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The Soviet Gas Network: Capacity and Vulnerability

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A Research Paper

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The Soviet Gas Network: Capacity and Vulnerability [redacted] 25X1

Scope Note

Natural gas exports are an increasingly important source of revenues to the Soviet Union, and Western Europe is an increasingly important Soviet market. This paper assesses Soviet capabilities to supply more gas to the West and still meet rising domestic and East European demand. It focuses on capacity and vulnerability issues, especially technical factors that determine Soviet gas deliverability, and examines the implications of Soviet gas network expansion on Moscow's options to increase further gas exports. [redacted] 25X1

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The Soviet Gas Network: Capacity and Vulnerability [redacted] 25X1

Summary

Information available as of June 1986 was used in this report.

Planned and probable expansion of the Soviet natural gas transmission network will put Moscow in strong position to compete for gas markets in Western Europe in the 1990s and beyond. New pipelines to be completed by 1990 will carry more gas from West Siberia and give Moscow the capacity to more than double hard currency gas exports. The opportunity for further inroads will apparently be limited by the early stages of Norway's planned development of its North Sea gasfields. Soviet decisions to use aggressively pipeline capacity and to price gas competitively in the early 1990s, however, could undermine the later stages of these expensive Norwegian gas projects designed to meet most growth in West European demand well into the next century. Pressures on Soviet hard currency earnings are likely to make this an attractive option. [redacted] 25X1

Already the world's largest producer of natural gas, the USSR is seeking to increase production by more than 50 percent by the year 2000. To accomplish this, Moscow plans to expand its extensive pipeline systems that deliver gas from giant fields in West Siberia to major domestic and export markets west of the Urals. The 1986-90 Five-Year Plan calls for six new 56-inch pipelines to be added to the main West Siberian corridor. Our analysis, using computer simulation of planned additions to the Soviet gas network, indicates that by 1990 overall capacity will exceed projected consumption and export levels by about 30 percent or more than 250 billion cubic meters (bcm). This excess capacity will include more than 30 bcm at the Czechoslovak border, where we estimate the Soviets will deliver between 80 to 85 bcm a year by 1990 to Eastern and Western Europe. Additional excess capacity may also be available at Romania's border for export to Turkey and Greece. [redacted] 25X1

The Soviets have a highly integrated natural gas network that has sufficient flexibility and redundancy to cope with most operational problems and equipment failures. [redacted] 25X1 [redacted] they are continuing to improve their capabilities to move gas from one system to another to avoid serious shortfalls. As the network expands, however, the operation and switching requirements become greater and more complex, and further improvement in operational sophistication will be needed. Even with planned capacity additions by 1990, demands on the system could still lead to localized gas shortfalls in the USSR and

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Eastern Europe because of the long system-response time to emergency diversions, wide seasonal swings in gas needs, and limited capability in some areas to tap alternative supplies. In particular, problems are likely to continue in the northern regions of the USSR--except Moscow--served by a system that is not presently scheduled for expansion. [redacted] 25X1

The four major export pipelines are less likely to be affected by problems elsewhere in the network because they are dedicated almost entirely to export deliveries. Some connections with other systems, moreover, could permit diversion of domestic supplies from other pipelines to help maintain exports in an emergency. Because of excess capacity, any two of the three systems delivering gas to Czechoslovakia for export could compensate for lost supply from the third, at least at 1985 export levels. Also, if additional export capacity is needed before new pipelines are built, the Soviets could increase the deliverability of their current network by using a number of shorter term measures, such as lowering the gas temperature in the pipeline, increasing the discharge pressure of compressors, or increasing the system's fuel efficiency. [redacted] 25X1

An examination of a large number of disruption possibilities indicates that only a combination of major problems would seriously affect exports and that impact would be relatively short lived:

--Disruptions of the pipeline corridor transporting gas from West Siberia would cause a major loss--affecting more than 50 percent of Soviet production by 1990.

--Loss of flow through five key compressor stations in the Central and Volga regions would result in a devastating loss of gas to Moscow, loss of at least half of export capacity, and a major reduction in overall domestic supplies.

Loss of compression equipment would cause a less severe reduction but would take longer to repair or replace. With the completion of scheduled expansion, even a major trade embargo on parts for Western equipment in the Soviet gas network would reduce projected 1990 exports to the West by only about 17 percent. [redacted] 25X1

Beyond 1990 much of the excess capacity built into the Soviet gas network will erode as scheduled deliveries to Eastern Europe increase and as domestic demand grows, unless Moscow further expands the system. If the Soviets intend to export gas

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to Western Europe at levels significantly above current commitments, Moscow would probably add another export pipeline to be completed by the mid-1990s. The Soviets probably will include designs in the next Five-Year Plan (1991-95) for additional large-diameter domestic gas pipelines to help service growing needs at home and to further substitute gas for oil in an effort to bolster oil sales. [redacted] 25X1

Soviet gas export strategy will not necessarily become evident over the next few years. Soviet exports should grow during this period, however, as a result of contracts already in hand. A decision to use excess capacity to pursue further sales could be delayed until around 1990. The Soviets would still have plenty of time to invest in further capacity expansion needed to compete aggressively and maintain a comfortable margin for reliable deliveries. They also could still directly affect the decision to proceed with the second phase of Norwegian development of its giant Troll field in the North Sea. The Soviets, with large reserves and low production costs, have an opportunity to offer West European customers an attractive alternative well in advance of the additional North Sea supplies. [redacted] 25X1

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The Soviet Gas Network: Capacity and Vulnerability [redacted] 25X1

Introduction

The Soviet Union holds a commanding position as leader in all phases of the worldwide natural gas industry. It has the largest gas reserves--40 percent of the world's total--and is the largest gas producer, consumer, and exporter. Moscow exceeded its 1985 production goal of 630 billion cubic meters (bcm) by a comfortable margin, according to the Soviet press, and now produces the gas equivalent of nearly 11 million barrels per day (b/d) of oil, more than the highest yearly Saudi Arabian oil production. Natural gas development has gained a high priority in the Soviet energy sector to compensate for the stagnation of oil production and will become increasingly important as a source of energy and hard currency. [redacted] 25X1

To deliver its enormous quantities of gas, Moscow has built the world's most extensive gas transmission network. The Soviets are the major gas exporter to Eastern and Western Europe, and the ability of the network to deliver gas exports in the future will influence energy policy and economic prospects in Eastern Europe and energy security and planning in the West. With the growing dependence of the Soviet economy on natural gas as the primary source of growth in energy supplies, the network's capabilities will affect Moscow's ability to move away from oil and still support steady economic growth. [redacted] 25X1

To assist in examining the capabilities and vulnerabilities of the Soviet gas network, a detailed computer simulation model was developed that enables analysis of a multitude of scenarios representing varying operating conditions. The model simulates the gas flow and control in all pipelines 32 inches in diameter and larger, accounting for about 95 percent of the total transmission capacity from the producing areas. [redacted] 25X1
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The Gas Network: Distribution and Capacity

Distribution Systems

Over the last 25 years, growth in natural gas production has been concentrated in the eastern USSR, increasing Soviet dependence on the pipeline network to deliver gas to major consumption centers and export outlets west of the Urals:

--In the 1960s, the North Caucasus and Ukraine regions supplied 85 percent of gas produced.

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--In the 1970s, the Volga-Urals and Central Asia regions paced production.

--West Siberia now supplies one half the USSR's gas production and will account for the majority of the growth in gas production and capacity. Because most of the vast Soviet gas reserves are located in remote areas of West Siberia, the importance of the pipeline system will grow as these are developed. 25X1

Natural gas is currently produced and distributed by pipeline from five major areas within the Soviet Union (see figure). The Soviets, over the last five years, not only have expanded their overall pipeline capacity but also have integrated their newer systems into a complex network that, by design, should help solve system shortfalls, increase dependability of gas exports, and alleviate some domestic supply problems. With the exception of the Northern Lights system--serving the northern areas of the USSR--the Soviets apparently have systematically intersected major pipeline systems to increase the flexibility of the overall transmission network. Analysis shows that even those pipelines dedicated primarily to exports--such as the Urengoy-Uzhgorod export pipeline--have the capability to supply domestic gas if required. Similarly, several systems typically used for domestic supply can divert gas to export pipelines in case of a disruption or demand surge. 25X1

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--Examine Soviet options to expand the network and explore the implications for capacity and vulnerabilities. [redacted]

The model of the Soviet natural gas network consists of 18 separate real-time computer simulation models. Each represents one of the major pipeline systems in the Soviet Union and allows analysis of systems hydraulics such as flowrates, pressures, and power requirements, and other fluid-related properties under various operating scenarios. Standard thermodynamic and gas-flow equations are used to represent flow in closed conduits. [redacted] 25X1

Only pipelines 32 inches in diameter and larger have been modeled. These lines represent the vast majority of the pipelines within the USSR's main transmission network, accounting for about 95 percent of total transmission capacity from the gas-producing areas. [redacted] 25X1 25X1

[redacted] In some cases where specific information was not available, assumptions were made, based on engineering practices in operating similar Western pipeline systems and on general equipment characteristics. In the worst case, it was calculated that these assumptions could distort capacity projections by as much as 10 percent. [redacted] 25X1

For this study many of the older pipeline names within the USSR have been dropped. Each system has been named with its most popular name or by its source and destination. [redacted] 25X1

a. The modeling effort includes the Soviet systems only. Quantitative estimates are given as a measure of Soviet capability to send gas to the Soviet border. Hydraulic restrictions of pipeline systems within the Eastern Bloc or Western Europe may reduce flows below estimates given in this study. [redacted] 25X1

West Siberian Systems. The West Siberian systems are the most important pipeline group, carrying about 50 percent of 1985 production. A total of 12 pipelines currently leave West Siberia through two major corridors, carrying gas from Medvezhye, Punga, Nadym, and Vyngapur as well as the giant Urengoy gasfield. Six pipeline systems originate at the Urengoy gasfield, including two

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of the four major export systems--the Urengoy-Uzhgorod pipeline and the Northern Lights--through which pass 60 percent of all exported gas. Scheduled development of the Yamburg gasfield in the current five-year plan will increase the importance of this corridor and may increase the number of pipelines to 18. [redacted] 25X1

The Volga-Urals Systems. The Volga-Urals systems include the Orenburg export pipeline to Uzhgorod and the Orenburg domestic system branching out in five directions from the Orenburg gasfield to serve the Volga-Urals regions. Orenburg gas is also high in hydrogen sulfide and is processed locally to remove it before being transported. Both systems cross several other major domestic pipeline networks and are assumed to be able to divert gas to those networks if needed. [redacted] 25X1

Central Asian Systems. Central Asia is the second-most-productive gas region in the Soviet Union. Central Asia has two major domestic networks: the Central Asia-Center network and the Central Asia-Urals network. Gas is transported through these networks from fields such as Gazli, Achak, Naip, Shatlyk, and Okarem to Moscow and industrial regions in the western USSR and Urals. The Central Asia-Center network is a complicated, tree-shaped pipeline network with a major trunk section made up of three to five 40- to 56-inch pipelines that run from Khiva to Moscow. Some Central Asian gas is high in hydrogen sulfide content, which has corroded portions of the lines. Although [redacted] the Soviets have been replacing many line segments along this corridor, the area east of the Caspian Sea apparently is still undergoing repairs. [redacted] 25X1 25X1

Before 1970 only two pipelines extended from the southern gasfield north to Moscow. With later additions of smaller gasfields, the Soviets added pipelines and installed four branches to deliver gas to various destinations other than Moscow, such as Frolovo, Kalach, Ostrogozhsk, and Gorkiy. The current network crosses or ties into most other major pipeline networks and probably has the capability to divert gas to those networks if needed. The Central Asia-Urals network also transports gas northward from the southern gasfields but is located just west of the Aral Sea and provides domestic gas mainly to industrial areas near Dombarovskiy and Kartaly. [redacted] 25X1

Caucasus Systems. The North Caucasus system was originally developed to deliver gas to the Moscow-Leningrad areas and to provide some gas for export to Finland. The function of this network, however, has changed over the last 10 years as the fields originally serving this system began to decline. Gas for export and for Leningrad is now provided by the Northern Lights

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system. In addition, [redacted] other sources of gas have been connected, probably to make the system a more secure source of gas for Moscow. West Siberian gas can now be transferred to the system at Yelets and Novopskov. Central Asia gas can also enter the system at Ostrogozhsk. In the Transcaucasus area, West Siberian gas is now delivered by a new pipeline--Urengoy-Baku--through Novopskov, permitting replacement of gas lost when Iran stopped deliveries to the USSR in 1980. [redacted] 25X1 25X1

Ukraine System. The Ukraine has a high demand for natural gas and is served mainly by the Shebelinka pipeline system. Fields associated with the Shebelinka system have been declining over the last 10 years. As a result, gas from West Siberia and Central Asia has been linked to the system to provide a stable gas supply. Part of the Shebelinka system is an export pipeline into Romania. This portion may become a major export link for the Soviets in the current five-year plan if plans to export gas to Turkey and Greece are implemented. [redacted] 25X1

Capacity Estimates

Total 1985 capacity in the major pipelines from all five major gas producing areas probably is just over 760 bcm per year. (1) Additional capacity in local distribution pipelines near the producing fields probably brings the total capacity of the USSR to deliver gas from its producing areas to over 800 bcm per year (see table), nearly 25 percent greater than 1985 gas production of about 645 bcm reported in the Soviet press. About half this capacity is in the West Siberian system--by far the country's most important. Capacity in this system is estimated at 425 bcm per year, more than 30 percent above 1985 West Siberian production of about 320 bcm. [redacted] 25X1

Domestic Delivery Capability. Analysis shows all domestic pipeline systems have sufficient capacity to meet normal consumption demands and limited excess capacity to provide flexibility in coping with system problems or seasonal swings. Some excess capacity is available in all systems at the major producing areas, and additional excess capacity may become available in many of these pipelines downstream, as gas is consumed and bottlenecks are passed (see table). In many cases, however, this excess can only be used in certain sections of the system because bottlenecks preclude its distribution throughout the length of the pipeline. For example, the Central Asian-Center system has a capacity of more than 100 bcm per year at the gasfields, but this is quickly reduced to just over 65 bcm per year as the gas approaches Aleksandrov Gay. Most of this reduction is the result of increased spacing between compressor stations, creating additional pressure drop and loss of flow potential. In this system, therefore, the majority of excess capacity exists between the gasfield and Aleksandrov Gay. [redacted] 25X1

The Northern Lights system has a limited amount of excess capacity and, as a result, has the least flexibility to respond to changing system demands. Because it has no access to gas from other networks and is responsible for delivering gas to the entire northern area of the USSR, additional demands made by consumers along the Northern Lights line--such as during peak winter periods--must be met by curtailing flow to other areas. Some of these regions--such as Baltic, Northern, and Belorussia--are not served by any other gas system. [redacted] 25X1

Regional Gas Consumption

The capacity and flexibility of the Soviet gas network depends heavily on regional gas demand. An analysis of the distribution of Soviet natural gas consumption is needed, therefore, as a precondition for study of the network's operating characteristics. Total domestic gas consumption for the Soviet Union is calculated at 572 bcm in 1985--reported production last year of 643 bcm, plus 2.0 bcm per year for imports minus an estimated 73 bcm per year for exports. [redacted] 25X1 25X1 25X1. For this study regional gas consumption is estimated by prorating the total production among 17 major economic regions [redacted] 25X1 25X1 and by accounting for increased pipeline construction over the last decade as well as differences in regional growth rates. This consumption was then apportioned among the various pipeline systems that traverse each economic region (see appendix table A-1). Fuel consumption by pipeline was estimated from the calculated horsepower used by gas turbines during a normal system operation--approximately 8 percent of total production--and was distributed by region for each appropriate system (see appendix table A-2). [redacted] 25X1

Exports Deliverability. [redacted] 25X1 natural gas is delivered by four major pipeline systems to six major locations in the Soviet Union for export to Eastern and Western Europe. The Northern Lights, Orenburg, and Urengoy-Uzhgorod export pipeline systems deliver gas to Uzhgorod near the Czechoslovak border,

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where gas is sent on to users in Czechoslovakia, Yugoslavia, East Germany, West Germany, France, Italy, and Austria. The Northern Lights system also provides exports to Poland, Finland, and Hungary. The Shebelinka system supplies gas to Izmail on the Romanian border for export to Romania and Bulgaria. [redacted] 25X1

Of the four export pipelines delivering gas to the border, the only system constrained by domestic consumption commitments is the Northern Lights, according to analysis. The Urengoy-Uzhgorod and Orenburg pipeline systems were originally planned to be used exclusively to export gas and are unaffected by domestic needs, except for fuel usage; at 1985 export levels, however, both have excess capacity to provide gas for domestic consumption if needed. In the Shebelinka system, exports are restricted by mechanical limitations along the pipeline. [redacted] 25X1

Based on an estimate of the distribution of domestic consumption, the Soviets could deliver up to 105 bcm annually through its four export systems and still meet domestic needs. This means that the Soviet network could deliver annually some 30 bcm--or about 500,000 b/d of oil equivalent--more than the amount exported in 1985 without any modifications to the system. About 28 bcm per year could be delivered to Western Europe if the connecting pipeline infrastructure is available in Eastern Europe. [redacted] 25X1

The Soviet gas network has sufficient capacity and flexibility to ensure that gas exports are maintained, at least at the 1985 level. Indeed, the Soviets could deliver the entire volume of gas exported to Western Europe in 1985 through the Northern Lights system alone, but the operation would be costly. The Northern Lights system has limited spare capacity under normal operating conditions, but this study shows that in an emergency the system could deliver gas to Uzhgorod at a rate of 83 bcm per year for a short period if gas reserves from the underground storage area near Dolina were extracted and almost all domestic gas consumption from the Northern Lights system were curtailed. Although this scenario is unlikely and carries an exorbitant cost to domestic consumers, it shows that the Northern Lights system could completely satisfy all current export demand at Uzhgorod for a short time if both the Orenburg and Urengoy-Uzhgorod export pipelines were disrupted. [redacted] 25X1

Options To Enhance Export Deliverability. Recent hard currency shortages reportedly are delaying construction of the new Progress gasline to Uzhgorod, which now may not be completed until the end of 1989. If additional export capacity is needed before then--or if the Progress project is further delayed--the

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Soviets' best option probably would be to expand the capacity of existing export pipelines. The model was used to estimate the potential gains in export capacity from methods typically employed to increase the deliverability of gas transmission networks short of laying additional pipelines--such as lowering the gas temperature in the pipeline, optimizing the performance of each compressor station, and modifying the pipeline hydraulics:

--Lowering the temperature in a gas pipeline involves the installation of additional coolers and possibly the improvement of existing pipe insulation to maintain a lower gas temperature between stations. Deliverability will increase as fluid temperature is decreased until the gas condenses, at which point flow in the line is obstructed and deliverability decreases. On the basis of the model, if the Soviets lowered the gas temperature from the base of 59F to 28F, throughput would increase by 2.5 bcm per year. Lowering the temperature to 5F would increase the flow by 5 bcm per year, assuming no condensation.

--Another method to improve deliverability that the Soviets may pursue is optimizing system performance to reduce internal use of gas to fuel turbines. Fuel requirements for each system are 20 to 25 percent of maximum deliverability. The Soviets may be purchasing regenerators--an addition to the gas turbine to preheat the combustion gas--to increase efficiency of the compressor's gas turbine drivers. For every 10-percent increase in efficiency the Soviets can add nearly 1 bcm per year in exports per pipeline.

--A common practice in Western countries is to supply peak short-term demands by increasing the discharge pressure of the compressor stations above the design pressure of the pipe to increase flows. Analysis of the four Soviet export systems indicates that running at supply pressures 10 percent above normal would yield a total export capacity about 20 percent higher than normal--or 125 bcm per year. Although no evidence suggests the Soviets have employed this practice, this option is especially feasible in areas with high peak demand and low excess capacity such as those served by the Northern Lights. This practice increases the frequency between required equipment maintenance overhauls, however, which might discourage its use in the USSR, where spare parts and the technical expertise needed to maintain Western equipment are scarce. [redacted] 25X1

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Moscow also has several longer term options to expand exports that would require some pipeline construction but fall short of adding an entire new export pipeline with compressor stations:

--One alternative is to loop an existing pipeline--that is, construct additional parallel pipelines between existing compressor stations to alleviate flow bottlenecks. This may be feasible for the Orenburg and Urengoy-Uzhgorod pipelines, but the only efficient way to loop either of these two systems would be to add a parallel 56-inch-diameter pipe the entire pipeline length that shares existing horsepower at all stations. This would increase deliverability of each system by 26 bcm per year.

--The capacity of poorly designed pipelines can usually be improved by adding additional horsepower--turbine and compressor sets--either at existing compressor stations or at intermediate locations. Reviewing the two major export systems--Orenburg and Urengoy-Uzhgorod--however, they had been found to be efficiently engineered and probably would not benefit from these additions. Of course, adding a parallel pipeline with duplicate compressor stations--a process that would take as long as constructing the Progress pipeline--would double current export rates for both systems. If the new parallel lines were built using pipe fabricated from experimental steel that can withstand pressures of 100 atmospheres--now being constructed by the Soviets--each additional pipeline could deliver flows up to 44 bcm annually, an increase of nearly 35 percent.

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Potential To Substitute Gas for Oil. The need to buoy hard currency earnings despite a decline in growth of Soviet oil production in the 1980s has led to increased natural gas consumption in the industrial, commercial, residential, and other petroleum-using sectors in the Soviet Union. Natural gas is consumed as feedstock in the manufacture of chemicals and plastics and as fuel for commercial and residential activities. Gas consumption has increased from 3 percent of energy consumption in the 1950s to nearly 40 percent in 1985. Future substitution potential probably exists in the electric power sector where additional gas may be substituted for oil. This potential depends on the availability of gas production and the ability of the pipeline network to deliver it to the regions where it is needed.

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Using the modeling capability, excess capacity is estimated to be available in the Soviet natural gas transmission network for each of the 10 economic regions where major thermal power

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plants--1,000 megawatts (MW) and above--are located. Analysis shows that nine of the 10 economic regions have excess pipeline capacity totaling 117 bcm per year. Allowing for some flexibility in the export market and to cope with domestic demand swings, nearly half the total excess capacity--58 bcm per year or nearly million b/d of oil equivalent--probably could still be available for interfuel substitution. At a fuel consumption rate of 1.8 bcm per 1,000 MW, the Soviets have the main trunkline capacity to substitute gas for oil in these five regions in the generation of over 29,000 MW--or roughly one-half of the existing power plant capacity. 25X1

Gas could also substitute for oil in the export market to Eastern Europe or compete with oil as a hard currency earner in Western Europe. A portion of the gas scheduled to be supplied by the Progress pipeline for East European consumption will probably be used to substitute for oil. If this substitution effort could be expanded, more oil would be available for export to the West. Several countries in Western Europe reportedly have indicated a willingness to convert more industry to gas if a reliable supply is available at an attractive price. By 1990 over 30 bcm per year of additional capacity probably could be available at Uzhgorod. We estimate that 20 bcm of this--over 300,000 b/d of oil equivalent--could be used for export if needed and customers were available, still leaving excess capacity of 10 bcm per year to meet surge demands. 25X1

The Soviets probably will continue their domestic substitution of gas for oil, but at a slow pace. Excessive interfuel substitution using the existing trunkline network would reduce the flexibility of the network to cope with disruptions and seasonal demand swings. In addition, smaller local distribution lines reportedly must also be built before serious progress can be made in this area. Many of these lines must be tunneled to prevent disruption of traffic and other activity. Although this is a common procedure, it is time consuming and will cause delays in Moscow's conversion plans. 25X1

The Soviets could also use a portion of the excess capacity at Uzhgorod to increase gas sales to Eastern Europe above those already expected through 2000--thereby freeing additional oil for sale to the West. Moscow now ships over 45 percent of its oil exports to Eastern Europe, which with the exception of Romania is heavily dependent on imported Soviet oil. Most of the Soviet oil sent to Eastern Europe is consumed in the transportation sector, although large amounts are also used in power generation and as feedstock in petrochemical processes. If a combination of investment and adjustments permitted the Soviets to meet East

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European energy needs with more gas and to cut back oil exports by just 10 percent, they might save enough oil to meet a couple of years' growth in their own oil consumption. Alternatively, this additional oil, if exported to the West, would raise hard currency oil exports by more than 10 percent above present levels and much more above lower levels likely to prevail in the 1990s. [redacted] 25X1

Future Network Capacity

Soviet gas development, according to press reports, will be focused in the northern part of the Tyumen Oblast in West Siberia, where six supergiant gasfields--Bovanenko, Kharasavey, Medvezhye, Urengoy, Yamburg, and Zapolyarnoye--contain more than 75 percent of West Siberian reserves. Only two have been developed thus far--Medvezhye was brought on line in 1972 and Urengoy in 1978. Production activities are also under way at Yamburg, which will be the next field developed. Elsewhere in the Soviet Union older gasfields are continuing to decline. New supplies are expected from development of the Astrakhan and Karachaganak gasfields southwest of Orenburg, but the gas from these fields will help compensate for declining production in other areas rather than increase overall output. [redacted] 25X1

Longer term future expansion will probably depend on finding new gas reserves in East Siberia, the Soviet Far East, and offshore areas in the Barents and Kara Seas. To handle the development of West Siberian fields, the 12th Five-Year Plan (1986-90) calls for six additional 56-inch-diameter pipelines to be constructed from the Yamburg field. One of these--the Progress pipeline--will parallel the Urengoy-Uzhgorod export pipeline. Gas from this line--not expected to be ready for delivery until 1989 --is intended primarily for export to Eastern Europe but could also be used to supplement exports to Western Europe. [redacted] 25X1

Using the modeling capabilities, the potential of the Soviet gas transmission network to meet future demand by adding the six planned new pipelines has been analyzed. Some of these new pipeline routes have been widely discussed, but others remain the subject of much conjecture. Pipeline routes were projected based on [redacted] regional needs to reduce restrictions and add flexibility. Where possible, the Soviets probably will use existing station locations, adding compression capacity as necessary. [redacted] 25X1 25X1

The six new lines should increase the total pipeline capacity from West Siberian gasfields by 245 bcm to 670 bcm per year. Total nationwide capacity from the major producing areas

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would increase to more than 1,045 bcm per year by 1990 or upon the completion of all six pipelines--one of which is completed between Yamburg and Yelets [redacted] The increased system capacity should be sufficient to handle all projected increases in Soviet production for at least the next decade. Even if production grows at just 3 percent, however, additional pipelines will be required by the year 2000. [redacted] 25X1

Gas Network Vulnerability

The Soviet pipeline network has sufficient flexibility and redundancy to cope with most, but not all, types of problems. In general, the network is capable of rerouting gas to alternative systems that are able to transport larger than normal flow rates on a continuous basis. As the network expands, however, the operation and switching requirements become greater and more complex. [redacted] Despite efforts to modernize the network, the Soviets will still face some problems in switching operations to divert gas from one area to satisfy increased demand in other areas. The Soviets, even though they have successfully built one of the largest gas transmission networks in the world, have had difficulty operating and maintaining sophisticated equipment purchased from the West. In addition to occasional operational problems, the network is also susceptible to problems caused by equipment malfunction, interruptions of flow because of pipeline or valve ruptures, and seasonal demand surges. [redacted] 25X1

A large number of contingencies have been simulated along with seasonal demand surges to help analyze the potential impact of various problems on Soviet domestic supplies and export deliverability and to assess Soviet options to offset supply shortfalls. Although possible scenarios are limitless, analysis has been concentrated on those most affecting exports and gas deliveries to Moscow. It was assumed that the Soviets would assign a high priority to maintaining supplies to Moscow and to Western Europe and that any necessary curtailments would primarily affect other domestic consumers or East European importers. [redacted] 25X1

Equipment Problems

Problems caused by equipment downtime--either planned such as scheduled maintenance or unplanned in cases of failure or sabotage--can be lengthy if spare parts or the technology needed for repairs are not readily available. Although the Soviets

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normally stock spare parts for the Western equipment they have on line, problems reportedly have arisen that have caused downtime to exceed several months. Spare equipment at each pipeline booster station usually can be brought on line to handle the shutting down of equipment for routine maintenance. If multiple units are off line or spare equipment is not available, these stations could restrict the deliverability of Soviet export or domestic systems. The reduction of available equipment for gas-pressure boosting--loss of one or more compressors or turbines--at a given station can be simulated by reducing the available horsepower on the model. This simulation effectively increases the distance between stations, resulting in increased pressure drops along the pipeline and the reduction of capacity. It was found that:

--In any pipeline system, even the loss of all compressor stations along the pipeline without rupture of the pipeline itself will still permit flows ranging from 20 to 30 percent of capacity, depending on such factors as the length and size of the pipeline and field pressures.

--Export pipeline systems operating at 1985 levels would have to lose at least three sequential compressor stations before exports would be affected. When operating at capacity, a pipeline is affected most by the loss of sequential compressor stations. For a 56-inch pipeline, such as the Orenburg or Urengoy-Uzhgorod export pipelines, the loss of several stations in sequence increases the distance between remaining operating stations and considerably reduces system capacity.

Equipment Impairment Caused by Trade Denial

Trade embargoes on equipment related to existing pipelines probably would have only a minimal effect on gas exports by 1990 but would affect domestic consumption. Western-produced equipment such as compressors and turbines are used in various parts of the Soviet pipeline network. A major boycott--that included the cooperation of European manufacturers--of spare parts needed to service these units would affect the entire network. [redacted] 25X1

Among the export systems, the Orenburg and Urengoy-to-Uzhgorod pipelines would be most affected. The Orenburg export pipeline uses Western turbines exclusively along its entire length, and the Urengoy-to-Uzhgorod export pipeline uses Western equipment in 33 of its 40 compressor stations. The loss of every

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station using Western equipment--on both the Orenburg and Urengoy-Uzhgorod pipelines--would reduce 1985 export capacity at Uzhgorod to nearly 37 bcm per year from the current level of over 81 bcm. This capacity loss, however, would have reduced total exports by only 23 percent at 1985 export levels. [redacted] 25X1

After the addition of the Progress pipeline in 1989--which will use mainly Eastern Bloc- or Soviet-made equipment--the effect of a boycott would reduce export capacity at Uzhgorod by 38 percent, causing a loss of only 12 percent of projected 1990 exports of 115 bcm. The Northern Lights system--although slightly affected by an embargo--has the potential to compensate for the loss of exports, although domestic cutbacks including redistribution of flows to Moscow would be required. [redacted] 25X1

- --While operating at capacity, loss of the last compressor station--or last two stations--on each of the four major export systems just prior to entering Eastern Europe would have significant impact on pipeline capacity:
  - --For the Orenburg export system, the loss of the last station would cause a 25-percent loss in capacity.
  - --The Urengoy-Uzhgorod export system would lose 17 percent of its capacity if the last station were eliminated.
  - --The Northern Lights export system would suffer a drop of 22 percent in capacity if it lost its last two stations. Because of the proximity of the stations to one another, the loss of just one would not reduce capacity substantially.
  - --The Shebelinka export system would lose 21 percent of capacity with the loss of its last station.
- --A major outage along the Shebelinka export pipeline--the only Soviet export system exclusively using electric motor-driven compressors--affecting all stations could reduce its export capacity by 63 percent. [redacted] 25X1

Flow Interruption

Rupture of the major pipeline corridor leading from the Urengoy gasfield would be the most devastating problem the Soviets could face. In the current pipeline configuration, the

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destruction of all pipelines in this corridor would disrupt gas flow in seven pipeline systems--including the Urengoy-to-Uzhgorod export pipeline and the Northern Lights--which now handle over 40 percent of current Soviet production. Loss of this corridor in harsh winter weather conditions would cause severe problems in all sectors of the Soviet economy. The entire northern half of the country would be affected, and gas supply, except to Moscow, would be severely restricted for as long as three months.

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Even in this case, however, the Soviets could maintain export flows to Uzhgorod at 1985 levels. The Urengoy-to-Uzhgorod export pipeline has the capability to receive gas from the Central Asia-Center system at Algasovo, from the North Caucasus system at Yelets, and possibly from the Shebelinka system as it crosses near Kiev. In addition, current deliveries to Uzhgorod from the Northern Lights system could be offset by use of excess capacities in the Orenburg and the Urengoy-Uzhgorod export pipelines. 25X1

A similar problem in this same corridor after development of the new Yamburg systems would be even more devastating. Six additional pipelines with a capacity of over 245 bcm per year would traverse the same general area. Losses would amount to more than 50 percent of total Soviet production by 1990, projected at nearly 800 bcm. Exports--which otherwise would be projected at 115 bcm for 1990--would be affected; not all could be restored by diverting gas from other systems, and the entire Soviet economy--by this time more heavily dependent on gas--would suffer until repairs are made. 25X1

A rupture of the four pipelines on the Northern Lights system in the Northern economic region would have the most serious impact on an individual system. Because the Northern Lights system is running at near full capacity in this area, a disruption would curtail production by 14 percent at current levels, virtually halting all gas deliveries to the entire northern half of the nation and forcing other systems to divert gas to Moscow and Uzhgorod to make up for lost supplies. This system may become even more vulnerable because current Soviet plans do not include adding a pipeline through this area to relieve system constraints. Several other new lines planned for completion by 1990, however, will provide gas to common consumers such as Moscow and Eastern Europe, which will help provide some backup for this system. 25X1

Loss of flow through five key compressor stations in the Soviet gas network--Yelets, Gryazovets, Algasovo, Aleksandrov Gay, and Novopskov--would result in the reduction of 85 percent

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of capacity to Moscow, at least 50 percent of export capacity, and the reduction of nearly 45 percent of overall domestic consumption. In addition, nearly all system switching capability west of the Urals would be lost. Such a loss would require only that the pipelines and valves used for switching from one pipeline to another be simultaneously destroyed. The additional loss of compressors at these stations would be a major annoyance but would not add to the reduction in capacity. Once the pipelines and valves were repaired--usually a one-month operation--consumption could be restored to near-normal levels even if compressors were lost. 25X1

Effects of Seasonal Demand

The Soviets have had difficulty coping with seasonal gas demand variation. Gas consumption exhibits very pronounced hourly, daily, and seasonal demand variations. Shorter term variations can be handled relatively simply with the limited amounts of storage capacity within the Soviet Union. Each pipeline system is also capable of accommodating minor variations in demand through the use of line pack--or pumping in more gas than is removed. Seasonal variation, however, creates a more serious problem for the gas industry and is the major factor determining gas demand fluctuation in a specific region. The ratio of industrial to domestic use and the types of industrial users also influence seasonal variation. Industrialized regions in the USSR with cold or temperate climates may have winter peak demands two or three times greater than summer requirements. 25X1

Standard methods used to deal with seasonal demand swings include:

--Varying gas production accordingly and underutilizing pipeline capacity in summer months.

--Installing storage capacity near market areas large enough to offset gaps between peak demands and supply shortfalls or deficient pipeline capacity.

--Making gas available during offpeak periods to users who normally consume another fuel. 25X1

The Soviets have used all of these methods to some extent but have failed to prevent seasonal gas shortfalls. According to published accounts, during the initial years of gas development in the 1950s, no buffer or storage areas were available and pipeline capacity had to be underutilized during offpeak periods. Older gasfields that are being depleted west of the Urals could

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be used for gas storage, but none is available in the northern portions of the USSR, where seasonal swings are greatest. The Soviets have experimented with artificial underground reservoirs, but these are expensive and progress in developing and using them has been slow. As of 1976, the goal for operating underground storage capacity was about 27 bcm, approximately 4 percent of current production, which would be very little help in meeting Soviet seasonal fluctuations. In comparison, Western gas systems typically have underground storage amounting to approximately 25 percent of production. Underground storage sites are currently located near Moscow, Leningrad, Riga, Minsk, Dolina, Kiev, Saratov, Orenburg, Mary, Yerevan, and Tashkent. 25X1

Even with this extensive pipeline network, the lack of adequate storage has given the Soviets considerable difficulty in meeting peak winter demands, reportedly forcing the Soviets to curtail supplies to some customers. The Baltic, Belorussian, and Northwest economic regions are especially susceptible to emergency shutdowns because they are supplied entirely by the Northern Lights system, which apparently was nearly fully utilized when accommodating average monthly flows in 1985. To handle the problems that arise during peak winter months in meeting export commitments, the Soviets could divert gas scheduled for delivery to Moscow from the Northern Lights system. Other systems could then compensate for loss of gas to Moscow from the Northern Lights system--at some expense to their own operating flexibility. 25X1

Large gas systems react very slowly to this type of switching operation, however, and several days may elapse before gas diverted from Moscow would reach export locations. With the aid of the simulation model, more than four days would be required under ideal operating conditions to divert all flow through the Northern Lights system from Moscow--14 bcm per year delivered by branch lines at Gryazovets and Torzhok--to Uzhgorod. In reality, it could take up to three times longer, because gas systems such as these are rarely at a steady-state condition and smooth gas transfers between systems without minor operational fluctuations rarely occur. This type of problem may well have been responsible for the Soviets' past slow responses to increasing gas demand during harsh weather conditions. 25X1

The problems caused by seasonal demands in the northern portion of the USSR could be alleviated by:

--Construction of another large-diameter pipeline, including compressor stations, from West Siberia to Brest.

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--Adding underground storage near peak demand areas.

--Gaining access to the northern regions from other systems within the Soviet network.

Other than the experiments with artificial underground storage, the Soviets, according to their published papers on pipeline construction projects, do not appear to be planning any pipelines linking the Northern Lights with other systems or construction of any new pipelines through the north. The problem of meeting seasonal demand variation is, therefore, likely to persist. [redacted] 25X1

Implications and Outlook

The flexibility of the Soviet gas network gives Moscow a range of options in devising an energy and export policy for the 1990s. The Soviets will have an excess capacity of 30 bcm available at the Czechoslovak border by 1990 that Moscow could use, either to try to capture a larger market share in the West or to increase the substitution of gas for oil--above current projections--in Eastern Europe. If it chooses the first option, however, Moscow must continue to invest heavily in its export system or face steep erosion of its export capability by increasing domestic and East European gas demand by the late 1990s. [redacted] 25X1

The flexibility of the Soviet gas system is particularly important with respect to future gas exports to Western Europe. The Soviets' share of West European gas supplies is already projected to increase from 13 percent in 1985 to approximately 20 percent by 1990, but the Soviets probably will be in a good position to increase their market share beyond this level if they choose. Under the current construction schedule, six additional large-diameter pipelines, bringing gas from the giant Yamburg gasfields, will be completed by 1990, and at least one of these will supply gas to the Czechoslovakian border--increasing capacity available to export gas to Eastern and Western Europe. The Soviets could export to the West an additional 20 bcm above projected levels by 1990 and still maintain an excess capacity of 10 bcm--approximately 10 percent of estimated exports--to help cover peak demand swings. Additional gas for export could be available at Romania's border for sale to Turkey and Greece. Overall, the Soviet Union will have enough capacity by 1990 to more than double 1985 sales to the West of about 34 bcm. [redacted] 25X1

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Whether the Soviets capitalize on this opportunity to further expand their market share in Western Europe will hinge largely on the progress of North Sea gas development. Statoil--Norway's state owned oil company--recently completed negotiations to supply gas to Western Europe from the first stage of development of its giant gasfields at Sleipner and Troll, beginning in 1993. A decision on the second phase of the development of Troll must be made by about 1995 if Western Europe is to continue meeting most of its anticipated growth in demand into the early 2000's. An aggressive Soviet marketing effort could help derail this project. 25X1

To compete with North Sea gas, Moscow would have to price its gas more attractively in export markets and further expand its export pipeline network in the 1990s. At a minimum, it will have to build capacity to compensate for the diversion of the Progress pipeline gas to the West from its original intent--to meet growing East European consumption requirements into the next decade. An early indication of a Soviet decision in this direction would probably be an announcement of an additional export pipeline to be completed in the mid-1990s. This would mean that more Soviet gas would be available well before large volumes of North Sea gas would flow to the continent. 25X1

The Soviets also face growing demand for gas in Eastern Europe and at home. If Moscow decides not to seek a larger share in the West European gas market--above the 20 percent we project for 1990--it probably will concentrate its efforts on even greater gas-for-oil substitution at home and in Eastern Europe to free more oil for sale to the West. Analysis shows the pipeline network has the potential for additional gas substitution and, even without additional export pipelines, Moscow could further increase gas use for that purpose. 25X1

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Appendix

Regional Gas and Fuel Consumption

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FOOTNOTES

1. Capacity estimate assumes that gas production is not a constraint--that is, producing gasfields can deliver as much gas as the system can handle. The estimate also incorporates hydraulic limitations downstream from the production zones that arise as the systems' capabilities to further deliver gas diminish. These constraints have been quantified using the pipeline simulation model. [redacted] 25X1

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