (Izhevsk, Udmurt ASSR)	Geophysical equipment, mud pumps for drill rigs	
Al'met'yevsk Submersible Pump Plant (Al'met'yevsk, Tatar ASSR)	Electric centrifugal pumps	Series production reportedly began in early 1980, with serious quality problems.
Kazan' Compressor Plant (Kazan', Tatar ASSR)	Gas-lift compressors	
Uralkhimmash (Sverdlovsk, Sverdlovsk Oblast)	Refining equipment	
E. Kazakh and Central Asian regions		
Ashkhabad Petroleum Equipment Plant (Ashkhabad, Turkmen SSR)	Mud mixers, shale shakers, pumping jacks, refinery equipment	Put into operation in 1960; expanded in the late 1970s.
Nebit-Dag Machinery and Repair Plant (Nebit-Dag, Turkmen SSR)	Derricks, mud mixers	Also repairs drilling equipment.
Ordzhonikidze Machinery Plant (Dushanbe, Tajik SSR)	Valves and all other types of fittings for oil industry, principally refining	A major oil industry supplier.
Mary Machine-Building Plant (Mary, Turkmen SSR)	Electric centrifugal pumps	Produces about 1,500 pumps per year.
Ust'-Kamenogorsk Plant (Ust'-Kamenogorsk, Kazakh SSR)	Valves, switches, large gate valves, wellhead equipment	
F. Siberia and the Far East		
Geological Prospecting Equipment Plant (Barnaul, Altay Kray)	Exploratory drilling rigs	
Nizhnevartovsk Plastics Plant (Nizhnevartovsk, Tyumen' Oblast)	Ion-exchange resins for protecting pipelines and other equipment	
Chita Machine-Building Plant (Chita, Chita Oblast)	Compressor stations	

Table 2
Strategic Oil and Gas Equipment Proposed for COCOM Controls

Item	Application	Non-COCOM Availability	Potential Military Significance
Deep, submersible, high-pressure pumps with a capacity of at least 135 tons per day of fluid at depths greater than 600 meters (IL-1131)	Secondary oil recovery (to handle increasing volumes of water produced with oil)	None; could be developed in about two years	Nuclear propulsion systems (pressurized water reactors) on submarines, strategic underground petroleum storage sites.
Geophysical/seismic survey vessels including geophysical hardware and software systems (IL-1416), including positioning and navigation systems	Offshore oil and gas exploration	None for onboard high-technology equipment	Antisubmarine warfare; electronic countermeasures; detection and identification systems; improved command, control, attack, and evasion capabilities.
Navigation, direction-finding, radar, and airborne communications equipment (IL-1501), including satellite navigation equipment	Offshore oil and gas exploration	None	Targeting; reconnaissance; support of submarine-launched ballistic missile systems; antisubmarine warfare.
Acoustic and/or ultrasonic systems or equipment specially designed for locating underwater or subterranean objects	Oil and gas exploration (onshore and offshore)	None for offshore positioning equipment; none for side-scan sonar equipment; [redacted] and Sweden for subbottom profiling equipment	Submarine navigation; underwater detection systems; antisubmarine warfare; weapons guidance systems; surveillance and fire-control systems.
Gravity meters and components thereof with an accuracy of 0.1 milligal (IL-1595)	Oil and gas exploration (onshore and offshore)	Sweden	Military inertial-guidance systems and mapping for land, sea, and air weapons systems.
Corrosion-resistant oil- and gas-producing equipment capable of operating in corrosive environments containing more than 10 parts per million hydrogen sulfide and carbon dioxide (IL-1100 NI)	Exploitation of sour gas/oil deposits	Argentina, Austria, Brazil, Mexico, Sweden, and Venezuela have limited capability to supply some of this equipment that is based on COCOM technology	Military applications requiring special materials, processing, and manufacturing techniques, and/or metallurgy for rocket and jet engines and new weapon systems where metal fatigue, failure, and wear are critical.
High-pressure/high-temperature oil- and gas-producing equipment capable of operating at pressures exceeding 350 atmospheres and at temperatures above 93°C (IL-1100 NI)	Exploitation of deep oil and gas deposits	Argentina, Austria, Brazil, Mexico, Sweden, and Venezuela have limited capability to supply some of this equipment that is based on COCOM technology	Military applications requiring special processing and manufacturing techniques, and/or metallurgy for rocket and jet engines and new weapon systems where metal fatigue, failure, and wear are critical.
Deep-well drilling rigs and systems capable of operating below 3,000-meter depths (IL-1500 NI)	Exploitation of deep oil and gas deposits	None for complete systems; Austria, Brazil, Finland, Mexico, Singapore, Sweden, and Switzerland have limited capability for some equipment items based on COCOM technology; USSR and Romania make systems of inferior quality	Manufacture of deep submersible vehicles; underground nuclear testing monitoring, and sampling; development of new weapon systems.
Magneto-telluric systems (IL-1500 NI)	Oil and gas exploration (onshore and offshore)	None at present in West; USSR (low quality)	Antisubmarine warfare; low-frequency communications systems.
Well-logging equipment and related computer hardware and software (IL-1500 NI)	Evaluation of oil and gas discoveries, especially deep deposits	None for complete systems; Austria, Hungary, USSR, Romania, Sweden, and Taiwan have limited capability to produce some items of inferior quality	Airborne electronic countermeasures; avionics; naval systems; antisubmarine warfare; underground nuclear testing; weapon systems.
Mud-logging equipment and technology and related computer hardware and software (IL-1500 NI)	Deep-drilling operations under high pressure, high-temperature, and corrosive conditions	Very limited in terms of computer hardware and software	Airborne electronic countermeasures; avionics; naval systems; antisubmarine warfare (nonacoustic detection).