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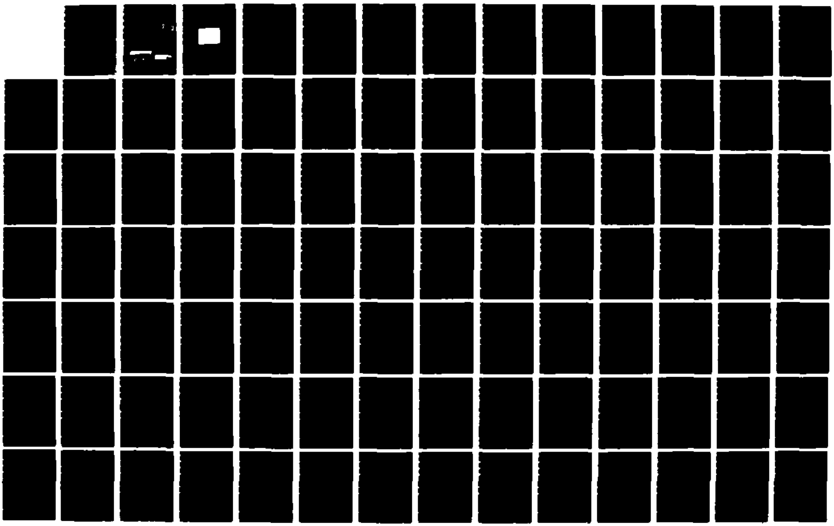

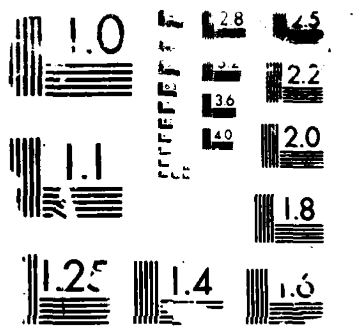
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IMPACTED MANUFACTURING VALUE ADDED– A FIGURE OF MERIT FOR TARGETING INDUSTRIAL INSTALLATIONS (U)

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number): (U) A variety of figures of merit have been developed and applied in the past for industrial targeting. Research was undertaken to determine if an improved measure could be developed. Research tasks include: (1) review of economic figures of merit in current use, (2) identification of advantages and disadvantages of the various current figures of merit, (3) postulation of alternative new figures of merit, and (4) selection and detailed evaluation of the more promising new figures of merit. This report describes the	

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18. SUPPLEMENTARY NOTES (Continued)

Multiple Classification Sources:

1. Evaluation of Recovery Denial Mission Effectiveness, SAI-77158-LJ, 30 September 1977, prepared for the Navy, SP202.

2. Evaluation of SLBM Weapon System Characteristics for Attacking Economic Recovery Targets, SAI-LJ-78:1072, 30 September 1978, prepared for the Navy, SP202.

20. ABSTRACT (Continued)

results of this research as it applies to a possible new and improved figure of merit, impacted manufacturing value added (IMVA).

(U) IMVA is defined, mathematical functions for IMVA are developed for key industries in the USSR, a detailed example is presented and approaches are described for possible implementation. IMVA offers a number of potential advantages over current figures of merit.

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PREFACE

(This Preface is Unclassified)

This report summarizes the results of research to develop alternative figures of merit for targeting industrial installation. All work was performed under the technical direction of Major Dave Williamson and Lt. Col. Dave Thomas of the Defense Nuclear Agency.

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SECTION 1

(U) INTRODUCTION AND SUMMARY

(U) Research was undertaken to determine if an improved economic figure of merit could be developed for SIOP applications. Research tasks included: (1) review of economic figures of merit used in the SIOP process and in strategic weapon analyses, (2) identification of advantages and disadvantages of the various current figures of merit, (3) postulation of alternative new figures of merit, and (4) selection and detailed evaluation of the more promising new figures of merit. The purpose of this report is to describe the results of this research as it applies to a possible new and improved figure of merit, impacted manufacturing value added (IMVA). A methodology for the development and eventual implementation of IMVA is suggested for SIOP applications.

(U) The methodology considers the Soviet Union economic target development problem in two parts. The first part deals with how deep the Soviet economy can be driven and the second part with the length of the recovery period. In the first part, peacetime conditions and priorities are relevant, at least in the immediate post attack period, and measures such as MVA and IMVA are expected to be useful in assigning priority to classes of economic targets. In the second part, because of changing post attack priorities and a wide variety of possible post attack resource allocations, peacetime measures such as MVA are not as relevant and another criteria which more directly measures post attack recovery time would seem appropriate.

(U) Specific interactions between industrial classes are very important in both parts of the problem as identified above and must be taken into account. For example, the fact that the removal of electric power would have an immediate effect on heavy electricity users such as machinery and equipment industries should be taken into account. IMVA accounts for such interactions in a direct fashion since IMVA is defined for some primary industry I as:

$$IMVA_I = \begin{pmatrix}\text{Destroyed}\\ \text{MVA}\end{pmatrix}_I + \begin{pmatrix}\text{Halted}\\ \text{MVA}\end{pmatrix}_I \qquad (1\text{-}1)$$

where the halted MVA is associated with industries dependent on industry I. In other words, IMVA is the MVA destroyed directly by the attack plus the MVA from other industrial classes which cannot operate or which operate at reduced efficiency due to the need for products that were destroyed directly. IMVA and MVA are recommended as measures of value for depth of attack since they indicate the degree to which an industrial class contributes to the gross value of output. These measures can be used to evaluate target classes which are most important to the economy based on peacetime or immediate post-attack conditions. Promising candidates for primary classes are selected and analyzed to determine which have the largest impact on the economy. Those with the largest impact are designated as primary classes.

(U) A possible implementation approach for IMVA would be the following three-step process:

(U) Step 1. Determine MVA for dependent and other industry classes and IMVA for primary industry classes based upon economic intelligence data.

(U) Step 2. Calculate the MVA and IMVA for specific installations by partitioning the industry values according to installation capacity data. Approximate attack size specification is input for this step.

(U) Step 3. Utilize overall objectives for industrial targeting (e.g., desired overall IMVA reduction or per weapon IMVA reduction or combined IMVA and MVA reduction) for DGZ development and weapon allocation. This requires careful accounting so that destroyed MVA for dependent or non-primary industries does not get counted as halted MVA for the primary industries.

(U) The procedure employed determines damage level objectives on primary class facilities which will provide a maximum IMVA by counting capacity which is directly destroyed and capacity which is halted. No credit is taken for bonus damage in the process on other facilities nearby and not part of the primary or dependent classes. Having defined the damage objectives, an attack can be carried out to achieve these damage objectives. Associated bonus damage for this attack can be calculated and added to the damage to dependent and primary class facilities. The physical damage to dependent class facilities should not be counted as it is already incorporated in IMVA. This is important in order to avoid double counting damaged facilities.

(U) The above process couples attack size to the economic value of primary installations such as electric power, steel, natural gas and oil. This occurs because of the direct consideration of industries halted when a particular primary industry is heavily damaged. For example, an electric power plant would have one value if it were the only plant destroyed in a small attack. However, if the electric power industry were heavily damaged in a larger attack, the overall economic impact would be far greater than simply the addition of individual plant values which were not accounting for halted industries.

(U) The above application of IMVA and MVA emphasizes immediate post-attack aspects of economic disruption and does not account explicitly for the recovery period. Although attacks directed against high IMVA and MVA targets obviously have a strong impact on recovery because of the basic importance of the primary industries (e.g., power plants) and the large capital investments generally associated with these industries, a second prioritized list of targets also is recommended. This list would consist of targets where their relative ranking would reflect the degree to which they delayed the economic recovery process. For example, if electric power generating facilities were important on the first prioritized list, manufacturing facilities for transformers, turbines, and generators would be important targets on the second prioritized target list. In addition, this list could include capital intensive industries which, if destroyed and rebuilt, would absorb post-attack resources which otherwise could be directed toward more rapid recovery of primary industries.

(U) In the remainder of this report, IMVA will be addressed as it relates to the first prioritized list discussed above.

Electric power and other energy related classes will be used to explain IMVA and to show how it can be derived and used in the targeting process.

(U) The methodology is to some extent iterative and in part involves a process of industry dependency definitions which is complicated and lengthy. Since the dependency process has only been started, preliminary estimates of specific dependent values will be used to demonstrate the methodology by way of an example. It is expected that the absolute values can be updated as the process continues.

(U) Section 2 provides background information regarding the current figure of merit, PRWV, current guidance, and the overall economic recovery problem. Section 3 discusses the methodology used in selecting primary and dependent industrial classes and the procedure for estimating IMVA. Section 4 provides a specific example of the methodology including the definition of economic classes, the determination of IMVA, and the percent of the total Soviet economic value which is effected. Other aspects and possible implementation approaches are briefly discussed in Section 6. Finally, capacity functions for several targetable classes and the impact of loss of electric power are discussed with other items in a series of appendices.

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(U) Table 2-1. MVA definition.[1]

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MVA COMPONENTS

"Wages and Salaries. Monetary wages and salaries paid to all state employees, including money payments, such as certain bonuses and premia that are not included in the Soviet statistical category "wages."

Labor Income of Kolkhoz Members. Money income and income-in-kind priced at average delivery prices.

Other Labor Income. Miscellaneous income, such as free clothing issued to workers, student scholarships paid by enterprises, travel expenses, etc.

Social Security Payments.

Profits of State Enterprises. Profits and losses (which would be entered with a minus sign, thus indicating a state subsidy). Presumably the profit shown must be related to the main productive activities of the enterprises.

Turnover Tax. This is shown in the column of the enterprise or industry manufacturing the taxed commodity, regardless of whether the tax is collected at the enterprise or at the retail trade level.

Other State Budget Collections (Positive Entry) or Subsidies (Negative).

Other elements of Net Product.

a. Interest on short-term loans;
b. Penalties and court fines;
c. Costs of personnel training;
d. Use of nonproductive services (passenger transportation);
e. Savings effected in administration-management expenses and payable into the state budget.

Net Income of Kolkhozes and Cooperatives.

Net Income of the Population."

(U) Table 2-2. Capital definition(1).

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CAPITAL

"The capital matrix shows the stock of fixed capital (valued in constant 1955 prices) employed in the productive sectors as an average for the year. In this case, however, the original table has only 105 productive sectors (95 in industry) instead of the 110 in the other tables. The capital assets are broken down into 30 types, of which 25 represent machinery and equipment. Also included is a vector of fixed capital in the nonproductive sphere. The data in this matrix are also adjusted for commodity-establishment differences."

"An aggregated version of the capital matrix was published in one of the statistical yearbooks and a fairly complete description of the original format is available. The original matrix shows the value of the stock of fixed capital assets broken down into 30 different types as utilized by 105 productive sectors and the prices, averaged for the year, and at book value (balansovaia stoimost'), i.e., without taking into account depreciation or attrition. Apparently, the definition of fixed capital assets used in the input-output matrix follows the standard Soviet statistical practice of excluding those assets that have a useful life of less than one year or are valued at less than 50 rubles."

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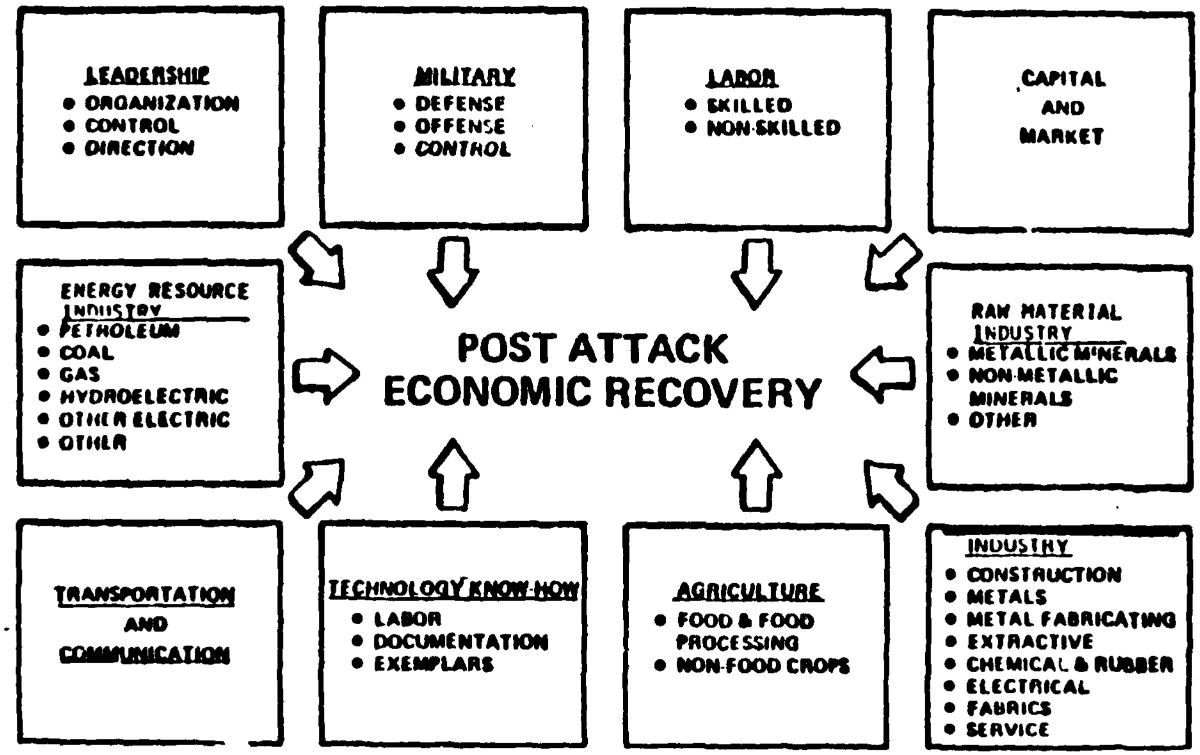
(U) 2-2 RESEARCH OBJECTIVES AND CONSTRAINTS

(U) From the onset it was recognized that the overall post attack economic recovery problem is very complex and uncertain. The requirements for post attack economic recovery, depicted in Figure 2-1, range from leadership for organization, control and direction of recovery, to military forces for national security, for population control, or coercion of economic resources from neighboring countries or for actual occupation; to the labor force, particularly skilled labor; to agriculture to feed the labor force to actual industries and national resources. Transportation and distribution systems also will play strong roles particularly because attacks are not envisioned to be uniform geographically and resources available for recovery are not uniformly distributed. Communication systems and the basic availability of technology are other factors. In addition, the existing inventories and the possibilities of product substitution or labor capital substitution are otner key considerations. When considering prolonging postwar recovery or achieving a decisive reduction of power and influence, all of these requirements must be considered. However, the current research was scoped only to the consideration of industrial installations and to attempt to develop an improved figure of merit for such installations as compared to PRWV.



(U) Figure 2-1. Requirements for post attack economic recovery.

(U) The review of other figures of merit besides PRWV included net present worth, MVA alone, K alone, GVO, physical output units, floor space, industrial concentration circles and several others. In each case no compelling improvement over PRWV could be identified when considering current guidance objectives and the SIOP development process. Therefore, an attempt was made to develop a new figure of merit. In so doing, however, and as a result of an understanding of the intelligence data potentially available and the current procedures in employment planning, the following objectives were established:

(U) 1. The figure of merit must be a measure of economic value at the installation level to support economic target development. Weapons are applied to specific targets (i.e. one or more installations) in the SIOP and therefore the figure of merit must be useful to measure the value of one installation as compared to another.

(U) 2. The figure of merit must address the functional importance of industries, particularly critical industries. It also must be a common measure applicable to both critical and non-critical industries in a consistent manner. This characteristic is critical to eliminate the current problems of treating critical industries separately and having only one quantitative meaure, PRWV, which basically is for gross capital destruction.

(U) 3. The figure of merit must lead to reasonable requirements on the intelligence data base. A significant and long effort has lead to the current Target Data Inventory and supporting analyses and documentation. Any new figure of merit proposed must offer not only a real and meaningful improvement but also at the same time it must not lead to unrealistic requirements on intelligence data collection and processing either in terms of the magnitude or duration of such efforts. This basic constraint is expected to have a strong impact on the feasibility of practical application of any new economic figure of merit for the SIOP process.

(U) 4. The figure of merit must be practical in terms of eventual implementation in the SIOP development process used by the Joint Strategic Target Planning Staff (JSTPS). The SIOP process has developed over the years since the National Strategic Targeting and Attack Policy (NSTAP) was first promulgated in 1960 at the same time that Secretary of Defense Gates directed the establishment of the JSTPS. Over recent years and at significant expense, the SIOP process has incorporated significant use of automated data processing hardware and software. Computer programs have been developed for various phases of this process such as installation selection, aimpoint development, allocation, application, timing and resolution as well as SIOP evaluation. Any new figure of merit must offer not only a real and meaningful improvement over current measures but also must offer the potential for implementation in the SIOP process without undue impact on the process in terms of the scope of the changes required or the time to complete the changes. This constraint also has a strong impact on the feasibility of practical application of any new economic figure of merit for the SIOP process.

(U) After consideration of the above objectives and after review of the advantages and disadvantages of current economic figures of merit, it was concluded that a real and meaningful improvement over current measures could be obtained if a new figure of merit could be developed which accounted for the functional importance of installations and industry classes but also met the other objectives above. This became the point of emphasis for this research.

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SECTION 3

(U) IMPACTED MANUFACTURING VALUE ADDED METHODOLOGY

(U) 3-1 INTRODUCTION

(U) The IMVA methodology depends upon the determination of economic sectors absolutely critical to the Soviet economy as defined below and other sectors dependent upon these critical sectors. This determination provides the basis for incorporating considerations of industry and eventually installation functional importance. Various economic sectors are defined in this section. In addition, an overview is presented of economic intelligence data avialable for these sectors.

(U) Once sectors are defined, a quantitative approach is required for IMVA in order to be able to calculate the halted industry MVA attributable to various levels of destruction of each primary industry. An approximate technique has been developed and is presented and compared with the PRWV approach.

(U) 3-2 ECONOMIC SECTORS

(U) The IMVA methodology developed involves dividing economic sectors of the Soviet Union into the following general classes:

Primary:	A critical set of industrial classes which will be directly targeted (e.g., oil, electric power, etc.).
Dependent:	A set of industrial classes which clearly require goods and services from the primary set (e.g., transportation, machinery and equipment, etc.)
Bonus:	A set of industrial classes which are essentially correlated with industrial floor space and may be destroyed or damaged when the primary targets are attacked (e.g., repair of machinery and equipment, etc.)

Isolated: A non-targetable set which is not correlated with industrial floor space (e.g., livestock).

Criticality for the primary classes is based upon. (1) having a large number of expected interactions with other classes, (2) being important to a large part of the total economic value, and (3) having a reasonably small number of locations and being feasible to damage for targeting purposes. The interactions with other classes and the economic importances of critical classes can be determined from Soviet Union input-output tables. Functional interactions also can be established by a knowledge of the use of various outputs or products from critical classes. The Target Data Inventory can be used to examine if the number of installations is small enough to be considered in targeting Physical vulnerabilities also affect the feasibility of targeting critical class installations.

(U) 3-3 AVAILABLE DATA FOR ECONOMIC SECTORS

(U) Considerable effort has gone into input-output table definitions for the Soviet Union. These definitions are useful in identifying important economic classes and will be used as one basis for analyzing the Soviet economic classes. The most detailed definition which exists is based on the Soviet economy in 1966 and involves 110 industrial sectors.[1] These are listed in Table 3-1. Data exist for 1966 on gross value of output, labor input, average annual employment, capital stock and depreciation for most of these 110 industrial sectors. Also, inter-industry transaction data are available in purchaser prices. Most recent data on inter-industry purchases for 1972 are given in Reference 2; however, these are for only 56 sectors. They can be directly compared to the same 56 sectors for 1966 which are given in the same document. Finally, an even more detailed breakout of specific industrial facilities is contained in the definition for the 110 sectors and these are also given in Reference 1.

(U) Table 3-1. Soviet input-output sectors.

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1	Ferrous Ores	38	Shipbuilding	75	Cotton Materials
2	Ferrous Metals	39	Automobiles	76	Silk Materials
3	Coke Products	40	Tract. & Agric M&E	77	Wool Materials
4	Refractory Materials	41	Bearings	78	Flax Materials
5	Industrial Metal Prod.	42	Medical Implements	79	Hosiery & Knitwear
6	Nonferrous Ores	43	Oth. Prod. of Mach. Bldg.	80	Other Textile Prod.
7	Nonferrous Metals	44	Sanitary Engr. Prod.	81	Sewn Goods
8	Coal	45	Other Metal Wares	82	Other Light Ind. Prod.
9	Oil Extraction	46	Metal Structures	83	Fish Products
10	Oil Refining	47	Repair of M&E	84	Meat Products
11	Gas	48	Abrasives	85	Dairy Products
12	Peat	49	Mineral Chem. Prod.	86	Sugar
13	Oil Shales	50	Basic Chem. Prod.	87	Flour & Cereals
14	Elect. & Thermal Power	51	Aniline Dye Prod.	88	Bread & Bakery Prod.
15	Energy & Power M&E	52	Synthetic Resins & Plast.	89	Confections
16	Electro Technical M&E	53	Synthetic Fibers	90	Vegetable Oils
17	Cable Products	54	Synthetic Rubber	91	Fruit & Veg. Prod.
18	Radio Technical M&E	55	Organic Synthetic Prod.	92	Tobacco Products
19	Electronic Prod.	56	Paints & Lacquers	93	Cosmetics
20	Machine Tools	57	Rubber & Asbestos Prod.	94	Other Foods
21	Forging & Pressing M&E	58	Pharmaceuticals	95	Industry Nec.
22	Casting M&E	59	Other Chem.	96	Industrial Const.
23	Tools & Dies	60	Logging	97	Transport Const.
24	Precision Instruments	61	Sawmills & Woodworking	98	Agriculture Const.
25	Oil Industry M&E	62	Plywood	99	Residential Const.
26	Mining M&E	63	Furniture	100	Other Construction
27	Metallurgical M&E	64	Other Woodworking	101	Crops
28	Pumps & Compressors	65	Paper & Pulp	102	Animal Husbandry
29	Chemical Ind. M&E	66	Wood Chem. Prod.	103	Forestry
30	Logging & Paper M&E	67	Cement	104	Rail Transportation
31	Light Ind. M&E	68	Prefab Concrete	105	Other Transportation
32	Food Industry M&E	69	Wall Material & Tile	106	Communications
33	Printing M&E	70	Asbestos-Cement & Slate	107	Trade & Public Din.
34	Hoistings & Transp. M&E	71	Roofing Materials	108	Supply and Dist.
35	Construction M&E	72	Construction Ceramics	109	Agricultural Proc.
36	Const. Mat. M&E	73	Other Const. Mat.	110	Other Branches
37	RR Rolling Stock & Equip.	74	Glass & Porcelain		

(U) The above type of economic intelligence data is essentially macroscopic. Sectors are used and they may or may not relate to individual industries. In fact, in some cases they relate to many industries. Mapping this type of data down to the installation level must be done in some approximate fashion to yield useful economic data by installation.

(U) Examples of functional dependencies derived from the above sources are given below; these and others are discussed in more detail in Section 4 and Appendix E:

(U) • Jet engine production requires high alloy steel

(U) • Transformer production requires specialized rolled steel products

(U) • 5 KW-HR are required typically to produce one bbl of oil

(U) • Primary rolling mills generally require more than 20 MW of input power

(U) 3-4 IMPACTED MANUFACTURING VALUE ADDED (IMVA)

(U) IMVA for industry I is the destroyed MVA for industry I plus the MVA of other industries dependent upon industry I. Dependent MVA simply means that if the required input goods and services are not available, the output goods and services will not be produced and thus the destruction of primary MVA will also halt the goods and services from dependent facilities.

(U) Some consideration was given to the concept of impacted capital (e.g. destroyed plus dependent capital). However, if capital were used, what would be the meaning of dependent capital? Capital as provided in the input-output table and defined in Table 2-2 is book value and does not account for depreciation so that it is not necessarily related to replacement value. Capital is made up of such items as buildings, machinery, equipment and inventory material. Some of these would deteriorate as time passed and others could be maintained at some state of value. At any rate, the removal of input goods and services would not immediately affect the amount of capital in the dependent industries. After a period of time some reduction of capital value should occur, but this reduction would be difficult to predict. Capital as it relates to replacement value might be a good measure for industries which are attacked directly (i.e., primary classes); however, there appear to be better measures of the ability of dependent classes of an industry to contribute to the gross output of the economy.

(U) 3-5 IMVA LIMIT FUNCTIONS

(U) In order to use impacted MVA for quantitative analysis, the relationship between primary and dependent MVA must be defined. Impacted MVA can be defined as the sum of the self MVA which is directly destroyed and the dependent MVA. The self MVA directly destroyed is readily defined as the product of the expected damage to capital and the undamaged total self MVA. Dependent damage is more difficult to define since it depends on post attack priorities, limiting processes and physical phenomenon; however, a limit function can be derived. If one assumes that in the post attack period all of the surviving products of a primary class (e.g. residual resources) are allocated to its dependent classes and that within the dependent classes, preattack priorities are maintained in the post attack case, it is possible to calculate the impacted MVA of industry I as a function of the expected damage to the primary class as follows:

$$IMVA_I = \begin{bmatrix}\text{CAPACITY}\\ \text{DAMAGE}\\ \text{EXPECTANCY}\end{bmatrix} \begin{bmatrix}\text{INDUSTRY I}\\ \text{MVA}\end{bmatrix} + \begin{bmatrix}\dfrac{\text{RESIDUAL RESOURCES}}{\text{DEPENDENT PREATTACK UTILIZATION}}\end{bmatrix} \begin{bmatrix}\text{DEPENDENT}\\ \text{MVA}\end{bmatrix} \qquad (3\text{-}1)$$

In equation form this becomes:

$$IMVA_I = DE_I MVA_I + \left(1 - \frac{(1-DE_I)}{B_I}\right) DMVA_I \qquad 0 \le 1-DE_I \le B_I \qquad (3\text{-}2)$$

$$= DE_I MVA_I \qquad 1 - DE_I > B_I$$

$IMVA_I$ = Impacted MVA for the Ith industry class

DE_I = Capacity damage expectancy for industry I

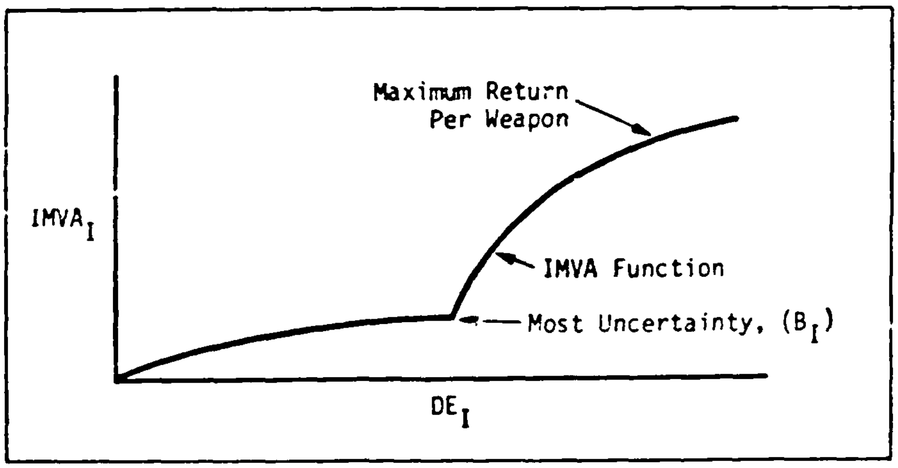
MVA_I = Total MVA of industry I (total self MVA)

$DMVA_I$ = Total MVA of industry dependent upon industry I

B_I = Preattack fraction of industry I class capacity used by dependent industry classes

(U) The IMVA which results from the use of Eq. (3-2) has the general characteristic shown in Figure 3-1. As the expected damage increases there will be a gradual buildup of value based only upon the self-MVA directly destroyed until point B_1 is reached. From that point, there will be a rapid increase in value as the dependent effect (e.g. halted MVA) accumulates until weapon inefficiencies and/or small remaining installations cause the function to bend downward. For these kinds of functions there is a value for DE_I which will maximize the return per weapon, and there is an incentive to drive the damage to relatively deep values or very high DE_I.

(U) The characteristics of IMVA curves are different than PRWV curves. A comparison of IMVA and WV is shown in Figure 3-2 for the Soviet Union electric power industry. The IMVA data is developed in more detail in Section 4. The WV data approximates TDI data and the number of .8 P_K weapons is used as opposed to DE in this comparison. With 100 such weapons, approximately 50% of the weighted value is achieved but only about 7% of the IMVA. With 200 such weapons, approximately 60% of the weighted value is achieved but only about 40% of the IMVA.



(U) Figure 3-1. Characteristic IMVA function.

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(U) It is evident that with functions resulting from the use of weighted value, maximum returns result from the first few increments in damage and there is no direct incentive to drive the damage to very deep levels. However, with IMVA for the primary industrial classes, there is a significant advantage to achieve very heavy damage to these classes because so much is dependent upon their operation. For example, electric power is a primary industry in the IMVA methodology. It is intuitively obvious that the loss of electric power generation in an industrial society will have an overall impact on the economy far in excess of the value of the electric power industry considered by itself. Calculations of IMVA in Section 4 leading to the results in Figure 3-2 demonstrate that this is indeed the case. This is also the case for other primary class industries; IMVA limit functions also are developed for them in Section 4.

(U) The fundamental point above is that the economic value of a primary industry is dependent upon the attack size. Value can not be constant for various primary installations in this industry (e.g. independent of attack size) if the functional importance of the industry is to be considered. For example, in Figure 3-2, the IMVA for the electric power industry is shown as a function of number of weapons. For small attacks, only the self MVA directly destroyed represent the value. For larger attacks, the significance of halted MVA comes into play. However, if an approximate attack size can be determined, the IMVA can be proportioned across installations to yield an appropriate installation value as will be discussed more in Section 5.

(U) Equation (3-2) represents a limit function since additional demands beyond the dependent class requirements will usually exist. Industries in the bonus and isolated classes will place demands on the primary class as will the military. The analysis to this point has not been definitive enough to quantify such demands. Equation (3-2) can also be affected by the allocation between the dependent classes since the value of $DMVA_I$ would depend on the dependent class priorities; however, it is relatively insensitive to such allocations especially when high damage levels are achieved. This is a direct result of $DMVA_I$ being the sum of the dependent class MVA. For these reasons most of the uncertainty involved in limit functions is about the value at point B_I and the least uncertainty exists in the region of maximum return per weapon.

(U) It should be noted that Eq. (3-2) does not include stockpiles or goods which are in the supply chain. Because of this, the loss of goods from the primary classes except for electric power will not be felt for a period of time which will vary depending on the amount stored and the amount in the supply chain and the rate of utilization in the post attack period. These issues are not treated for the following reasons:

(U) • Data are not available on the amount of stockpiles or material in the supply chain.

(U) • Delays on the order of months are expected and these are short compared to recovery periods which are expected to be measured in years.

An approach which could be used to include stockpile and supply chain material given the necessary data is discussed in Section 5.

(U) 3-6 APPLICATION OF MULTIPLE WEAPONS TO PRIMARY CLASS INSTALLATIONS

(U) The use of IMVA for primary class industries provides a method to account for the greater importance of these industries as compared to dependent class industries. As mentioned, IMVA for an industry can be partitioned over the installations of that industry in proportion to capacity data. When an industrial class has installations with variable capacities (i.e., electric power) each weapon that is assigned should maximize the expected marginal return in order to achieve the highest IMVA. In subsequent sections IMVA limit functions are developed and examples are presented for targeting using .8 P_K weapons. High capacity primary class industries receive multiple weapons because of their importance. It is useful at this point to provide the tables used in these types of calculations.

(U) If the smallest plant targeted has a capacity of 10 units and a .8 P_K weapon were used, the expected return from targeting that plant would be 8 units. If the largest plant had a capacity of 1,000 units, the first weapon would achieve an expected return of 800 units, the second weapon an expected return of an additional 160 units, the third weapon 32 additional units, and the fourth weapon 6 additional units. Therefore, one should assign a third weapon to the highest capacity plant before assigning one weapon to the lowest capacity plant. One could either specify that three weapons be assigned to the large plant and one to the small plant or that the large plant be assigned a damage expectancy of .992 and the small plant a damage expectancy of .8. The latter approach permits use of different kinds of weapons and is therefore preferred.

(U) Given the capacity of each installation, it is possible to determine threshold plant sizes which represent transitions from N weapons to N+1 weapons. The weapon assignment thresholds can be determined as shown in Table 3-2 for weapons with a single shot kill probability of .8.

(U) Table 3-2. Weapon assignment thresholds.

UNCLASSIFIED

Single Weapon Kill Prob.	Number of Weapons Assigned	Multiple Weapon Kill Prob.	Incremental Expected Return	Capacity Multiplier
.8	1	.8	.8	1
.8	2	.96	.16	5
.8	3	.992	.032	25
.8	4	.9984	.0064	125
.8	5	.99968	.00128	625

The key to the use of Table 3-2 is the capacity multiplier. If the range in capacity is such that the largest plant is 625 times larger than the smallest plant and all are to be targeted, then the largest plant receives five weapons while the smalles* eceives one.

(U) If the single weapon kill probability is cha would be the case for mixed weapons, the magnitude of city multiplier will change. For the case of mixed weap damage levels should be calculated based on the single sho damage probability for the most effective weapon rather than .8 and then when less effective weapons are used, the number required can be determined and the process will be essentially independent of weapon type. However, to simplify subsequent examples only .8 P_K weapons will be used.

SECTION 4

(U) AN IMVA EXAMPLE

(U) 4-1 INTRODUCTION

(U) The basic development and application of IMVA is demonstrated by a four step process:

(U) 1. Non-overlapping primary, dependent, bonus and isolated economic classes are established.

(U) 2. Quantitative MVA relationships are developed between primary and dependent classes to facilitate the development of IMVA for the primary classes.

(U) 3. IMVA limit functions are established for primary class industries and are related to actual installations in the industries.

(U) 4. A weapon allocation procedure is developed to demonstrate the application of the IMVA limit functions for targeting.

(U) In the following example, each of the criteria suggested in Section 3.1 are considered and the resulting primary, dependent and bonus targets are analyzed to demonstrate the calculations of IMVA and its use in strategic targeting.

(U) 4-2 PRIMARY CLASSES

(U) 4-2.1 Highly Interactive Primary Classes

(U) In searching for industrial classes likely to show significant interdependencies, first it was decided to consider economic sectors most heavily dependent upon basic energy. These can be readily determined by processing data contained in Soviet input-output tables. The source of data was the 1972 Soviet input-output table contained in Reference 2. To reduce the complexity of the process, all chemicals were combined into one sector (48 through 59 of Table 3-1) and all machinery and equipment (M&E) sectors were combined (15 through 46 of Table 3-1). Figure 4-1 shows the resulting classes which use 5% or more of oil output, of gas output, of coal output or of electric power output. The MVA of each sector is also shown. These sectors along with export, self-use and consumption account for more than three fourths of the basic energy output in the Soviet Union as shown in Table 4-1.

(U) The MVA represented in Figure 4-1 is about 170 billion rubles out of the 1972 total of 300 billion rubles and the sectors in combination represent essentially all of the readily targetable MVA except for that associated with generalized industrial floor space.

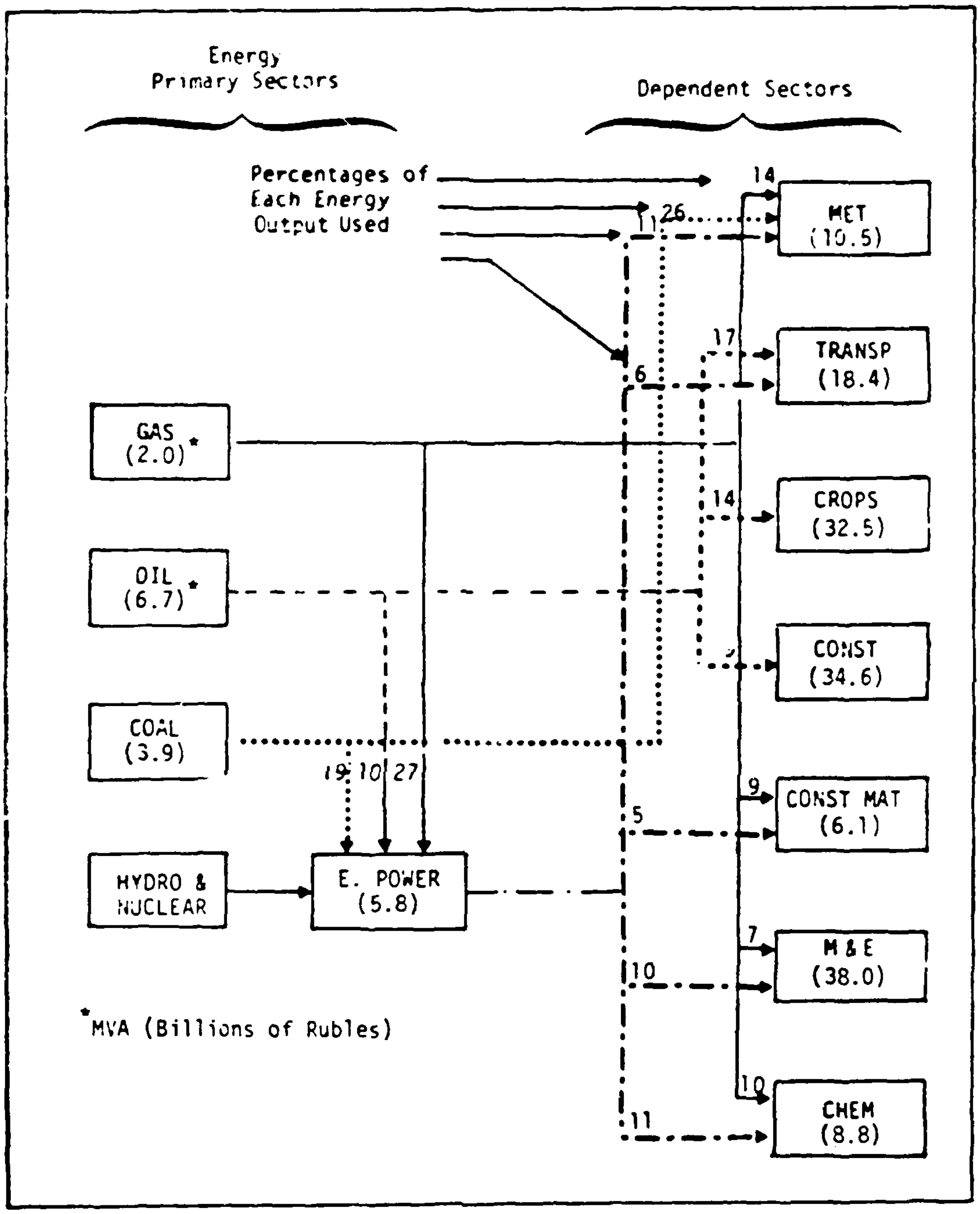
(U) 4-2.2 High Dependent Value Primary Classes

(U) Two other classes, rolled steel and cement, also were considered initially as primary classes because of their high economic value dependencies. Machinery and equipment with an MVA of 38 billion rubles is dependent upon rolled steel (c.f. Appendices B and E). Construction with a MVA of 34.6 billion rubles is dependent upon cement.

(U) As a result of the above process, the six classes that make up the initial primary set are: gas, oil, coal, electric power, rolled steel and cement. For purposes of limiting the IMVA example, no other classes were considered for the primary set.

(U) 4-2.3 Targeting Feasibility of Primary Classes

(U) Any primary class industry must be feasible to target by having a small enough identifiable set of installations. consistent with U.S. weapon resource constraints and by being vulnerable to nuclear weapons. From this point of view, rolled steel and oil are highly concentrated and vulnerable and therefore feasible to target. This is discussed in more detail later in



(U) Figure 4-1. Energy dependent economic sectors.

Section 4 as well as in Appendices B and E. Electric power has been analyzed in some detail[3,4] and in 1975 it was estimated that 95% of the generating capacity was contained in about 500 plants (c.f. Appendix A). Electric power also is feasible to target.

(U) Table 4-1. Energy uses in the Soviet Union.

UNCLASSIFIED

Use	Sector: Gas	Oil	Coal	E. Power
Export	3	17	2	1
Consumption	15	7	13	27
Self-Use	3	3	27	1
In Figure 4-1	67	50	45	43
Percent of Total Output	88	77	87	72

(U) There are a large number of cement plants widely distributed throughout the Soviet Union. Cement plants also exist in the TDI and are feasible to target.

(U) 4-3 DEPENDENT AND OTHER CLASSES

(U) Criteria for selection as a member of the dependent set is that the class or fraction of a class be clearly dependent on one or more outputs of goods and services from the primary set. Although input-output data and data from econometric models can be useful in identifying the primary set, they generally are not useful in defining the dependent set. This results from the fact that input-output tables and econometric models do not generally account for one or more of the following:

(U) • Some industrial classes require input goods for which substitutions are not currently possible. For example, transformers require specialized rolled steel.

(U) • Some industrial classes require inputs beyond a definable threshold before any output can be provided. For example, a primary steel rolling mill cannot operate without more than 20 megawatts of input power.

(U) • For many industrial classes the relationship between inputs and outputs are non-linear. For example, the aluminum industry is probably unaffected until the power capacity has been reduced to around 70% of the pre-attack level and is probably completely shut down when the power capacity is reduced to around 15% of the pre-attack level.

(U) • Considerable substitutions are possible. For example, cement kilns require concentrated sources of heat and these can be provided with natural gas, coal or with oil products and thus all three must be removed to insure that cement kilns cannot operate.

These kinds of issues are involved in determining that an industrial class is <u>clearly</u> dependent on goods and services from the primary set. An example of a set of dependent industrial classes is shown in Table 4-2. All of the indicated dependent classes require input goods and services from one or more of the primary classes. This table also lists other classes not placed in either the primary or dependent categories. Obviously, industries in these other classes are dependent to varying degrees on the primary classes. However, since these dependencies were not as easily or clearly definable as for those classes currently in the dependent set, and since there was a desire not to over estimate IMVA, certain classes were relegated to this other class category.

(U) Table 4-2. Specific non-overlapping economic classes selected initially.

Initial Primary Classes	Set of Dependent Classes	Other Classes
Oil[1,3]	Oil Extraction	Textiles
Gas[1,4]	Transportation	Trade
Electric Power[1,5]	Crops	Other Industry
Rolled Steel[2,3]	Construction	Repair of Machinery and Equipment
Cement[2]	Construction Materials	Wood Products
Coal[6]	Machinery and Equipment	Other Branches
	Chemicals	Food/Processing
	Metallurgy	Livestock
		Forestry/Pest and Shale
24 Billion Rubles MVA (8% of Total MVA)	150 Billion Rubles MVA (50% of Total MVA)	126 Billion Rubles MVA (42% of Total MVA)

( ) 1. Basic energy and highly interactive.
( ) 2. Critical to large economic segments.
( ) 3. Highly concentrated.
( ) 4. Collection stations.
( ) 5. 95%, 500 installations.
( ) 6. Coal is essentially non-targetable.

(U) 4-4 QUANTITATIVE RELATIONSHIP OF MVA BETWEEN CLASSES

(U) The process of assigning dependent MVA to primary classes is a complicated and lengthy one which has only begun. It involves identifying absolute contingencies such as those for which no substitutions are possible as discussed previously and this in turn requires an understanding of the specific processes employed in each dependent sector. As a result, estimated values are uncertain and may change as deeper understanding of

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the underlying processes is gained. Preliminary dependencies have been identified and preliminary value estimates have been made in the following discussion in order to demonstrate the methodology. The magnitude of the value estimates should be modified as better information becomes available.

(U) These dependencies were based on the following specific issues underlined in the text:

(U) Rolled steel, ferrous metallurgy, non-ferrous metallurgy, oil, irrigated crops, open pit coal mining and the electric driven portions of transportation are considered to be dependent on electric power.

(U) Reference 4 specifically considered these relationships (c.f. Appendix E). The steel rolling process in the Soviet Union was examined in terms of its electric power requirements. The entire steel rolling process will stop if power is removed to about the 20 megawatt level and all major complexes will be adversely effected if power is removed down to the 50 megawatt level.

(U) *Irrigated crops are dependent on electric power to* pump water at key pumping stations and also dependent on the water supply from large dams which are likely to be destroyed as a means of removing electric power generating units. Irrigated lands are responsible for about 30%* of the agricultural output. The fraction of transportation using electric locomotion and crude oil pipelines also requires electric power. This fraction is

(U)*From Reference 5 it is noted that in 1977 8% of the viable land, fruit and berry area produced 30% of the total volume of agricultural production on kolkhozes, sovkhozes and other state agricultural enterprises. From Reference 6, it is noted that in 1975 irrigated crops comprised 14,500,000 hectare of 217,000,000 hectare or 6.7%. From Reference 7, it is predicted that irrigated acreage will be 28,000,000 by the 1980's or 13% of the 1975 total. Therefore, the fraction irrigated could range from 30/8 x 6.7 = 25% to 30/8 x 13 = 49% and the higher figure has more uncertainty. As a result the value 30% is used.

estimated to be about 40%.* Finally, it was generally concluded that since the system losses will be nearly 10% the removal of generating capacity to a level of about 90% would cause a breakdown in the high voltage distribution system and would insure that less than 10% of the dependent classes would be available.

(U) Machinery and equipment production is considered dependent on rolled steel.

(U) Machinery and equipment is an aggregation of sectors (i.e., 15 to 46 of Table 3-1), which produce basic items such as machine tools, turbines, transformers, generators and automobiles. Although these all require some amount of cast or forged metal products they also have one or more requirements for rolled steel products. For example, transformers cannot be made without special rolled steel for cores and automobiles require rolled sheet as well as axles and bearings, all of which depend on the steel rolling process. The removal of machinery and equipment would not stop basic production such as steel production which could continue using in place equipment; however, new plant additions and replacement of worn equipment would not be possible.

(U) Crops, transportation and construction are considered to be dependent on oil.

(U)*From Reference 8, page 163, it is noted that in 1975, 60% of the freight turnover was handled by rail and 11% by oil pipelines leaving 29% for other categories of freight transportation. The transportation sector in the 1966 inout-output table given in Reference 1 includes freight-only for rail and other transport and communication; however, communication is only 4% of the 1966 GVO. From Reference 9 at least some and probably all crude oil pipelines have pump driven by electric motors (e.g., 6300 kw) and from Reference 10 electrified lines handled a little more than one-half of all freight. Combining these issues result in the following:

$$.96[60/2 + \text{fraction of oil and other transport}] = .40$$

(U) Agriculture is made up of livestock and crops. Although neither of these is directly targetable because of the large number of farms and their geographic distribution, most of the crops (i.e., non-irrigated) and to some extent livestock require oil products. Without gasoline or diesel for tractors, other farm machines and local electric generating stations, crops as currently defined would be essentially eliminated and livestock outputs would decline. Clearly, some farm activities could continue since, for example, horses could still be used to pull plows if plows of the right type were available; however, the output of crops would not be expected to significantly exceed local demand and for all practical purposes the MVA of crops would be eliminated. It is expected that reduced efficiencies in livestock would more than balance residual activities relating to crops and therefore the MVA of crops is assumed to be dependent on oil while livestock is considered to be isolated and therefore not available.

(U) Transportation as defined in the 1972 input-output tables includes rail transportation (diesel and electric) pipelines and water transport (marine and river) as well as communications. The removal of oil products would eliminate diesel dependent rail services, most pipelines, water transport and much of communications which is dependent on small local diesel or gasoline driven generators. If electric power was still available from the distribution system, electric rail and some communications would remain in service. Therefore, it is expected that without oil products and without power from the high voltage power distribution system or oil products, transportation as currently defined would be eliminated.

(U) Although construction in the Soviet input-output table is handled differently (i.e., there are no purchases of construction by other sectors by definition) it has an MVA and construction does purchase from other industrial sectors. Construction as currently defined (e.g., construction of heavy industry) is dependent on oil products for fuel directly or on electric power from small generators which in turn require oil products for fuel. Log cabins could still be built; however, construction as currently known in the Soviet Union would not be expected to continue without oil products.

(U) Construction is dependent on cement

(U) Construction is also dependent on cement including prefabricated concrete structures. Although the cement part of construction material has a relatively small MVA, the combination of self MVA and construction MVA is large. The issue of whether construction should be credited to oil or cement (since it requires both) will be treated subsequently.

(U) Chemical production is dependent on electric power

(U) Chemical production is an aggregation of basic chemicals such as ammonia and secondary chemical products such as synthetic rubber. In 1962, the energy equipment installed in chemical production processes was 8,895 MW of which 7,076 MW was for electric motors.[11] Although some production might continue in small chemical complexes and in small parts of larger complexes based on other energy sources, the bulk of chemical production is considered to require electric power.

(U) Construction material requires coal, gas or oil

(U) Construction material requires concentrated sources of heat either from coal, gas or oil. Most construction material involves the use of a kiln (e.g., cement); however, considerable possibilities for substitution exist and it is considered that either coal, gas or oil will be sufficient for the construction material processes to continue.

(U) Open pit coal mining is dependent on electric power as was indicated previously and deep coal mining is dependent on oil.

(U) The fraction of coal production using each method is shown in Figure 4-2. Deep coal mining requires pumps for water removal, fans for ventilation, power for hoists and equipment and most of these are dependent on electric motors; however, it is expected that back-up power supplies will be available at each mine which can be used when the electric power is not available from the distribution system and these will be dependent on oil products. Efficient open pit mines are dependent on large automated shovels which receive power from high voltage portable cables and the power requirements are large enough that they depend on the high voltage distribution system or they are supplied with units which will be targeted.

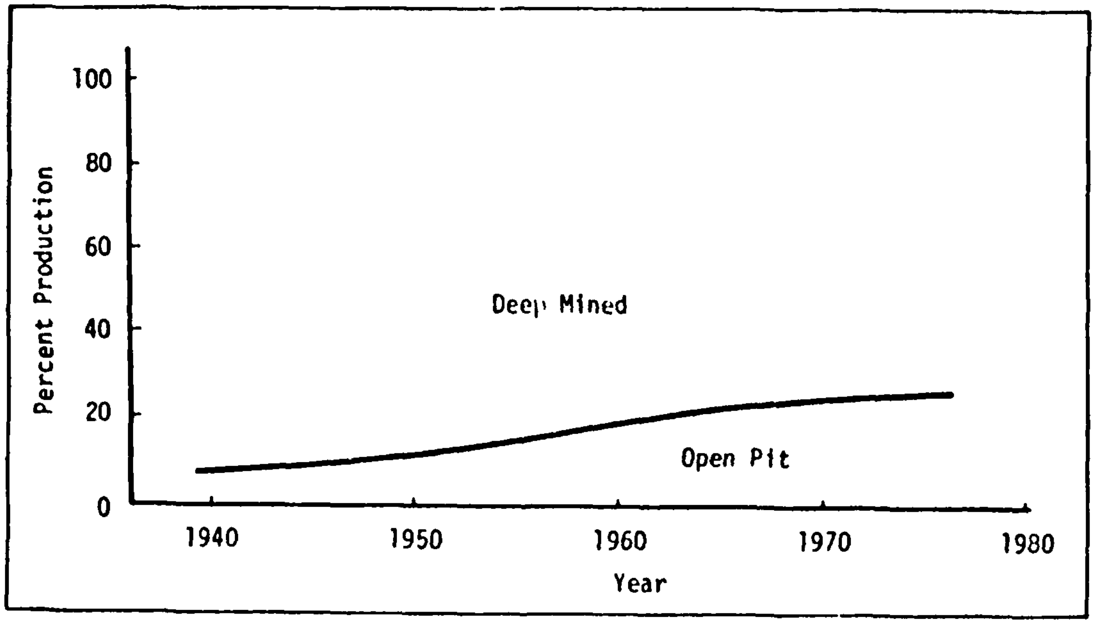
(U) Figure 4-3, summarizes the sectors and dependencies which have been considered. Targeted sectors are shown on the top and each interaction which has been considered is indicated with an arrow. The dashed arrows represent dependencies which will be considered or rejected. The solid arrows represent the final dependencies. The rationale for these decisions are presented in the next section.

(U) Of the 1972 total of 300 billion rubles, the final primary set of four classes* accounted for 17.0 billion rubles or only about 6% of the total MVA, however, the dependent set accounted for 154 billion rubles or about 51% of the total MVA.

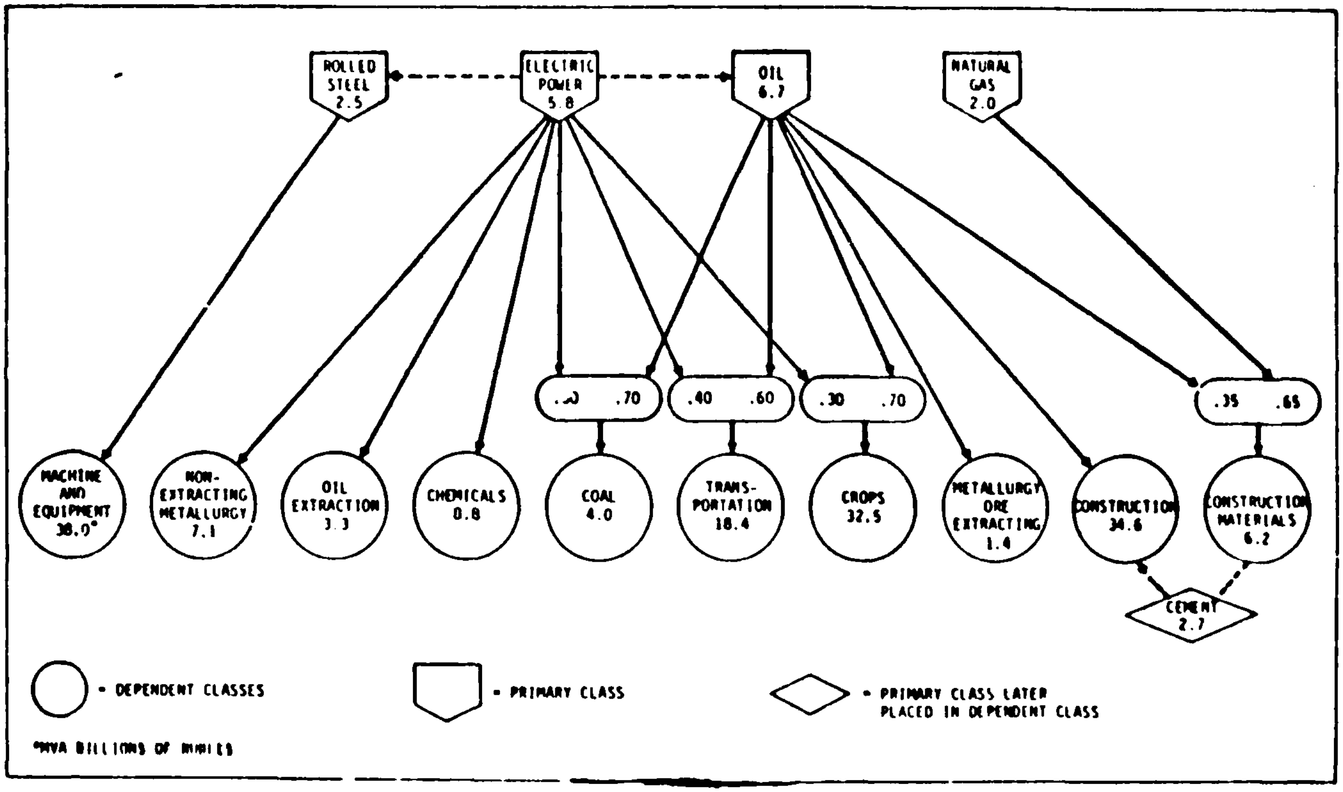
(U) 4-5 IMVA LIMIT FUNCTIONS

(U) The basic interactions shown in Figure 4-3 relate the dependent classes of Table 4-2 to the primary classes and it is

(U)*Cement is eliminated from the primary set later in the text.



(U) Figure 4-2. Coal mining methods[6].



(U) Figure 4-3. Basic interactions between classes.

clear that certain choices are possible (e.g., assign construction MVA to oil or cement). Since these choices involve large segments of value (e.g., 34.6 billion rubles MVA for construction) their resolution will have a significant impact on the relative value of targetable classes. The interaction questions include the following:

(U) • Should M&E be removed by taking out rolled steel or electric power?

(U) • Should construction be removed by taking out cement or oil?

(U) • Should rolled steel and oil be removed by taking out electric power or by direct targeting?

(U) • Which class among coal, gas and oil will be targeted last since construction material requires that all three be removed?

The resolution of these questions requires that limit functions be developed as defined in Section 3. Limit functions are needed for electric power, oil, steel, natural gas and cement and in the case of electric power, two functions are needed. One is needed for the case where oil and steel are dependent on electric power and this will be referred to as total electric power limit function and another for the case where oil and steel are targeted directly.

(U) The data required to develop limit functions are as follows:

MVA_I: The self MVA of each primary class

B_I: The pre-attack purchases of the primary classes by the dependent classes plus the self utilization of the primary class as calculated using input-output data for 1972 and represented as a fraction of pre-attack values.

$DMVA_I$: The dependent MVA.

DE_I: The capacity damage expectancy to be achieved against each primary class.

(U) Except for cement, supporting data for the limit function constants are given in Table 4-4. The MVA_I and $DMVA_I$ values are given directly; the dependent definitions permit processing of the 1972 input-output table to determine the values for B_I. The resulting constants are given in Table 4-5. Examples of damage functions for the first four classes are shown in Figure 4-4 through 4-7 and examples of limit functions are shown in Figures 4-8 through 4-11. The damage functions were obtained using a maximum marginal return approach going from largest capacity installations to the smallest. The IMVA limit functions were calculated using the parameters in Table 4-5, Equation (3-2) and the damage functions. The damage functions relate capacity damage expectancy to the number of .8 P_K weapons. With these results and similar data on cement and total electric power, it is possible to resolve the questions raised above and underlined in the text below.

(U) Should M&E be removed by taking out rolled steel or electric power?

(U) The impacted MVA attainable with each of these options is shown in Figure 4-12. For example, with electric power, the impacted MVA is small (i.e., only self MVA) until about 40 installations have been targeted and at this point impacted MVA rapidly increases to a point which corresponds to about 50% of capacity. Beyond this, the functions levels off since smaller plants are involved. A similar function results for rolled steel except that the return per weapon is significantly greater than for electric power. It is clear that of the two options, it is more efficient to target rolled steel directly than to target electric power as a means of impacting the M&E sector. Even if the number of rolled steel locations used here was low by a factor of 2 or 3* (cf Appendix B) one would prefer to target them directly.

(U)*This could happen, if rolling mills for copper and aluminum could be converted to rolling steel products. The feasibility of this option has yet to be studied.

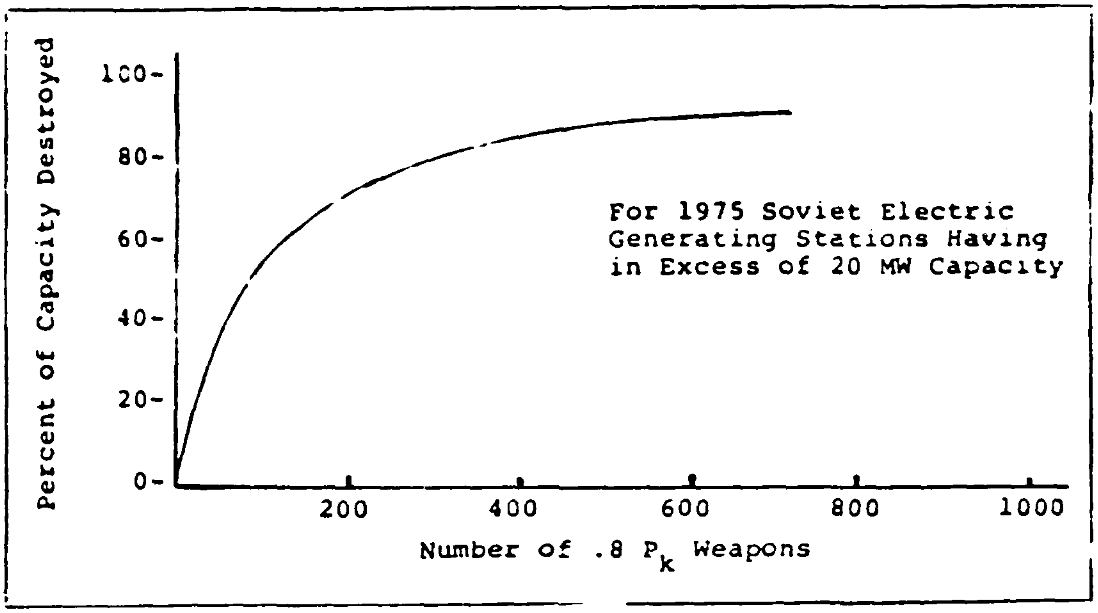
(U) Table 4-4. Quantitative MVA relationships between primary and dependent classes.

PRIMARY CLASS	SELF MVA*	DEPENDENT CLASS	DEPENDENT MVA	IMVA
NATURAL GAS	2.0	65% OF CONSTRUCTION MATERIAL	4.0	6.0
OIL	6.7	35% OF CONSTRUCTION MATERIAL	2.2	
		NONELECTRIC TRANSPORTATION	11.0	
		NONIRRIGATED CROPS	22.8	
		CONSTRUCTION	34.6	
		ORE EXTRACTION	1.4	81.4
ELECTRIC POWER	5.8	NONEXTRACTIVE METALLURGY	7.1	
		CHEMICALS	8.8	
		ELECTRIC TRANSPORTATION	7.4	
		IRRIGATED CROPS	9.7	
		OPEN PIT COAL MINING	1.2	
		OIL EXTRACTION	3.3	43.3
ROLLED STEEL	2.5	MACHINERY AND EQUIPMENT	38.0	40.5
TOTALS	17.0		154.2	171.2
% USSR TOTAL	6		51	57

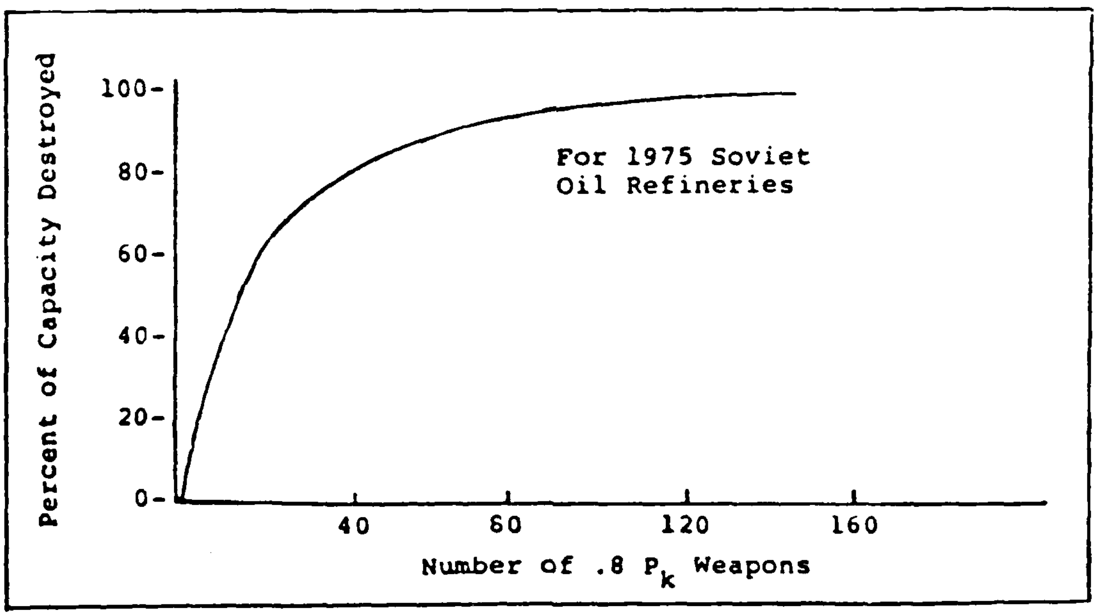
*BILLIONS OF RUBLES

(U) Table 4-5. Limit function parameters.

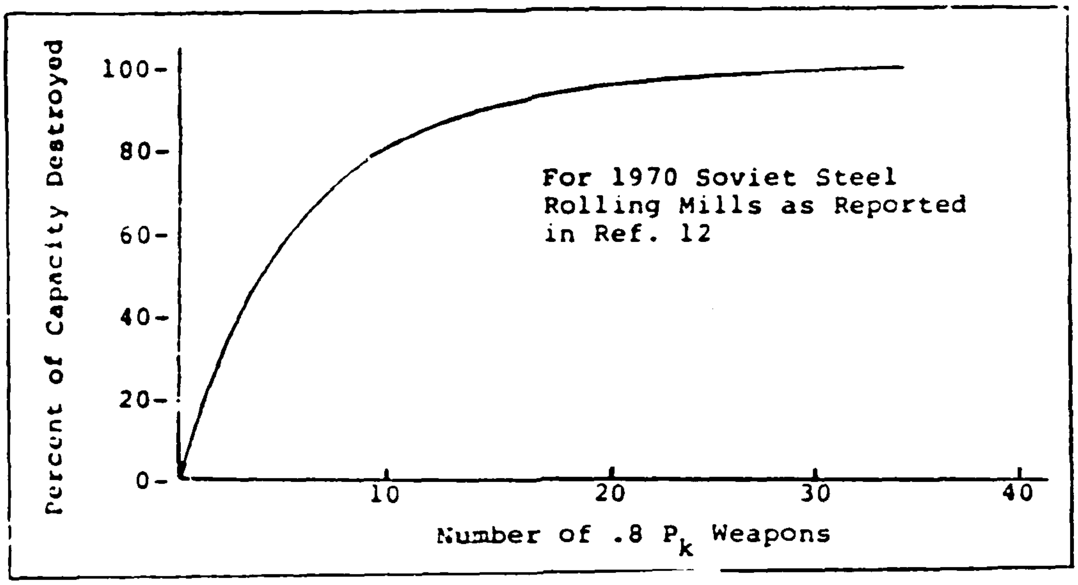
Primary Class	MVA_I	B_I	$DMVA_I$
Rolled Steel	2.5	.32	38.0
Oil	6.7	.69	74.7
Electric Power	5.8	.44	35.5
Natural Gas	2.0	.27	4.0
Cement	2.7	.44	35.0
Total Electric Power	5.8	.57	150.2



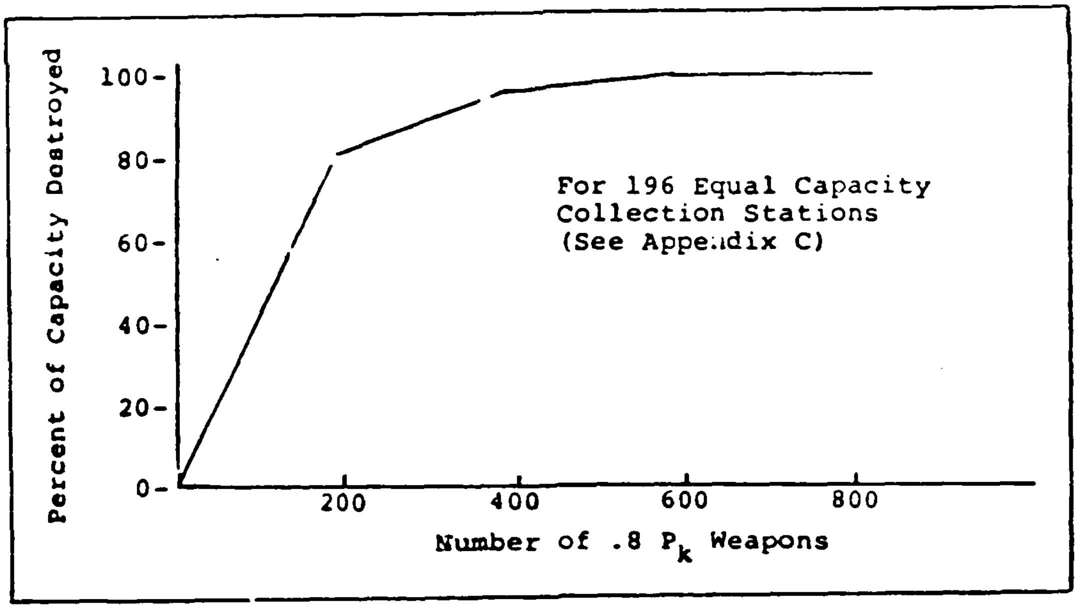
(U) Figure 4-4. Damage function for electric power.



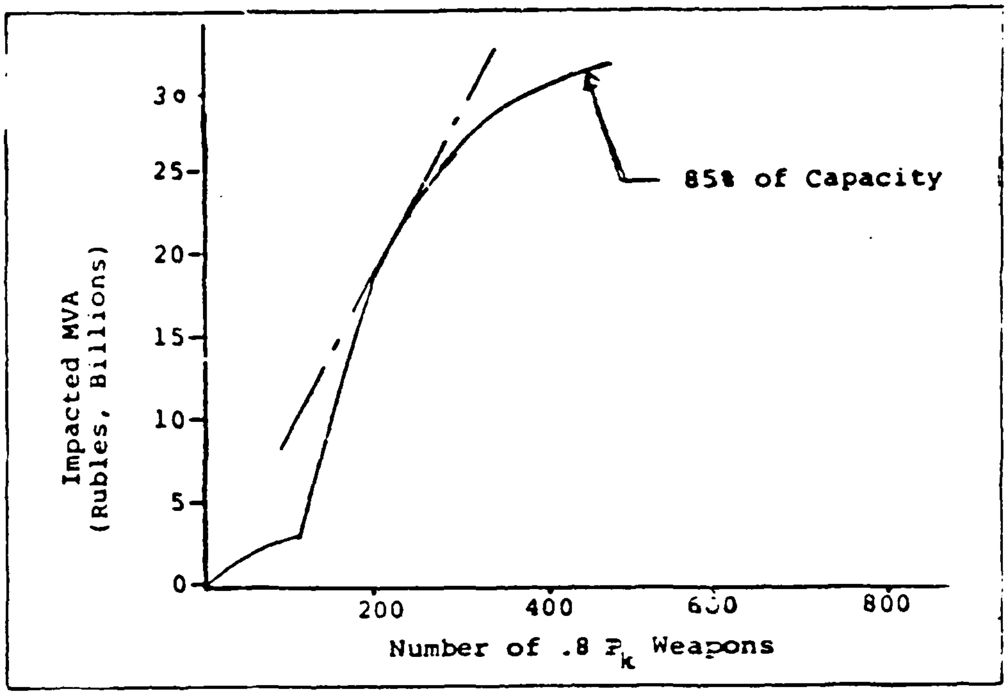
(U) Figure 4-5. Damage function for oil refineries.



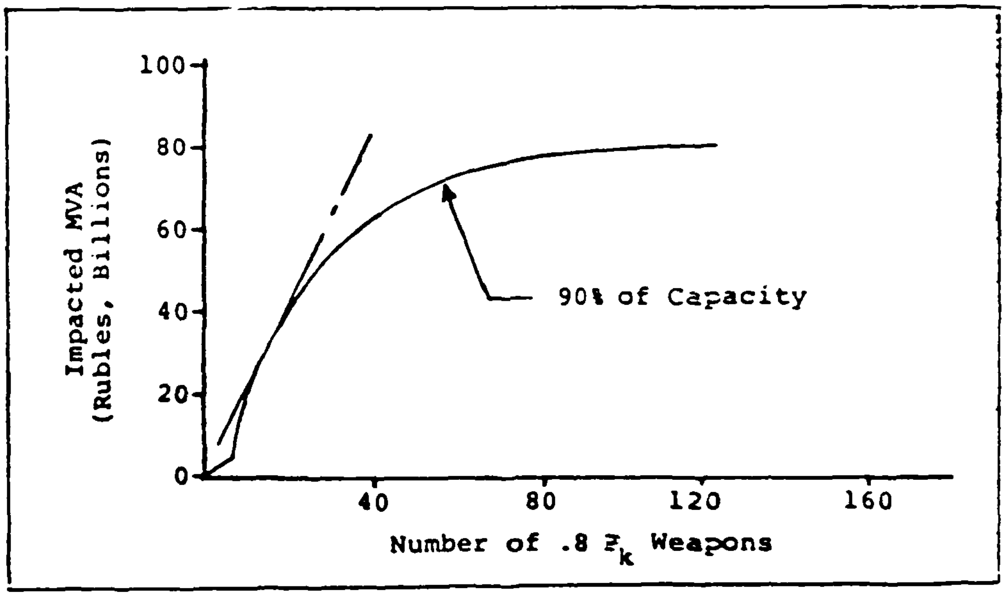
(U) Figure 4-6. Damage function for rolled steel.



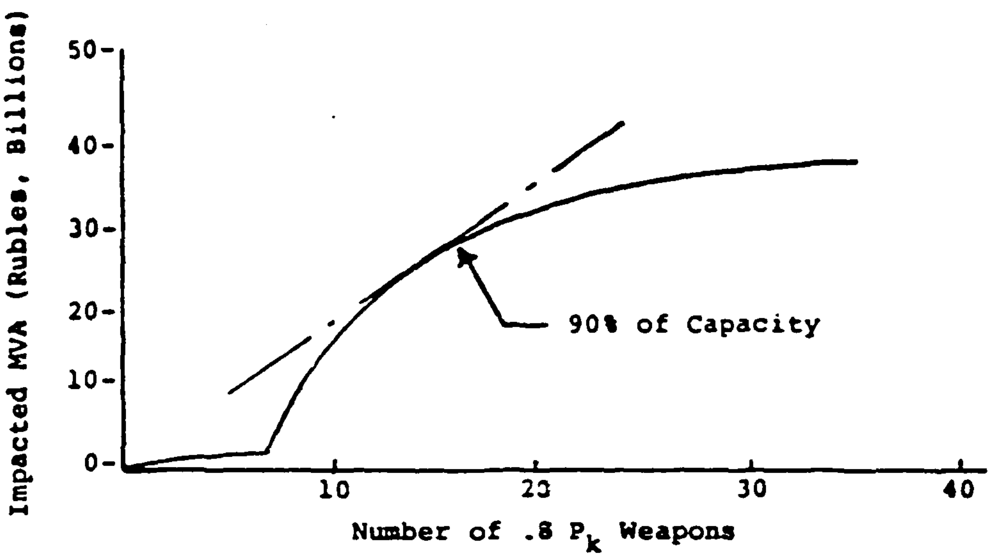
(U) Figure 4-7. Damage function for natural gas.



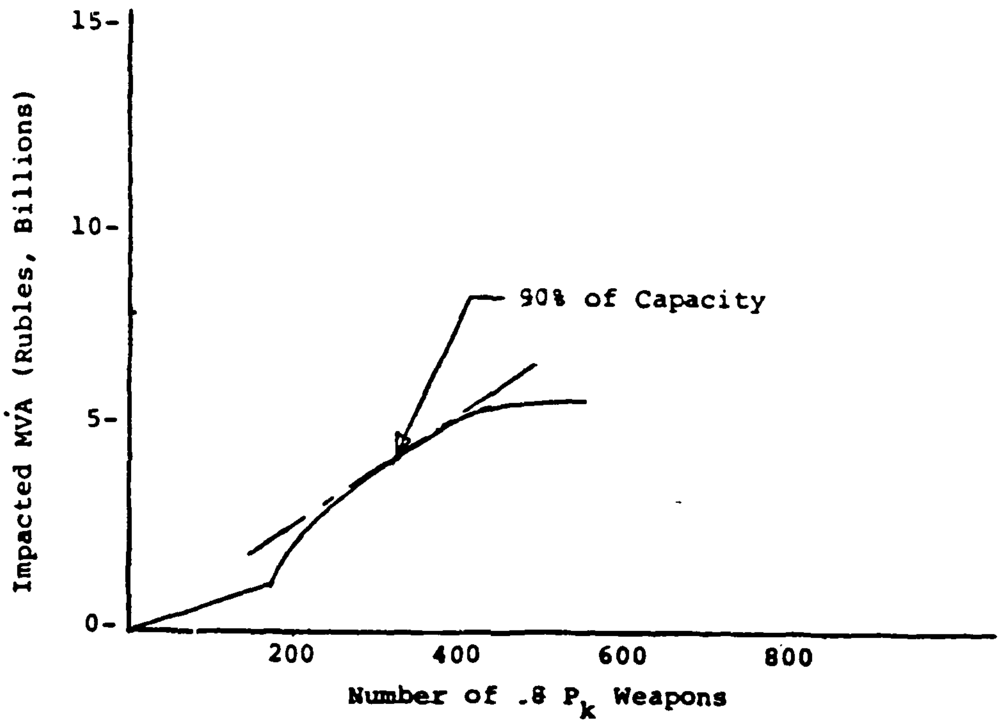
(U) Figure 4-8. Limit function for electric power.



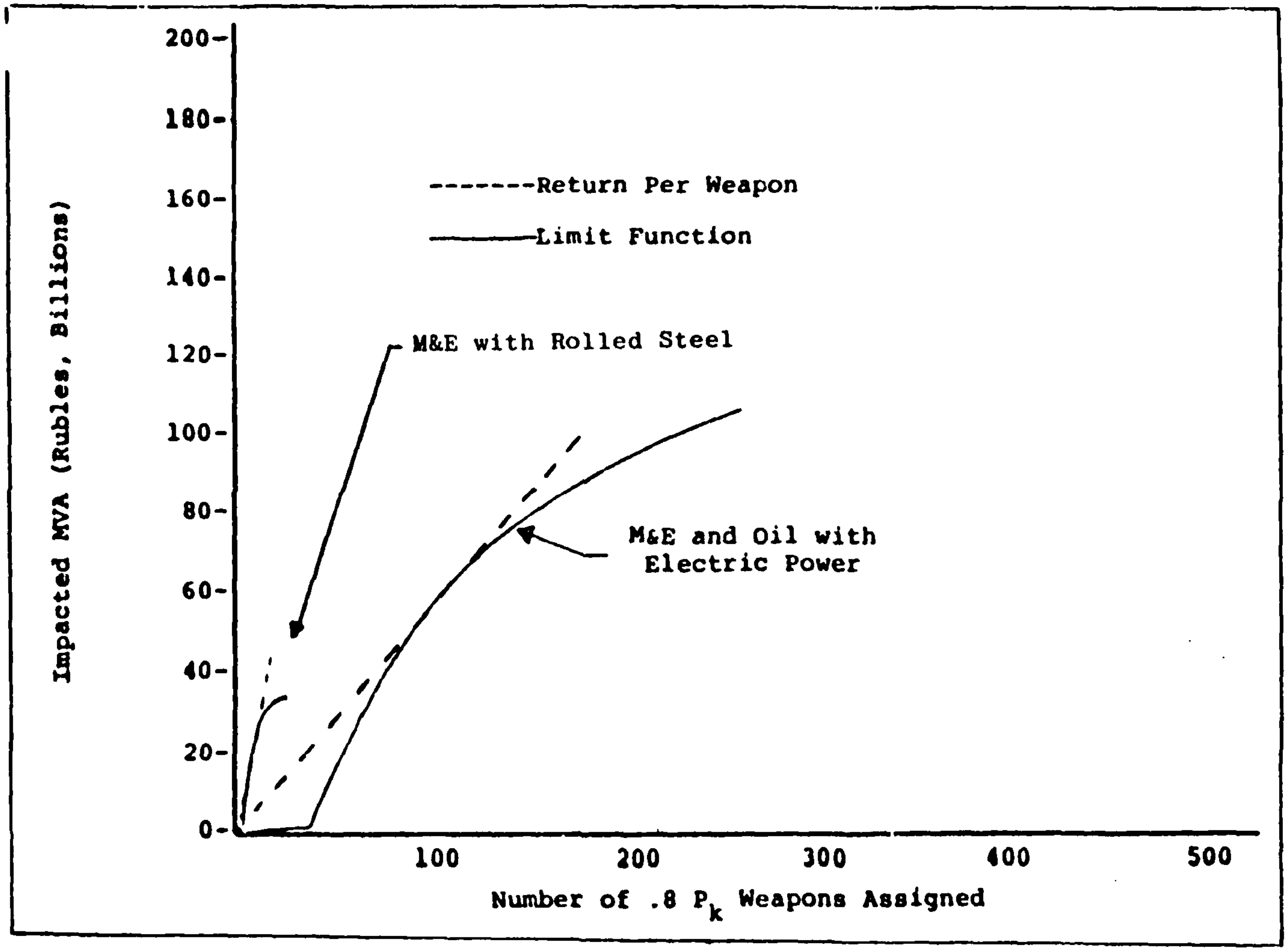
(U) Figure 4-9. Limit function for oil refineries.



(U) Figure 4-10. Limit function for rolled steel.



(U) Figure 4-11. Limit function for natural gas.



(U) Figure 4-12. M&F option.

(U) The approach used to resolve this question was to determine which of the two options offers the greatest marginal return of IMVA per weapon. Since there are only about 14 rolled steel plants as compared to over 500 electric power plants, the IMVA per weapon possible with M&E with rolled steel becomes clearly preferred. Similar techniques are applied to resolve the other questions.

(U) <u>Should construction be removed by taking out cement or oil?</u>

(U) The IMVA attributable to each of these options is shown in Figure 4-13. In this case, weapon efficiency dictates that construction should be considered as an impact of the loss of oil. As a result, cement becomes relatively unimportant as a primary class and its value will be included in construction material as a dependent class.

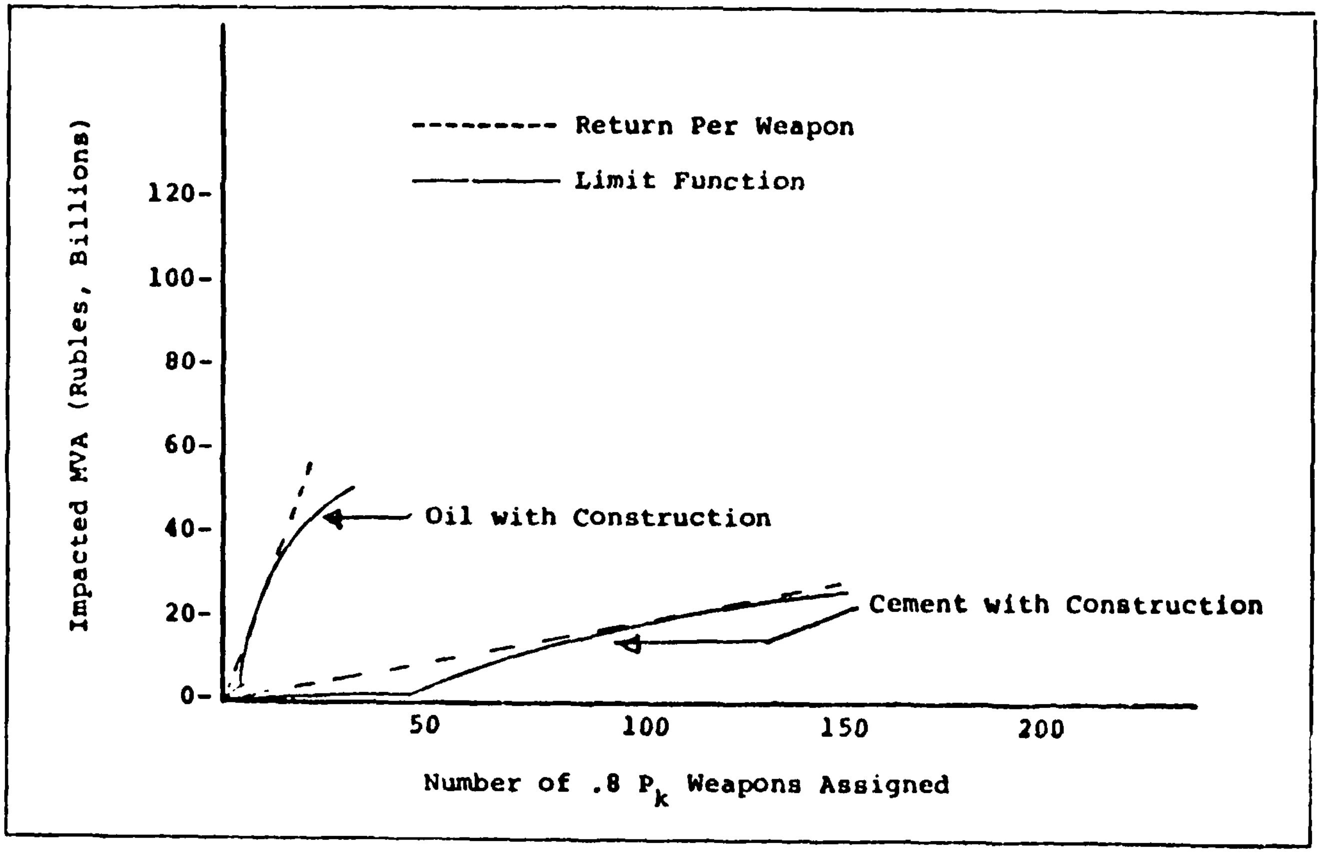
(U) <u>Should rolled steel and oil be removed by taking out electric power or should they be removed by direct targeting?</u>

(U) The IMVA for each of these options is shown in Figure 4-14 and one should directly target rolled steel mills and oil.

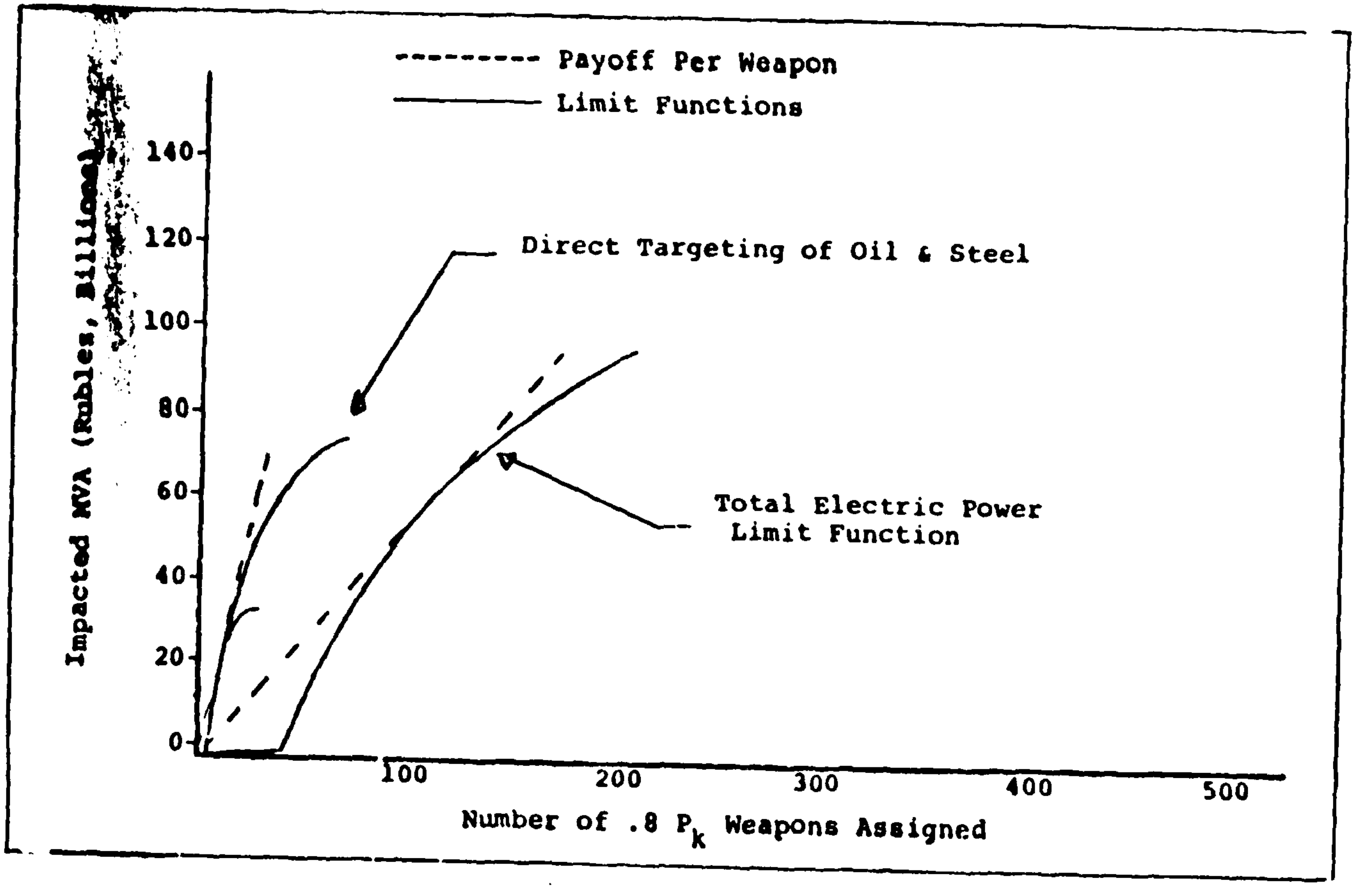
(U) <u>Which class among coal, gas and oil will be targeted last since construction material requires that all three be removed?</u>

(U) The above question needs to be resolved if it is assumed that each fuel can substitute for the other. The average value of IMVA per installation for oil is about 1.8 billion rubles, for coal is about 110 million rubles* and for gas 71 million rubles. Therefore one should attribute the construction material MVA to gas rather than to coal or oil.

(U)*Coal was considered as non-targetable in the previous example; however, if targeted, would have an impacted MVA of about 8.3 billion rubles based on self-MVA, 10% of chemicals and pig iron production.



(U) Figure 4-13. Construction options.



(U) Figure 4-14. Direct targeting options.

(U) Having resolved each of the interactive questions based on targeting efficiencies, specific IMVA values for the remaining 4 primary sectors can be identified as oil, steel, electric power and gas. Self-MVA, dependent MVA and total MVA are listed for each primary class in Table 4-4. The total MVA associated with the targetable sectors is 171.2 billion rubles. The remaining MVA is shown in Table 4-6 as a matter of interest. The elements of remaining MVA which are correlated with floor space would represent bonus MVA if they are destroyed as the primary classes such as oil are attacked or they represent collateral value which might represent undesirable destroyed value in escalation control situations.

(U) 4-6 IMVA RELATIONSHIP WITH INSTALLATIONS

(U) The basic relationships between primary and dependent classes have been developed (cf Table 4-4), the limit function parameters have been developed (cf Table 4-5), and the limit functions have been developed (cf Figure 4-8 to 4-11) for the primary class industries. The prior calculations of limit functions have been based on the limit function equation and the capacity damage functions. The basic assumption has been that the class IMVA is proportioned across the installations in a class according to capacity. A cross plot of the limit functions and the capacity damage functions results in Figure 4-15. This figure is in terms of percent of capacity destroyed. It also could be drawn in terms of number of installations with the installations ordered from highest to lowest capacity.

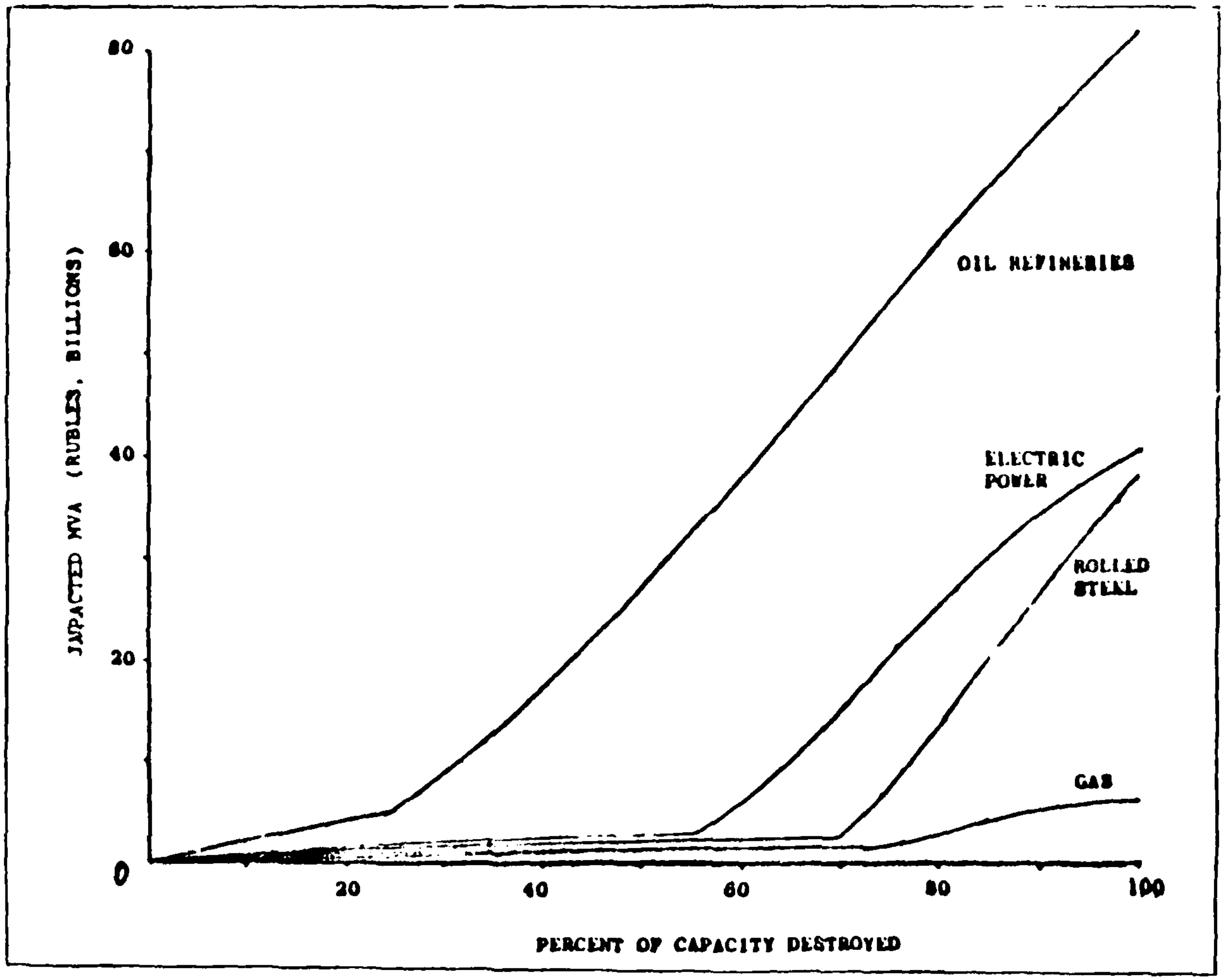
(U) 4-7 WEAPON ALLOCATIONS BASED UPON IMVA

(U) The final step in the IMVA example is to demonstrate a weapon allocation procedure that could be used. All four of the limit functions are shown in Figure 4-16. With functions such as these, optimum allocations can be found by finding

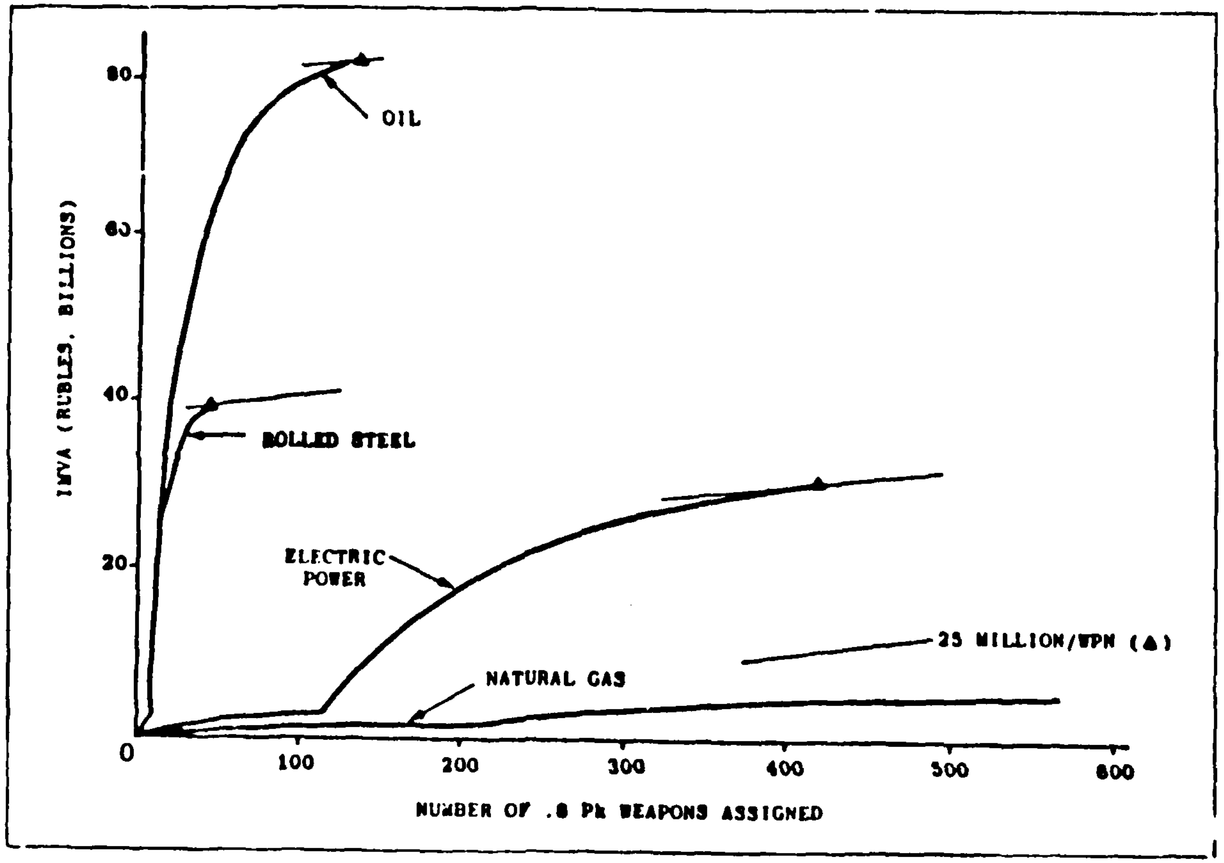
(U) Table 4-6. Bonus and isolated class MVA.

Bonus/Collateral Classes		Isolated Classes	
Textiles and Sewing	22*	Food	-5
Trade and Dist.	21	Livestock	27
Other Industry	13	Forestry	
Repair of M&E	7	Peat and Shale	1
Wood Products	7		
Food Processing	32		
Other Branches	3		
Total MVA	105	Total MVA	23
Percent	35	Percent	8

(U)*Billions of rubles.



(U) Figure 4-15. IMVA relation to installations.



(U) Figure 4-16. Weapon allocation for maximum marginal IMVA return.

points for which the rates of change on all functions are equal. Such points can be found for whatever slope is desired. For example, the case where 25 million rubles per weapon is the desired IMVA return per weapon is shown in Figure 4-16. In this case 46 weapons would be allocated to rolled steel, 134 to oil refineries and 425 to electric power. None would be allocated to natural gas because of the poorer marginal return per weapon. By repeating this procedure for various slopes, the results in Table 4-7 can be obtained. This table also shows the damage expectancy required for each industry in the primary class.

(U) The example with 25 million rubles per weapon requires a high degree of multiple weapon application to high value installations. This is shown in Table 4-8. There were 14 rolled steel installations. The top 6 received 4 weapons each. The next 6 received 3 weapons each. The last 2 received 2 weapons. The 45 oil refineries received from 2 to 4 weapons each. This result is expected given the characteristic shape of the limit functions and the large differences between individual limit functions shown in Figure 4-16. Because of the relatively few number of rolled steel and oil installations and yet their high IMVA potential, the largest return per weapon occurs when these installations have very high damage expectancies.

(U) Another interesting aspect of the results in Table 4-7 is the large weapon requirements for the lower IMVA per weapon cases. This is shown in Figure 4-17. Beyond about 300 weapons the IMVA return per weapon decreases rapidly. This case corresponds to heavy emphasis on oil and rolled steel with about 120 weapons and about 180 weapons on the electric power installations. Referring to the electric power limit function in Figure 4-16, the 180 weapon case occurs at the place where

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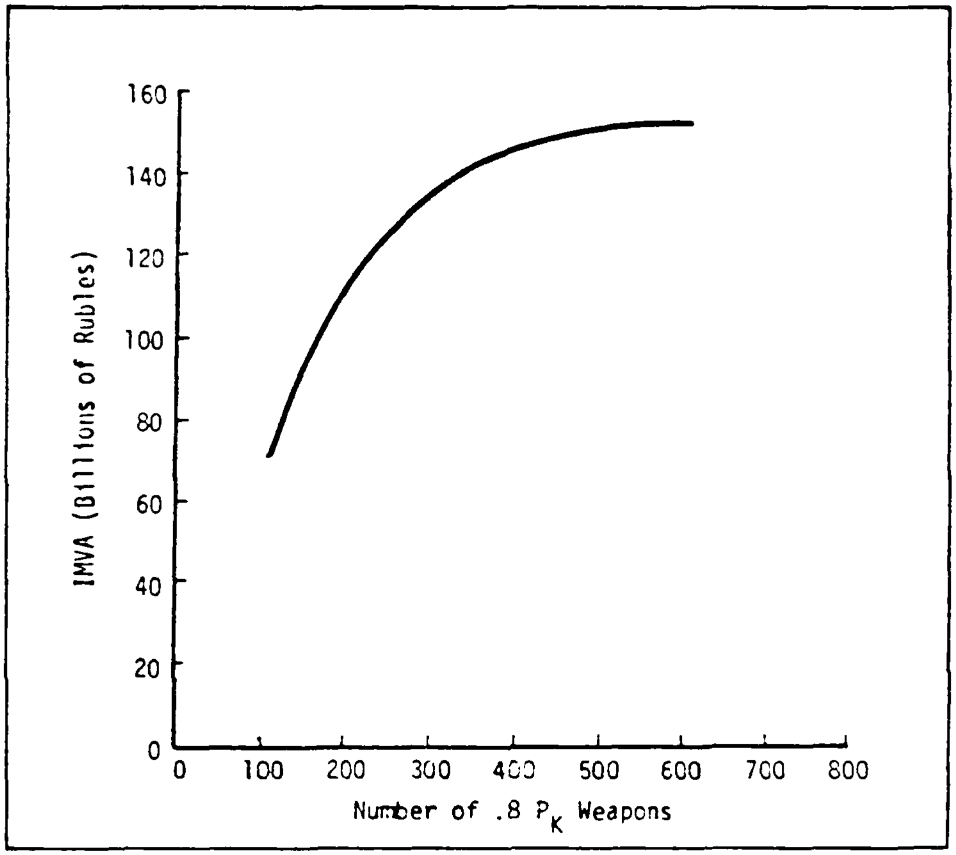
Table 4-8. Installation damage levels at 25 million rubles IMVA per weapon.

Installation Number	Average Capacity	B = 25 Damage Expectancy	Class
0- 25	2650	.96	ELECTRIC POWER
26- 50	1777	.96	
51- 75	1200	.96	
76-100	208	.96	
101-125	208	.80	
126-150	208	.80	
151-175	208	.80	
176-200	208	.80	
201-225	208	.80	
226-250	208	.80	
251-275	208	.80	
276-300	208	.80	
301-325	208	.80	
326-350	208	.0	
351-375	75	.0	
376-400	75	.0	
401-425	75	.0	
426-450	37	.0	
451-475	37	.0	
476-500	37	.0	
501-520	20	.0	

Installation Number	Average Capacity	B = 25 Damage Expectancy	Class
0- 5	509	.9984	OIL
6-10	312	.9984	
11-15	225	.9984	
16-20	180	.9984	
21-25	131	.992	
26-30	88	.992	
31-35	44	.96	
36-40	25	.96	
41-45	10	.96	
1	14,100	.9984	ROLLED STEEL
2	13,700	.9984	
3	13,300	.9984	
4	12,400	.9984	
5	11,000	.9984	
6	9,500	.9984	
7	7,100	.992	
8	3,000	.992	
9	2,300	.992	
10	1,800	.992	
11	900	.992	
12	850	.992	
13	850	.96	
14	800	.96	

No. 8 Pk Weapons	4	3	2	1
Damage Expectancy	.9984	.992	.96	.8



(U) Figure 4-17. IMVA relation to weapon requirements.

there is a large slope. This may be a point on the curve where the uncertainty in the shape is of concern leading one to increase weapon requirements for electric power to reduce uncertainty (e.g. about 250 weapons). Also, Figure 4-4 indicates that 180 weapons on electric power results in 65% capacity destroyed while 250 weapons results in about 80% capacity destroyed. The main point of the above results is that IMVA signifies the importance of primary class industries given the fact that many other industries are dependent upon the operation of the primary class industries. In other words, if the primary class industries are heavily destroyed then the effect on the economy is far greater than the economic value of the primary class industries alone. Therefore, rather than spreading available weapons around across primary and dependent class industries, it is far better first to cause significant damage to the primary class industries.

(U) The above allocation technique represents one possible allocation method for IMVA application. Only primary class industries received weapons in this example. Other industries are destroyed only if they are collateral to these primary class industries. An economic targeting approach such as this might be regarded as being too dependent upon the validity of the intelligence data and the approach for development of IMVA and too open to unforeseen contingencies the Soviets might employ for recovery. SIOP plans can not be allowed to have much intuitive uncertainties in order to be perceived credible to the planners, the NCA and any other party. Other techniques discussed in the next section have been developed to augment the application of IMVA. However, the basic fundamental thesis remains of first emphasizing weapon resources on the primary class industries.

(U) 4-8 COLLATERAL DAMAGE RESULTS

(U) In the above example for attacks on primary class industries only, it was mentioned that some collateral industries also would be destroyed. A calculation was completed to estimate the degree of collateral damage for an attack only on electric power, steel and oil.

(U) Based upon the primary class installations and the above weapon characteristics, a total of 653 DGZs were developed. Consistent with the oil, rolled steel and electric power limit functions, a dynamic programming allocation technique was used to allocate the 1000 weapons and maximize the IMVA. This was a very approximate calculation since the TDI does not contain IMVA or even MVA for each installation. It provides for the calculation of PRWV and these values had to be used. Therefore, the limit functions provided scaling techniques to be used in conjunction with PRWV data. The TANDEM program was used to calculate the expected value destroyed for the allocation of 1000 weapons to the 653 DGZs. Some DGZs received no weapons, some received as many as 4 weapons. The results of the TANDEM calculation are shown in Table 4-9. Note that more collateral value was destroyed than direct value destroyed for the primary class. Also, note that important industrial categories were in the collateral destroyed class.

(U) The above result simply indicates that collateral or bonus damage can be large when primary class installations are attacked and if actual destroyed value is the parameter of interest. Impacted values only affected the allocation and are not presented in Table 4-9.

(U) Table 4-9. Collateral damage results.

Class	Expected Value Destroyed (Millions U.S. Dollars)	Example Categories
Primary	$47,000	Oil, Electrical Power, Steel
Other	$56,000	Chemicals, Rubber Products and Plastics, Construction Material, Machine Tools, Electric Power Equipment Manufacture, Boilers, Turbines Manufacture, Industry Concentration Centers

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SECTION 5

(U) IMVA IMPLICATIONS FOR TARGETING

(U) 5-1 INTRODUCTION

(U) There are a variety of methods possible for implementation of IMVA into the SIOP process. Several methods are discussed in this section. In addition, since IMVA depends upon MVA and therefore emphasizes the immediate post attack time period, other techniques are warranted to augment IMVA and address explicitly prolonging recovery. These techniques also are described briefly in this section.

(U) The above discussion displays the complexity of SIOP development yet deals with only a portion of the development and evaluation process. Possible approaches for IMVA implementation must be sufficiently consistent with the total process so as not to cause excessive complexities in comparison to the benefits obtained using IMVA. The following six step implementation approach potentially offers this feasibility:

(U) 1. Complete more detailed research to define primary class industries, dependent class industries and the MVA relationships between the two classes. This is expected to be an intelligence agency function and will lead to the basic data necessary for IMVA calculations.

(U) 2. Development MVA for all economic installations and add it as a parameter to the TDI. The MVA is to be used mainly for IMVA estimates during target development and weapon allocation; it measures the decisive reduction aspects in the guidance.

(U) 3. Develop limit function parameters (cf Table 4-5) and provide these, the limit function equations and the primary-dependent class relationships are like those in Table 4-4. This data together with the MVA data is sufficient to describe: (1) maximum IMVA associated with each primary class and, (2) each of the IMVA limit functions. The limit functions can be expressed as a function of capacity damage expectancy rather than the number of .8 P_K weapons.

(U) 4. Specify the desired total IMVA or the IMVA per equivalent weapon or the total equivalent weapons for attacks on primary class industries. An equivalent weapon concept is useful when considering a mixed weapon force. IMVA per unit of capacity damage expectancy also would suffice. One of the above three parameters is needed to determine which limit functions are used (e.g. which primary class industries are targeted) and the point to be used for each limit function (e.g. the specific IMVA associated with a particular capacity damage expectancy or number of equivalent weapons).

(U) 5. Once the above data is developed, the primary class installations can be assigned IMVA values for DGZ development. Therefore, basic value data at the installation level would exist. It is important to note, however, that this data would be calculated based upon the installation MVA data, the primary-dependent class relationships, the limit function equations and the overall IMVA per weapon, or total IMVA or total attack size requirement. The primary class IMVA would be proportioned over the installations according to installation capacity or MVA data.

(U) 6. Once DGZ's were developed based upon installation IMVA, the weapon allocation process could be completed using various allocation approaches (e.g. maximum marginal return, dynamic programming, etc.) to optimize total IMVA consistent with the IMVA limit functions.

(U) The above procedure is developed to the point for targeting only for IMVA. The economic measures are primary class MVA destroyed, dependent class halted MVA and bonus MVA destroyed. The use of K to account for prolonging recovery is not developed above but is addressed later. It is recognized that the above method is more complex than the PRWV method principally because of the increased amount of data and data manipulation (e.g. limit function application) for DGZ development and weapon allocation. However, there is a fundamental difference between PRWV and IMVA which leads to this increased complexity. PRWV is a measure which applies only to the specific installation. For example, a particular power plant has the same PRWV whether it alone is destroyed or whether the total power generation industry is destroyed. IMVA, however, accounts for the impact of large scale destruction of a primary class industry in the sense of other industries halted. For example, the economic impact of destroying a single power plant is not as significant as when this power plant is destroyed as part of a large attack on the power generation industry. Therefore, using IMVA requires coupling of value data to attack size in some fashion.

(U) A very useful by-product of IMVA is its potential suitability in the building block concept. The application of IMVA for primary class industries would result in a measure of the economic impact of, for example, a building block for oil refineries or a building block for steel mills or one for electric power. PRWV is not an appropriate measure for these smaller attack levels because it applies only to the damage to the attacked industries and not to the potential economic impact of the loss of these industries.

(U) Although a potentially feasible approach for implementation, the above approach has a number of deficiencies. One is the emphasis on depth of attack even though primary class industries (e.g. oil, steel, electric power, etc.) have not only high IMVA but also high impacted capital. In other words, the capital in the halted industries in many cases is not useable until the primary class industries have been restored. However, the method does not explicitly address prolonging recovery. Another possible deficiency is that only primary class industries and bonus industries are destroyed. Large plants, either by MVA or K and not in the primary class are not targeted. This includes significant facilities such as the Kama River truck plant. One may argue that such a procedure may be very appropriate in a significantly constrained weapon resource environment or for selected attack options based upon the building block concept. However, the risks associated with IMVA definition uncertainties as well as other uncertainties such as inventories, substitution and expropriation may be unacceptably high for large attacks such as major attack options. In other words, as long as the primary class industries are destroyed sufficiently to achieve a very high total IMVA, it may be desirable that other large installations also are targeted for greater confidence in overall attack effectiveness.

(U) Another implementation approach has been developed to address the above deficiencies. It is the same as the IMVA approach above but includes the following additional steps:

(U) 1. Develop capital stock data, K, for each economic installation and add it as a parameter to the IDI. The K is a measure used for the aspects of the guidance for prolonging recovery. More details regarding the use of K are presented in the next section.

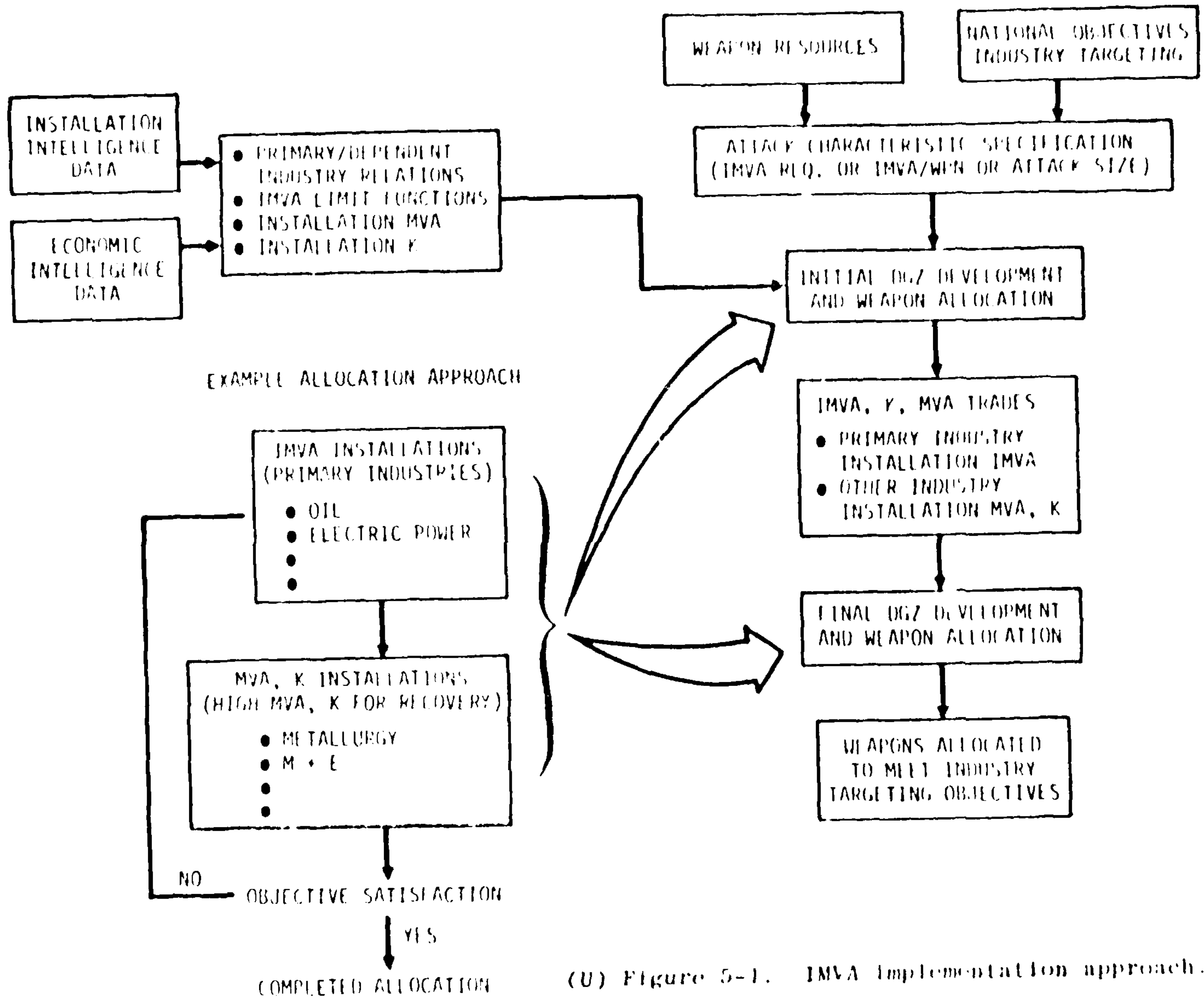
(U) 2. Specify basic attack size data in terms of: (a) IMVA per weapon, or total IMVA or IMVA attack size and (b) MVA per weapon or total MVA or MVA attack size and, (c) K per weapon or total K or K attack size. These data allow the definition of the IMVA related portion of the attack and the trades necessary to describe destroyed versus halted industries. As initial rough allocation of weapon resources to preliminary DGZ's would be useful to determine the trade offs. The objective of such analysis is to not count targeted MVA or K installations as halted in the IMVA calculations.

(U) 3. Develop DGZ's based upon IMVA, K and MVA installation value data.

(U) 4. Complete weapon allocations to meet IMVA, K and MVA objectives in a weapon efficient manner.

(U) The above approach, diagrammed in Figure 5-1, is not the only one to address the possible deficiencies in the approach based upon only IMVA. Research in progress has resulted in MVA and K relations. Also, it may not be desirable to consider IMVA, MVA and K. Perhaps IMVA and K are sufficient to address both aspects of the guidance. These issues remain to be addressed to determine the preferred implementation approach which allows utilization of the beneficial aspects of IMVA and is relatively straightforward to include in the SIOP process. In addition, it is unknown at this time how incorporation of IMVA with or without additional MVA and K targets would change laydowns as compared to the use of PRWV. Prior research* indicated that for large attacks, the use of PRWV and GVO resulted in essentially the same laydowns and damage irrespective of the particular value system used for laydown development or evaluation. It would be expected that for very large attacks, the same type of results would occur using

(U)*JSTPS SAG Briefing May 1979.



(U) Figure 5-1. IMVA implementation approach.

IMVA. This is expected because enough weapons could be used so that almost all industry was destroyed and, therefore, the halted MVA in IMVA no longer would be relevant. However, it is not known how many arriving weapons in a laydown would be required to achieve this expectation. It is known that with 800 arriving .8 P_K weapons, the targets attacked using IMVA would be largely primary class installations. This is far different from what would be expected with PRWV.

(U) 5-3 ASPECTS FOR PROLONGING RECOVERY

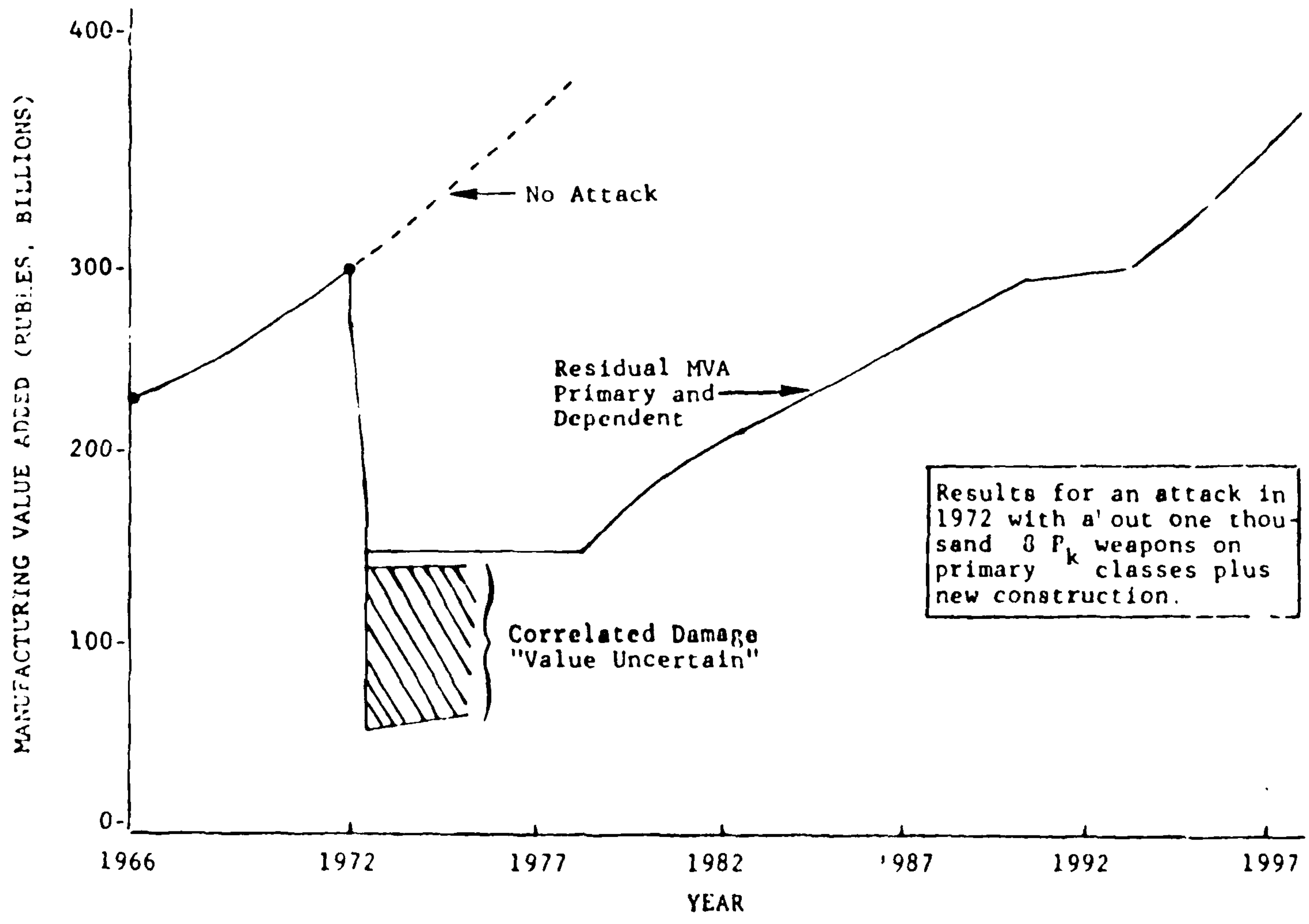
(U) The previous discussion has suggested methods for assigning relative value to Soviet economic assets in terms of immediate post attack impact. Although of considerable importance, this relative value is only one of several issues involved in targeting economic assets. In general, recovery denial attacks have two objectives including the depth to which the attack is driven and the length of time required for the economy to recover. These issues are complicated by lack of current guidance as to the relative priority of depth of attack and length of recovery period.

(U) The methodology for assigning value based on depth of attack which was described in an early section of this report is based on IMVA and was only recommended to measure the immediate post attack impact. The length of recovery time was not addressed except to suggest that it be considered a separate issue and that targets important to long recovery times be identified and added to the IMVA list if they were not already included.

(U) The Soviet recovery process has been studied under other analysis programs for the Navy for SAI and for DNA. As a result of the Navy work,[13] a preliminary methodology was developed for analyzing the recovery of the Soviet electric power industry. This preliminary methodology has been broadened by SAI to include other key industries and targeting issues. The primary issues identified in this work include the role of new construction in delaying the recovery process and a more generalized methodology which permits one to include such issues as technology relative to growth of investment, time phasing of the economic impact, and the impact of depth of attack on any particular industrial installation or class as well as depth of attack on related industrial classes. These developments have provided a basis for DNA activity which has just been completed and which will estimate the recovery times for electric power, steel and oil industries in the Soviet Union. IMVA as developed in the early sections of this document is compatible with these activities and provides the basis for estimating recovery functions; however, additional considerations are required for a true assessment of the economic impact.

(U) As an example of the time phasing of the attack impact and the remaining portions of the recovery function resulting from the SAI effort, it was possible to identify dependent MVA where the impact was immediate, would occur in less than three months and in less than six months. Based on these time considerations, modified IMVA limit functions were developed and the example recovery function of Figure 5-2 was estimated.* The function in Figure 5-2 is based on an attack in 1972 with about one thousand .6 P_k weapons on the primary classes defined in Section 4 and on new construction for each class. The rise in MVA shown between 1966 and 1972 is the actual value taken from input-output tables. There would be an immediate reduction of 30 billion rubles due to the loss of electric power followed by an additional 6 months as the goods in stockpile and supply lines were used up leaving 150 billion rubles after 6 months if no bonus damaged was involved. Adding bonus damage causes the surviving level to be somewhere in the cross-hatched region. Because the attack included new construction there would be an estimated period of 6 years during which the electric power industry backlog was replaced and then

(U)*These early results are presented as an example. Subsequent work has resulted in a preliminary methodology for generating recovery functions. The basic computer program called ARITA (Attack and Recovery of Industry Targets Algorithm) is currently being developed.



(U) Figure 5-2. Basic recovery function.

the indicated recovery process could be achieved. The basic recovery function does not include the increased delays which would be expected as bonus damage was considered.

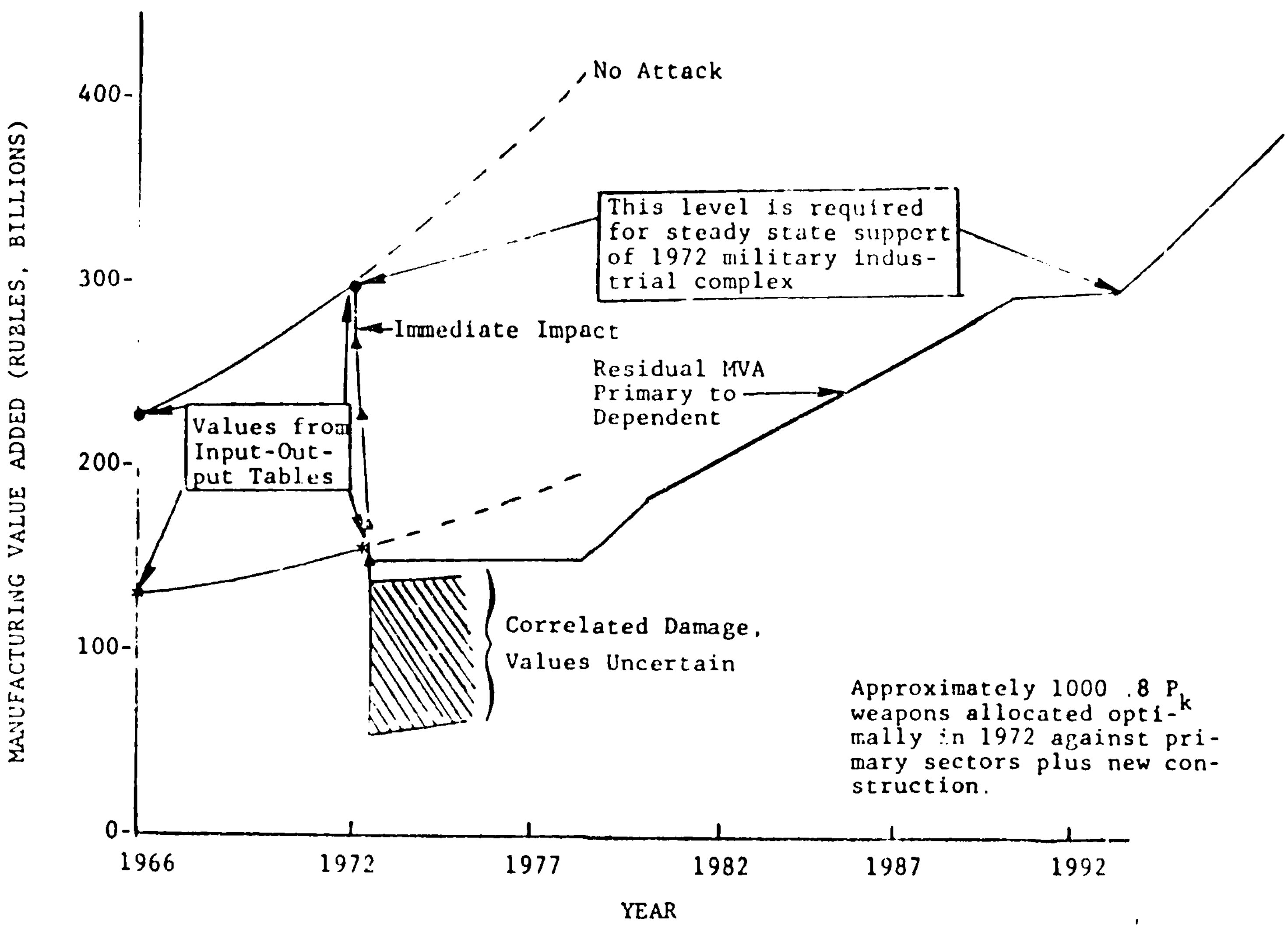
(U) If the bonus damage is not considered, this recovery function would look very much like comparable functions which have been developed in past studies and one could argue that this is only marginally more than the situation during World War II. There can also be countering arguments which suggest that during the 15 to 20 year recovery period, other major powers would have continued to develop and on a relative basis the situation would be much more serious than shown in Figure 5-2. However, the more serious condition involves a consideration of which sectors of the economy remain and how they might relate to post-attack world power status.

(U) If, rather than classifying economic sectors relative to the targeting problem of maximizing the attack depth, one classifies the sectors by heavy industry and by subsistance sectors a different perspective is provided. Such a classification is provided in Table 5-1 in comparison with depth of attack classifications which were previously defined. Heavy industry is essentially the industrial complex required to support the 1972 world power status and military complex and subsistance sectors essentially are required to support the 1972 population at the 1972 level of economic well being. The significance of the attack defined above now becomes more obvious if one superimposes the subsistance sectors value on the function of Figure 5-2 as is shown in Figure 5-3. The subsistance sector level would exceed surviving value for a significant period of time and if the Soviet civil defense program had been successfully carried out and some bonus damage accounted for, it is unlikely that subsistance levels would be available.

(U) It is also clear that the long term support of the 1972 military complex would require the replacement of the 1972 industrial complex and this can be one definition of recovery. It is

(U) Table 5-1. Heavy industry and subsistance sectors.

Classes	1966 MVA (Rubles, Billions)	1972 MVA (Rubles, Billions)
Heavy Industry		
Rolled Steel	1.7	2.5
Oil Refineries	3.8	6.7
Natural Gas	.8	2.0
Electric Power	4.7	5.8
Metallurgy	5.8	8.5
Transportation	15.0	18.4
Construction	20.9	34.6
Construction Material	4.4	6.2
Machinery & Equipment	23.1	38.0
Chemistry	5.9	8.8
Coal	2.6	3.9
Oil Extraction	1.1	3.3
Repair of M&E	4.6	7.0
	94.4	145.7
Subsistance Sectors		
Crops	29.5	32.5
Textiles & Sewing	15.8	22.0
Trade & Distribution	13.4	21.0
Other Industry	13.2	13.0
Wood Products	5.9	7.0
Other Branches	2.9	3.0
Food	24.8	28.0
Animal Husbandry	25.4	27.0
Forestry, Peat and Shale	.6	.9
	131.6	154.4



(U) Figure 5-3. Subsistance sectors.

believed that the issues portrayed by Figure 5-3 more nearly represent the true economic impact of the attack than by Figure 5-2. The concept of IMVA was needed to determine the basic recovery functions of those figures and to identify efficient targeting options, however, additional considerations of issues important to the recovery process were required to better assess the overall economic impact.

(U) An additional targeting issue which was also addressed in Reference 13 was that some critical elements will result in longer recovery times than others. For example, targeting turbines and generators was estimated to nearly double the recovery time for electric power when compared to targeting transformers. This can have a significant effect on nuclear weapon requirements since turbine and generators are considered to be on the order of harder (500 psi[13] compared to transformers which are on the order of 15 psi). Furthermore, it is expected that comparable results will occur with steel rolling mills since the rolling mills themselves are considered much harder than the blast furnaces, buildings and other steel plant elements.

(U) Finally, an attack based upon IMVA results in heavy destruction of primary class installations which must be rebuilt to support recovery. If other high MVA or K installations are targeted, besides those mentioned above which provide inputs for the reconstruction of the primary class, then recovery resources would be required to rebuild these installations. This delays recovery to the extent that this process uses recovery resources which could be devoted to primary class reconstruction. Obviously there are trade-offs between how much damage should be obtained based upon IMVA which emphasizes the immediate post attack condition and how much should be obtained based upon high MVA or high K which emphasizes prolonging recovery. One interesting aspect, however, is that with the possibility of new guidance which may divide economic targets into war supporting, immediate post attack and long term recovery categories, the IMVA and K measures may be very appropriate to address the latter two categories.

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SECTION 6

(U) CONCLUSIONS AND RECOMMENDATIONS

(This Section is Unclassified)

6-1 CONCLUSIONS

A figure of merit called Impacted Manufacturing Value Added (IMVA) has been developed for industrial targeting during SIOP development and evaluation. This figure of merit is a potentially attractive alternative to the current figure of merit, postwar recovery weighted value (PRWV) The potential benefits, problems and other conclusions are as follows:

1. IMVA provides a common quantitative measure that can be used for both critical or primary industrial classes as well as other non-primary industrial classes. This occurs because IMVA is the sum of destroyed and halted MVA for primary industrial classes and MVA can be used for the non-primary classes.

2. The functional interdependence between primary and dependent industrial classes is treated explicitly in IMVA as is the economic interdependence. Physical engineering constraints are considered in the IMVA development regarding inputs required to produce specific output products.

3. IMVA is dependent upon attack characteristics which determine attack size. As an example, if a large electrical power plant is destroyed in a single weapon attack it has one value based upon its MVA. However, if the same plant is destroyed in a larger attack against the electrical power industry the plant's value is greater than its MVA because the economic impact of the loss of electrical power industry is greater than simply the summation of individual plant MVA's. This type of dependence on attack size is treated explicitly in the IMVA methodology. Halted dependent industries are considered.

4. An approximate quantitative approach based upon limit functions has been developed to facilitate the calculation of IMVA as a function of attack characteristic specifications such as attack size, total IMVA required or IMVA per weapon required. Once one of these specifications is

made, IMVA can be proportioned across the industrial class to the industrial installations according to capacity or MVA installation data.

5. The IMVA methodology considers more Soviet economic elements than the current PRWV methodology. For example, IMVA considers construction, crops and a broader treatment of transportation.

6. One approach has been developed for implementation of IMVA into the SIOP process. This approach requires additional intelligence data and changes in the DGZ development and weapon allocation procedures. The additional intelligence data includes: (1) MVA and K (capital stock) data on an installation basis, (2) definition of primary and dependent industrial classes and associated functional interdependencies and, (3) parameters for IMVA limit functions. The changes in DGZ development and weapon allocation include: (1) consideration of attack size to establish IMVA installation values, (2) an initial allocation step to establish the trades between IMVA, MVA and K and (3) use of IMVA, K, and MVA data at the installation level. Various allocation approaches exist for use of IMVA (e.g. maximum marginal return per weapon, dynamic programming, etc.) The preferred overall implementation approach has not been determined.

7. A potential problem with IMVA is that it emphasizes depth of attack. Although IMVA is considered useful in targeting to achieve a maximum reduction in immediate post-attack value and in constructing generalized recovery functions, it must be supplemented by additional considerations of issues important to the recovery process for a true assessment of the impact of economic attacks. The use of capital stock, K, to emphasize prolonging recovery represents a potential method to address this problem. This method results in two figures of merit used together: IMVA and K.

8. IMVA appears useful considering the evolving national guidance. When used in conjunction with K, both short term recovery and long term recovery can be addressed explicitly. In addition, IMVA may be particularly useful for building blocks if various industrial target classes (e.g. oil, electric power, etc.) offer the potential of becoming building blocks.

9. IMVA as defined herein tends to undercount the economic impact of large levels of damage to primary industrial classes because of the conservative method used to define dependent classes. Dependent classes only qualify when they clearly need the goods and services from the primary set. Various secondary effects which are apt to occur especially with a large surviving population remain unmeasured and the economic impact will likely be greater than predicted. As the process of defining dependent classes and related value is continued, it is likely that the dependent value will increase and the bonus value will decrease.

10. IMVA does not account for non-dependent post attack consumption. The IMVA limit functions developed assume all residual post attack capacity from primary industrial classes is allocated to dependent classes and that post-attack and pre-attack primary class resource allocations to dependent classes are the same.

11. The overall significance of using IMVA with or without K and MVA applications has not been determined or compared with the current methods based upon PRWV. However, it is expected that the IMVA methodology will lead to a significantly larger fraction of destroyed or halted MVA for a fixed strategic force than the current PRWV methodology.

12. More than 150 billion rubles of 1972 MVA out of a total of 300 billion rubles can be destroyed or halted using less than 900 .8 P_k weapons. The actual amount will depend on the amount of bonus damage which occurs. Furthermore, high priority targets based on impacted MVA tend to be capital intensive and the recommended targeting procedures should result in higher overall damage levels than will result using current procedures even if the metric is some combination of MVA and capital.

6-2 RECOMMENDATIONS

It is recommended that the IMVA methodology be given serious consideration for implementation into the SIOP. It is recommended that the intelligence data collection and processing required and the implementation approaches receive particular attention. It is recommended that laydown analyses be completed to assess the overall significance of using IMVA with and without MVA and K as compared to using PRWV. It is recommended that the concept of IMVA and MVA and K be explored in more detail particularly with respect to the evolving national guidance. It is recommended that the uncertainties and key assumptions in IMVA be critically reviewed and that methods to reduce uncertainties be developed.

APPENDIX A

CAPACITY FUNCTION FOR ELECTRIC POWER

(Appendix A is Unclassified)

There is a trend in the construction of electric power generating facilities which over a period of time has made Soviet generating capacity relatively available to a U.S. attack. Table A-1 shows the number and size of electric generating plants in the Soviet Union[14] in 1955. Note that there were over 107,000 plants in 1955 and, although most of the capacity was in larger regional units (48%), a large fraction (32%) was made up plants with less than 25 megawatts capacity. Thus, in 1955 several thousand weapons would have been required to destroy 80-90% of the Soviet Union generating capacity and destruction to these levels appears to be required to nullify the effectiveness of substitution and allocation options to essential processes.

The cumulative capacity is shown in Figure A-1 as a function of time. In 1975 the total installed capacity was 217,500 megawatts.[16]

These data are supplemented by inputs from the intelligence community[17] which indicate that in 1970 there were 12,500 megawatts of non-turbine units, in 1975 there were 9,400 megawatts of nonturbine units and in 1980 only 8,400 megawatts are expected. These are mostly small diesel driven units of less than about one megawatt capacity.

Until 1955, the largest generating installations in Russia were between 100 and 200 megawatts.[14] In 1955, a decision was made to build large units in excess of 1,000 megawatts and during the period 1959 to 1965 several 2,400 megawatt units were started. Thus, one could expect that at about 1961, these larger units would begin to come on line. Beyond 1961, selected data from Soviet Geography (see for example, Ref. 15) can be used to

Table A-1. 1955 Electric generating capacity.

Capacity Range (KW)	Number of Stations	Capacity (MW)	Output of Electric Power (Million kwhr)
Less than 14	28,585	281	283
15- 50	46,356	1,475	1,843
51- 200	26,685	2,251	3,204
201- 500	3,409	1,032	1,696
501- 1,000	1,128	805	1,833
1,001- 2,500	725	1,114	3,113
2,501- 5,000	308	1,015	3,635
5,001- 10,000	213	1,444	5,817
10,001- 25,000	164	2,573	11,680
25,001- 50,000	75	2,623	12,635
50,001-100,000	72	4,899	25,925
Over 100,000	85	17,724	98,561
TOTAL	107,805	37,236	170,225

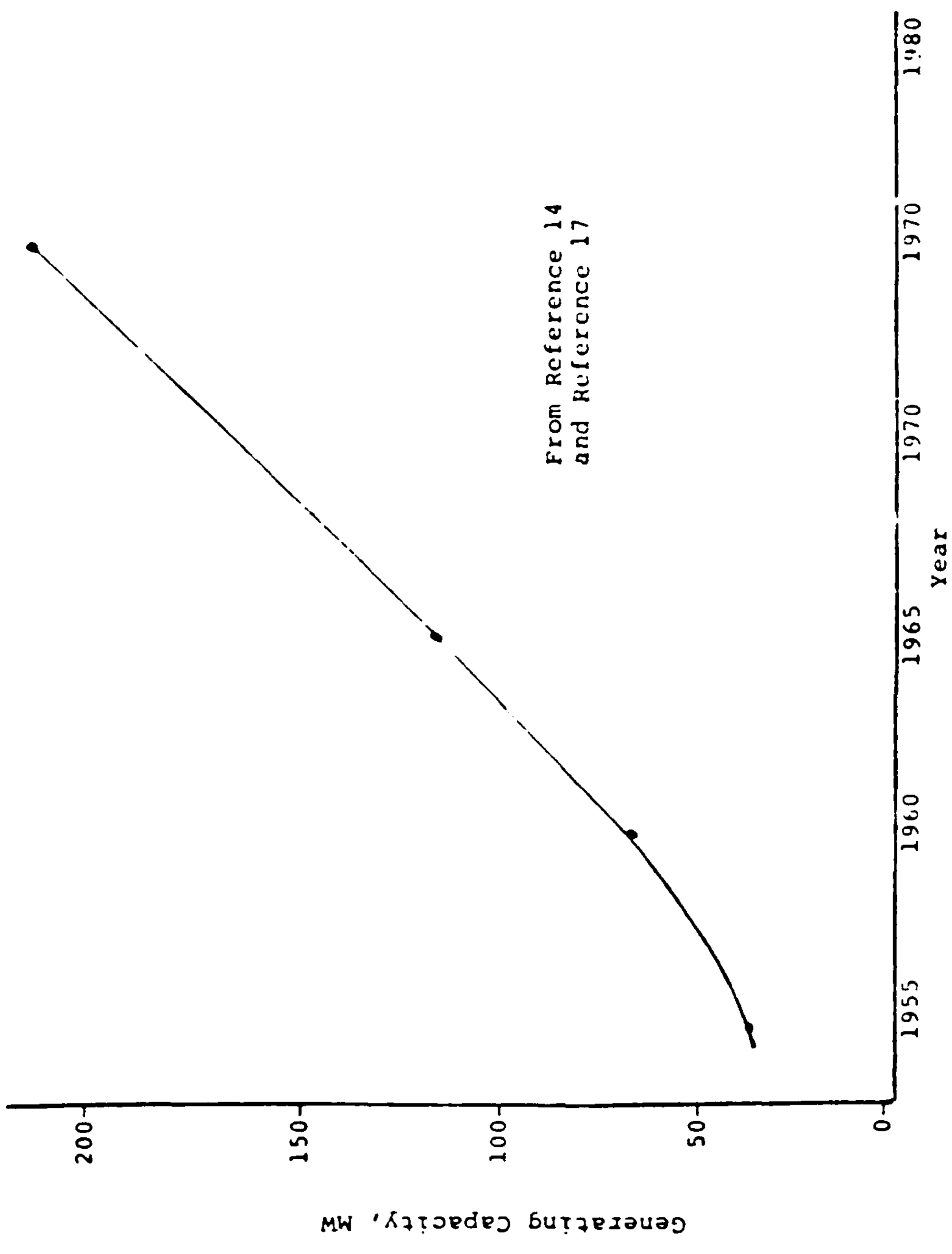

Figure A-1. Growth in generating capacity.

determine an average design capacity as shown in Figure A-2. The resulting average capacities are 1,200 megawatts for 1961 to 1965, 1,777 megawatts for the next 5 years, and 2,650 megawatts for the period from 1970 to 1975.

If one starts with the 9,400 megawatts in non-turbine units which are expected to be less than 25 megawatts and assumes that the units 25 to 100 megawatts are retained and that new units of added capacity are the larger units in each time period, the number of units in each capacity range can be determined by combining the capacity data of Figure A-1 and the average units size. Using this procedure, the number of plants can be estimated as in Table A-2.

Table A-2. Expected number of generating plants in 1975.

Unit Capacity (MW)	Estimated Number
<25	--
26-50	75
51-100	72
(208)	85+183=268
(1200)	33
(1777)	28
(2650)	20
	496

The values in parentheses are average values. Thus, the total number of generating units above 25 megawatts which account for 95% of capacity is about 500.

This is quite different than the situation in the United States. We have about twice the capacity but in more than 2000 facilities. The U.S. system is spread over many more installations and therefore is less vulnerable than the Soviet system.

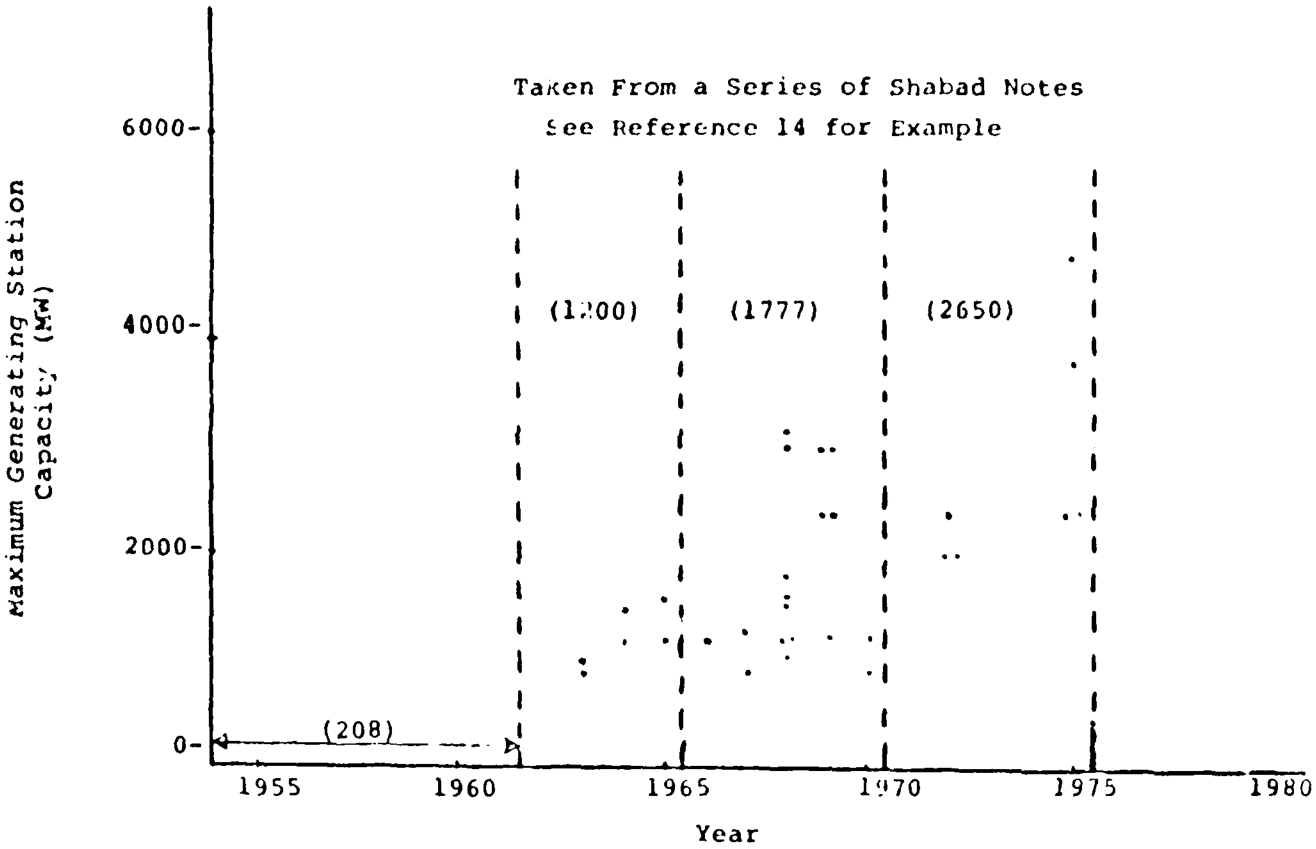

Figure A-2. Selected generating plant capacities.

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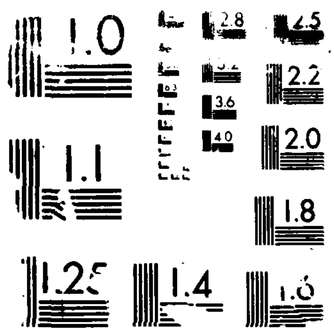
AD-A189 469 IMPACTED MANUFACTURING VALUE ADDED A FIGURE OF MERIT FOR TARGETING INDUTT (U) DEFENSE NUCLEAR AGENCY WASHINGTON DC D H TAYLOR ET AL 13 NOV 79 DNA-5124F 2/2

UNCLASSIFIED DNA001-78-C-0056 F/G 13/8 NL


1.0
2.8
2.5
3.6
2.2
4.0
2.0
1.1
1.8
1.25
1.4
1.6

APPENDIX B

CAPACITY FUNCTION FOR ROLLED STEEL
(Appendix B is Unclassified)

Reference 12 contains a listing of Soviet steel rolling mills by type for 1970. These have been extracted and are shown in Table B-1. The total capacity is 91,600,000 tons and the rolled steel output in 1970 was 80,600,000 tons. Thus it appears that Reference 8 has included most of the capacity in 1970 and that these were not all operated at full capacity.

As was indicated in Appendix E of this report, some rolling mills are dependent upon others. Mills which process basic steel include primary mills, billet mills and plate mills. All other rolling mills depend on the output from these basic steel processing facilities and one needs only target the basic mills to stop the process. They are the first 14 listed in Table B-1. Dependent mills which are colocated with basic mills are attributed to those installations (i.e., the broad strip mills at Chelyabinsk). The capacity of the last 4 installations is not colocated with basic mills and is dependent; therefore, it is spread evenly among the first 14 installations in the capacity function used in the main body of the report.

The Soviet steel industry is currently being analyzed as a part of a DNA funded study of the recovery period for several Soviet industries. As a result of this study, it is expected that the data of Table B-1 will change in content and in number. For example, Magnitogorsk should currently be a direct target rather than a dependent target and the number of rolling mill locations will significantly increase. One expected change in Table B-1 is an increase in the number of installations to about 30 to 40. This will not change the overall conclusions and results of this report.

Table B-1. Rolled steel capacity function.

	LOCATION	TYPE	CAPACITY
(1)	Krivoi Rog	Primary	6000
		Billet	5500
		M&L Sect.	600
		M&L Sect.	800
		Wire	600
		TOTAL	13300
(2)	West Siberian	Primary	6000
		Billet	5500
		M&L Sect.	800
		Wire	800
		TOTAL	13100
(3)	Chelyabinsk	Primary	6000
		Billet	5500
		Broadstrip	1200
		TOTAL	12700
(4)	Karaganda	Primary	5000
		Broadstrip	4500
		Cold Sheet	1300
		Temper	1000
		TOTAL	11800
(5)	Ilyich	Primary	5000
		Broadstrip	3500
		Cold Sheet	1900
		TOTAL	10400
(6)	Cherepovets	Billet	3200
		Broadstrip	1800
		M&L Sect.	1000
		Cold Sheet	1900
		Temper	1000
		TOTAL	8900

	LOCATION	TYPE	CAPACITY
(7)	Novo-Lipetsk	Cont.Casting	250
		Cold Sheet	250
		Broadstrip	6000
		TOTAL	65[illegible]
(8)	Orsk-Khallilovo	H. Sect.	1400
		Plate	1000
		TOTAL	2400
(9)	Azovtal	Plate	1700
(10)	Amurstal	Cont.Casting	250
		Plate	1400
		TOTAL	1[illegible]50
(11)	Nizhne Tagil	Cont.Casting	300
(12)	Donetsk	Cont.Casting	250
(13)	Electrostal	Cont.Casting	250
(14)	Rustavi	Cont.Casting	200

Magnitogorsk	Cold Sheet	1500
	Broadstrip	3850
	TOTAL	5350
Kommunarsk	H. Sect.	1600
Dzerzhinsky	M&L Sect.	1000
Ena Kievo	Wire	800

APPENDIX C

CAPACITY FUNCTION FOR NATURAL GAS
(Appendix C is Unclassified)

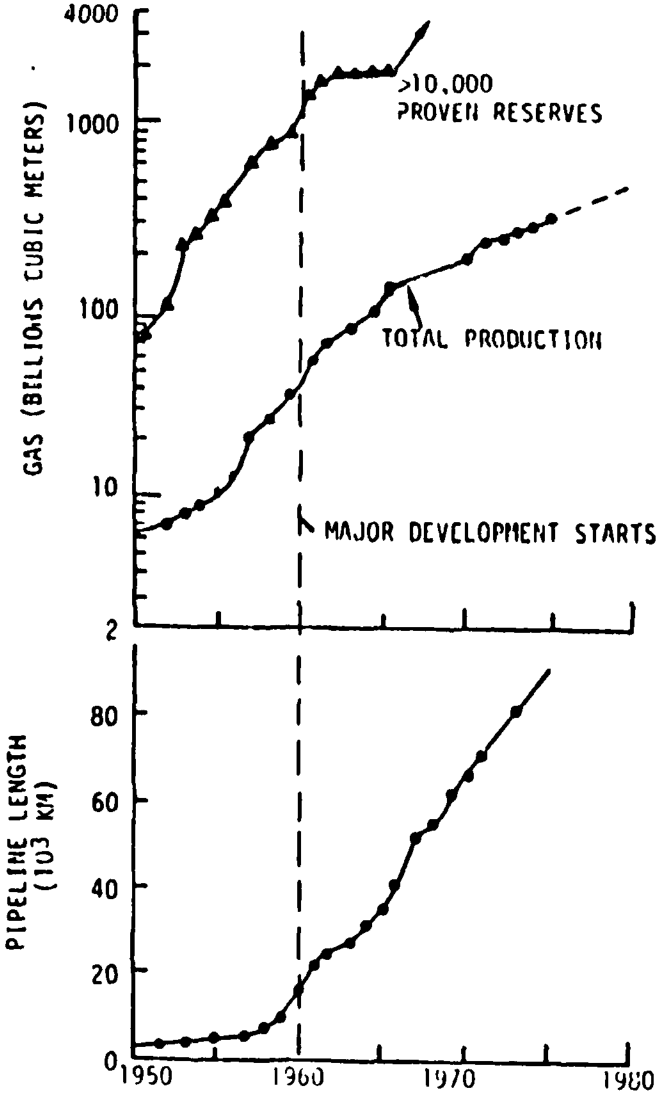
The natural gas capacity function which was developed for the General Electric Company[12] by SAI as discussed below has been used in this analysis.

NATURAL GAS PRODUCTION

The Soviet Union occupies a leading position in energy production as the owner of the world's largest natural gas reserves. In recent years, exploration in remote parts of Siberia have uncovered some of the richest gas deposits. As a result, the government is spending vast sums of money to develop these resources. Figure C-1 illustrates the rapid growth in natural gas production and construction of major gas pipelines that has taken place since 1960. Russia is currently the only major exporter. During the latest 5 year plan, they have increased production by 60 percent, pipeline length by 50 percent, and their budget for development by 88 percent.

Figure C-2 shows the locations of the nine major gas basins in Russia. Within these basins are about 75 gas fields which are connected to over 50 major distribution centers by nearly 100,000 kilometers of large diameter (>20 inch) pipelines. The large Tyumen Basin in West Siberia is reported to have larger gas deposits than all of the U.S. reserves combined. The newer East Siberian basin near Yakutsk is estimated to have larger reserves than the Tyumen Basin.

The 1975 production and consumption of natural gas by the Soviet Union is summarizes in Table C-1. It is noted that despite the large reserves in Western and Eastern Siberia, these major basins only produced about 11.5 percent of the total USSR production (332.9 billion cubic meters per year). As these basins come into full production during the next 10 years, they will begin to dominate the statistics.



- RUSSIA IS CURRENTLY SECOND LARGEST PRODUCER OF NATURAL GAS -- US IS LARGEST
- RUSSIA IS ONLY MAJOR PRODUCER TO GENERATE MORE GAS THAN IT CONSUMES
- LATEST FIVE YEAR PLAN CALLS FOR --
  - 60% PRODUCTION INCREASE FROM 1970-1975
  - 88% BUDGET INCREASE FOR DEVELOPMENT
  - 50 INCREASE IN PIPELINE LENGTH OVER 1970
- RUSSIA HAS LARGER GAS RESERVES THAN US (1971-BILLIONS CU METERS)

	PROVEN	POTENTIAL
USSR	10,251	59,468
US	7,895	32,452

Figure C-1. The Soviet policy concerning gas development.

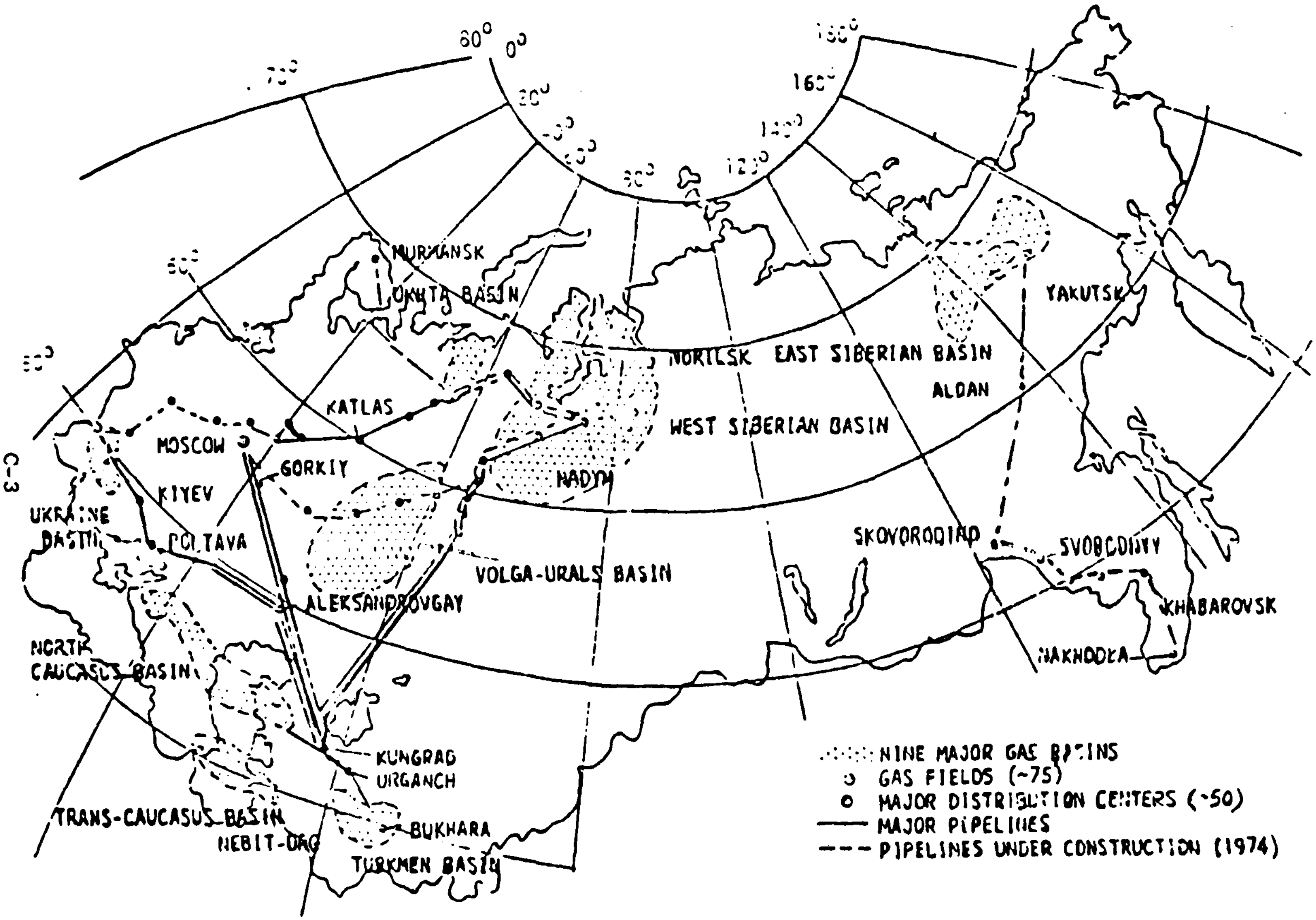


Figure C-2. Location and extent of Soviet gas development.

Table C-1. Primary Soviet production and consumption of natural gas.

BASINS (1975 est)[15]	PRODUCTION BILLIONS $(M)^3$	PERCENT TOTAL
UKHTA	17	5
NORTH CAUCASUS	45.2	13.5
TRANS-CAUCASUS	15.9	5
VOLGA-URALS	40	12
UKRAINE	67.2	20
TURKMEN	100	30
SIBERIA	9	3
WESTERN SIBERIA	37	11
EASTERN SIBERIA	1.6	0.5
TOTAL USSR PRODUCTION	332.9	100.0

CONSUMPTION (1975)[20]	BILLIONS CU METERS	PERCENT TOTAL
PRODUCTION TOTAL	332.90	102.6
IMPORTS (TOTAL)	13.99	+4.3
EXPORTS (TOTAL)	22.49	-6.9
NET AVAILABLE	324.00	100.0
HOUSEHOLD & MUNICIPAL	35.18	10.9
INDUSTRY	184.88	57.1
CHEMICAL	-26.28	- 8.1
METALLURGY	-75.85	-23.5
CEMENT	-22.77	- 7.0
MACHINERY/METAL WORK	-33.28	-10.3
CONSTRUCT. MATERIALS	- 8.76	- 2.7
LIGHT INDUSTRY	~1.05	~ 0.3
FOOD INDUSTRY	~2.09	~ 0.6
OIL & GAS PROD.	~8.40	~ 2.6
OTHER	~6.40	~ 2.0
ELECTRIC POWER	84.42	26.0
TRANSPORTATION	1.69	0.5
AGRICULTURE	4.22	1.3
OWN NEEDS & LOSSES	13.61	4.2
TOTAL CONSUMPTION	324.00	100.0

19. ESTIMATES FROM "OIL AND GAS DEVELOPMENT IN THE USSR", C.E. STOWELL, THE PETROLEUM PUBLISHING COMPANY, TULSA, OKLAHOMA, 1974.

20. SCALED TO 1975 BASED ON DATA OF PAST YEARS, "THE ECONOMICS OF SOVIET OIL AND GAS", R. W. CAMPBELL, THE JOHNS HOPKINS PRESS, BALTIMORE, MARYLAND, 196[illegible].

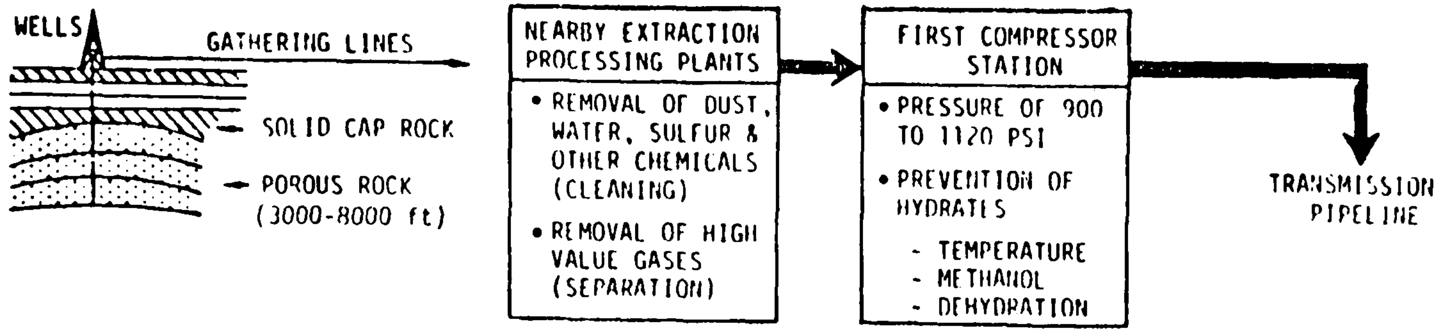
Table C-1 also shows that Russia imports some natural gas (about 4.3 percent) along its western borders to cut down the costs of transmission; however, exports at 6.9 percent exceed the imports. The largest user of natural gas is the electric power industry (26 percent). The metallurgy industry (aluminum, copper zinc, etc.) is the second largest user at 23.5 percent followed by heating for households and municipal buildings (10.9 percent) and machinery/metal working (10.3 percent). It is probable that a major cutback in natural gas supplies, due to destruction of production capacity, could be accommodated by a shift to other fields (coal or oil) for electric power production and/or a reduction in heating.

GAS FIELDS, PROCESSING PLANTS AND COMPRESSOR STATIONS

It is important to understand the characteristics of the various elements of the Soviet natural gas production, transmission, and distribution system in order to identify critical candidate targets. This section describes the characteristics of the wells, gas fields, processing plants and compressor stations.

Natural gas in Russia is generally found by drilling deep wells (3000 to 5000 feet) into natural deposits trapped in porous rock below a solid cap rock geologic structure as illustrated in Figure 23.[20] These deposits are often associated with petroleum (oil) fields but are also found as gas only. Typically, the gas comes from the wells as a mixture with different percentages of hydrocarbons, rare gases (helium, etc.) and unwanted water vapor plus hydrogen sulfide. Figure C-3 shows two typical distributions for sweet and sour gas which are distinguished by their percent of sulfur content.

As the gas comes out of the ground under various pressures, it is fairly corrosive due to the water vapor and sulfides. Therefore, it is immediately transmitted a short distance (less than a mile or so) through gathering lines to a nearby extraction processing plant. This plant does two things: it removes the unwanted



TYPICAL GAS MIX FROM WELLS	SWEET GAS (LOW SULFUR)	SOUR GAS (HIGH SULFUR)
METHANE	82	52
ETHANE	4	8
PROPANE	3	11
BUTANE	3	10
HEXANE	2	3
NEPTANE	5	2
PENTANE	nil	5
OTHER HIGH HYDROCARBONS	1	nil
HYDROGEN SULFIDE	nil	9
TOTAL GAS	100	100
HEATING VALUE (BTUS/CU METER)	45,800	31,700

TYPICAL GAS READY FOR TRANSMISSION
METHANE - 93 ETHANE - 5 PROPANE - 2 TOTAL - 100 $\Big\}$ SPECIFIC GRAVITY 0.6
• GAS IS COLORLESS AND ODORLESS (MERCAPTANS ADDED TO GIVE ODOR)
• HEATING VALUE - 36,200 TO 38,700 BTU/CU METER
WATER CAUSES HYDRATES WHICH PLUG PIPELINES AT LOW TEMPERATURE AND HIGH PRESSURE (E.G., 15.6°C AND 2000 PSI)

Figure C-3. Natural gas production, cleaning and separation.

dust, water vapor, sulfur, and other chemicals by cleaning and it removes high value gases such as helium by separation (gravity or centrifugal). Liquid hydrocarbons are trapped by bubbling the gas through oil; these are later used to make gasoline. Carbon dioxide and hydrogen sulfide are acidic gases and are absorbed by bubbling through aqueous monothonolamine. Water vapor is removed by absorption in ethylene glycol or desiccant beds of calcium chloride. Most natural gas is then distilled at very low temperature to remove the valuable components like helium, propane, and ethane and propane) with a specific gravity of about 0.6 is ready for transmission. However, the mixture is colorless and odorless; therefore, mercaptans are added as a safety precaution at the load end to give it an odor.

To improve transmission efficiency through the pipelines, the gas is generally put through a compressor station located near the processing plants. The pressure is increased to about 970 to 1125 psi. This step requires some care since hydrocarbons and water vapor at high pressures and low temperatures from hydrates which, like snow crystals, tend to plug valves and pipelines. Note that hydrates form at pressures of 2000 psi and temperatures of 15.6°C which are not far from the conditions experienced in northern regions of Russia even during summer months.

The locations and estimated 1975 production capacities of 75 gas fields representing nearly the total Soviet production have been incorporated in the Soviet target data base. Two typical large Soviet gas fields are shown in Figure C-4. One at Shebelinka above the Black Sea and the other at Gazli in West Turkemenia.[21] Both of these fields produce on the order of 30 billion cubic meters of gas per year. It is noted that these fields cover about 15 square miles of area. Figure C-5 provides an organizatonal flow chart for the field at Shebelinka.[22] It shows about 400 wells feeding through gathering lines to 26 group collection stations. Each group collection station contains two collection points serviced by four separator towers. Each separator tower handles 1 to 4 wells or about 15 wells per collection point and 30 wells per group collection

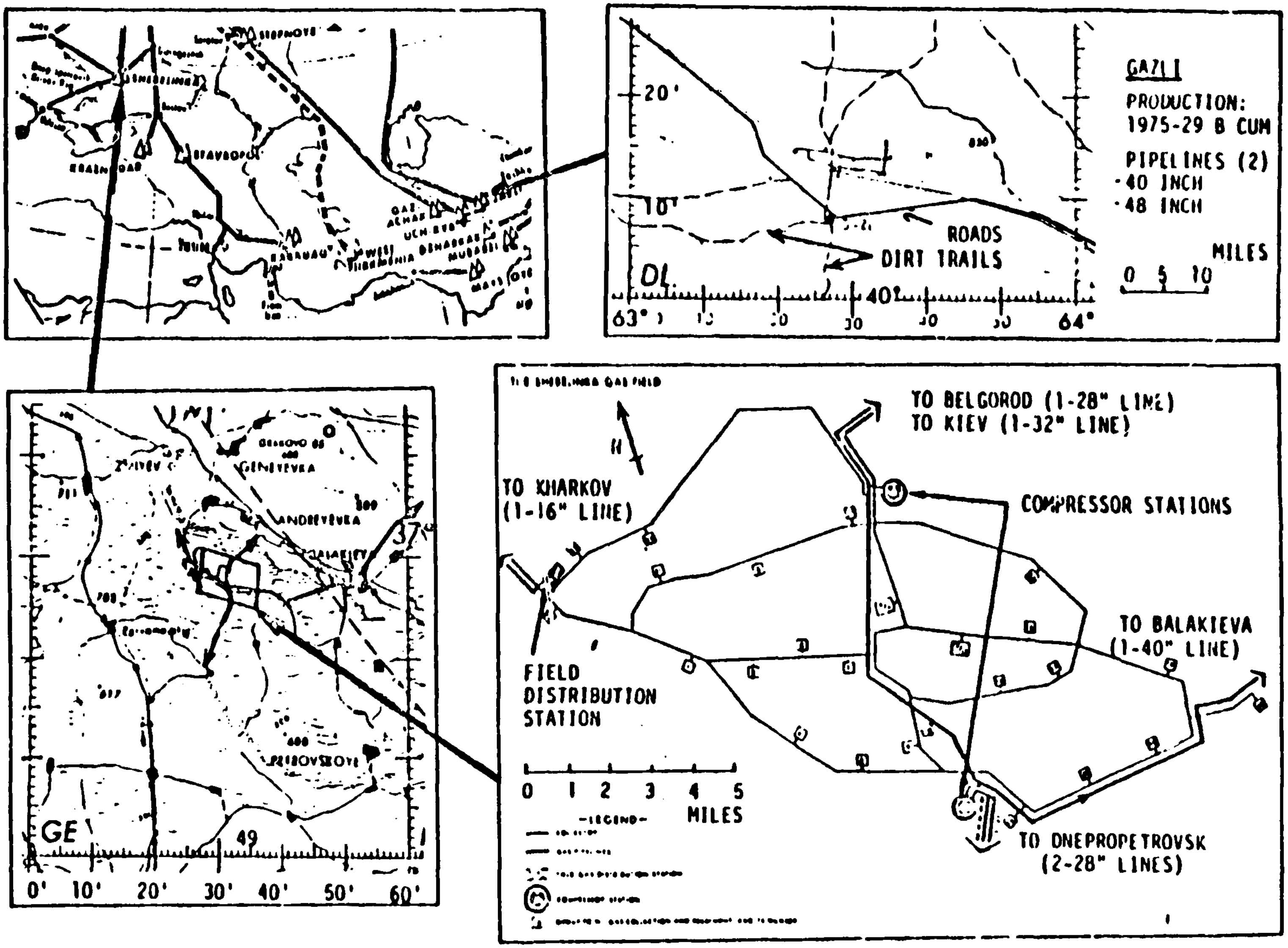


Figure C-4. Typical Soviet gas fields.

station. A typical layout of one of these group collection stations is shown in Figure C-5 based on photographs of the Shebelinka and Gazli fields provided in Figure C-6.[23]

The gas separator tanks are tall, steel shell, pressure vessels which must be insulated to prevent formation of hydrates during operation. Two types of separator design (gravity and cyclone or centrifugal) are commonly in operation throughout the country. Typically, these units are 12 to 13 meters tall, 3 meters in diameter and have steel shells 3 to 5 centimeters thick. They sit on prepared concrete pads which are poured around the necessary plumbing and valve systems. Their most critical failure mode is considered to be blown-down or over-turning rather than collapse or splitting of the pressure shell. Consequently, their estimated hardness to equivalent blast overpressure is in the range of 15 to 20 psi.

It is useful to estimate the numbers of natural gas processing plants and compressor stations in Russia since they represent candidate targets. In the case of processing plants, there is at least one at each gas field and an additional plant for each 2 billion cubic meters of annual capacity (based on shebelinka and Gazli examples). Therefore, using the 75 fields in the data base and the capacities of production at each field, it is estimated that there are nearly 200 processing plants in Russia.* Turning to the compressor stations, each field generally has one station and larger fields have two (e.g., one for each 16 billion cubic meters of annual capacity). Therefore, there are about 80 compressor stations at the gas fields. However, due to the drop in pressure which takes place as the gas moves through the pipelines, there are generally additional compressor stations about every 150 miles of major pipeline. In 1975, there were 56,000 miles of major pipelines in Russia which indicates approximately 365 additional compressor stations.[24] Consequently there were about (80 + 375 = 455 total) compressor stations in Russia. A typical compressor station is shown in Figure C-7.

(U)*Evidence accumulated since this analysis was computed indicate that more modern processing stations are much larger and if this is a general trend, the total number of processing plants is probably less than 200.

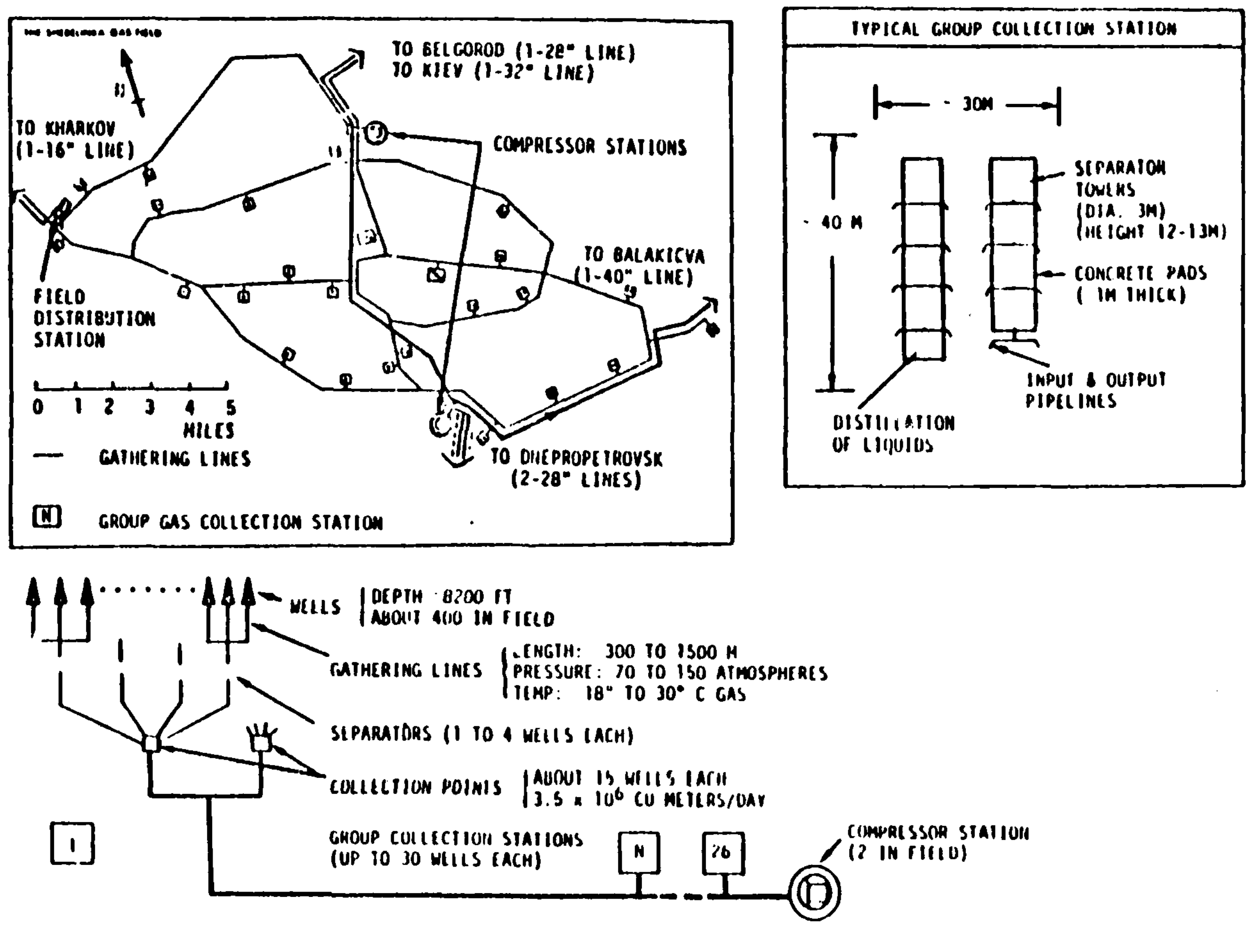
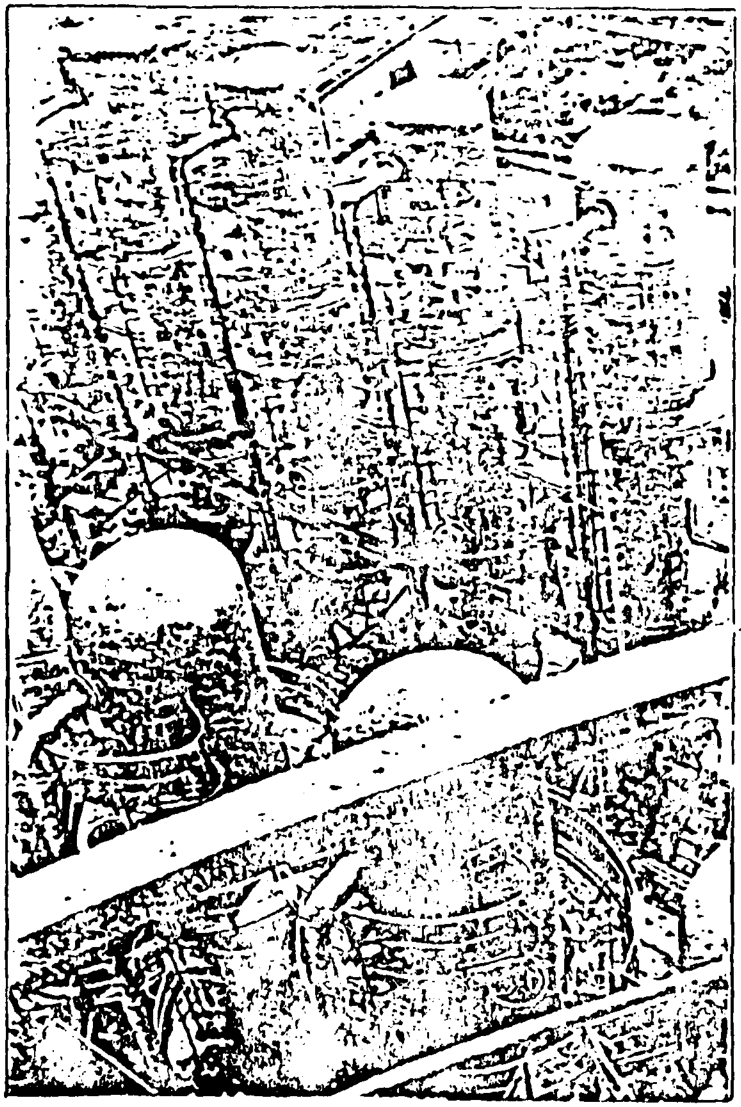
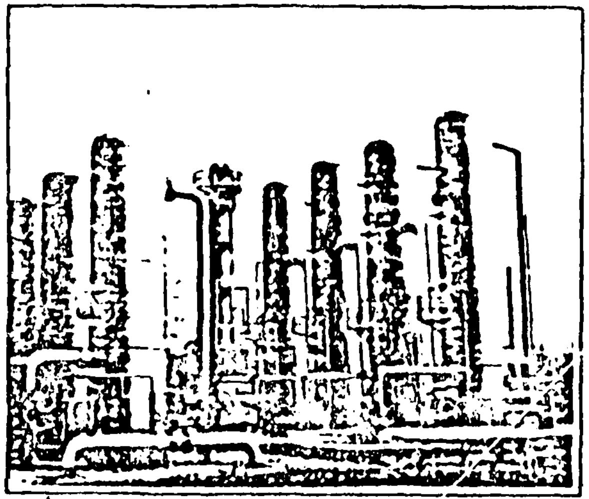


Figure C-5. Exemplar Soviet natural gas processing plant.





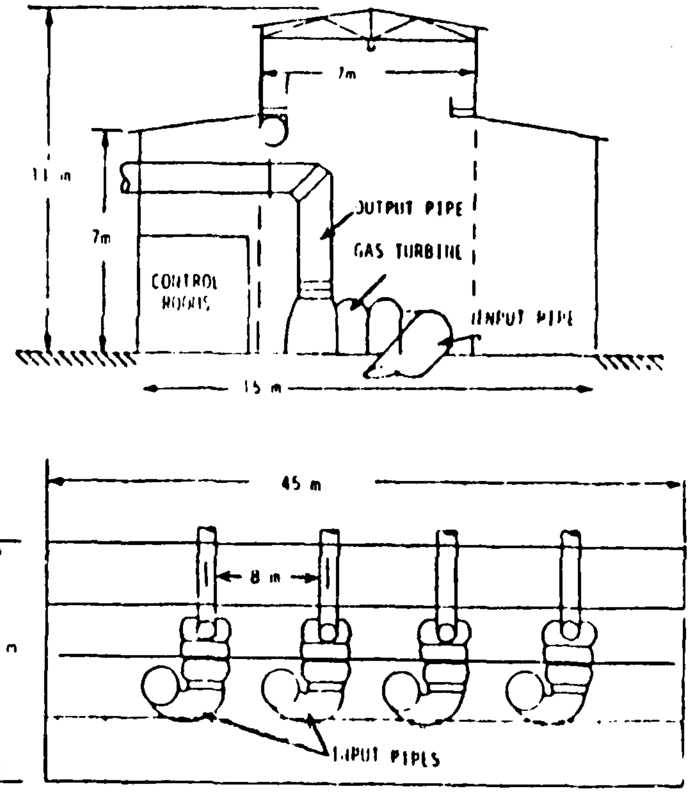
SHEBLINKA PROCESSING PLANT

GAZLI PROCESSING PLANT

CHARACTERISTICS OF GAS SEPARATORS

- TWO TYPES (GRAVITY & CYCLONE)
- HEIGHT - 12 TO 13 METERS
- DIAMETER - 3 METERS
- STEEL SHELL (HEAT INSULATED TO PREVENT HYDRATES DURING HIGH PRESSURE DROP-HIGH GAS VELOCITY)
- STEEL THICKNESS - 3 TO 5 CM
- ESTIMATED HARDNESS -

Figure C-6. Typical Soviet natural gas processing plants.



- GENERALLY ONE (OR MORE) COMPRESSOR STATIONS AT EACH GAS FIELD
- GAS TURBINE COMPRESSORS OF 1000 TO 10,000 HP -- **SOME RUN ON GAS FROM PIPELINE**
- HARDNESS
  - BUILDING/CONTROLS
  - GAS TURBINES -
- COMPRESSORS LOCATED ALONG MAJOR PIPELINES (EVERY 50 TO 100 MILES) -- HENCE, ABOUT 150 STATIONS IN THE USSR

Figure C-7. Typical Soviet natural gas compressor station.

Based on the above discussion, it is clear that there are more than twice as many compressor stations as there are processing plants. Furthermore, the critical elements at the compressor stations (e.g., gas turbines) are harder to destroy than the processing plants. Finally, the Russians have been known to run some of their pipelines using the gas pressure from the ground without the use of compressor stations (this is not efficient but it does permit gas flow at reduced pressures). Hence, the processing plants appear to be more attractive targets than the compressor stations.

PIPELINES

The major natural gas pipelines represent a potentially interesting target class in that they are relatively soft and can be used to cut the flow of gas to large areas. As indicated in Figure C-1, the Russians are building major gas pipelines at a phenomenal rate. The latest 5-year plan has allocated 3.9 billion rubles to build 33,000 kilometers (20,625 miles) of gas pipeline (11,200 km was the goal for 1973 alone). In fact, the building of gas lines has been given priority over construction of oil popelines.[19]

The construction of pipelines in Russia has also experienced a dramatic change in pipe diameter. At the end of World War II, the maximum pipe diameters in use were about 15 inches. In 1954, 28-inch diameter pipe was introduced, by 1959, 40-inch, by 1968, 48-irch, by 1971, 56-inch and currently; plans are being made to use 100-inch pipe in 1980.[22] In this respect, it is interesting to note that the NATO countries refused to sell Russia pipe greater than 19 inches in diameter in 1966 since it was considered a strategic material. As a result, the Soviet State Institute for Pipeline Design and Special Construction, Leningrad, began designing 48-inch diameter pipe which was put into mass production in a special mill at Chelyabinsk. Today the Soviets manufacture 56-inch diameter pipe while the U.S. buys most of its largest pipe from Japan (e.g., Alaskan pipeline). A new U.S. plant to manufacture 48-inch pipe has just started in early 1976 in Los Angeles.

The CIA had made a survey[26] of smaller diameter pipeline systems in the USSR in 19ϵ5. In addition, SAI reviewed approximately 85 magazines, books, translations and newspaper (Pravda) articles dealing with the construction of more recent large diameter gas pipelines in order to summarize current Soviet capabilities. Table C-2 provides the results. Although it is not considered an exhaustive listing of all the new major pipelines, it covers over 24,000 miles and provides sufficient data for analysis.

Using the data of Table C-2, it is possible to plot the miles of installed pipeline as a function of years required to complete the project. These results are shown in the upper left of Figure C-8 and are labeled Soviet experience. Superimposed is a curve of 400 miles per year which represents the average rate used in Soviet planning. Note that the longer pipelines appear to be completed sooner than expected while short lines (<500 miles) seem to take longer. Based on comments in various sources, it appears that the Soviets can repair or replace about a mile of pipe per day depending on the terrain, weather conditions and availability of materials. This suggests that even multiple breaks in the major pipelines can probably be repaired in about a week.

The curves on the right of Figure C-8 show that Soviet theory concerning pipeline capacity and their experience with modern pipe operations tend to be in excellent agreement. Clearly, economics favor the use of larger diameter pipelines. About 25 percent of the cost of natural gas production is involved in purchase, maintenance, and operation of the pipelines. Figure C-8 shows that these costs are significantly reduced per cubic meter of gas delivered when pipes having diameters greater than 40 inches are used. In terms of U.S. money, it costs the Russians about 0.01 cent to move 1000 cubic feet (28.2 cubic meter) of gas a distance of 1 mile.

Table C-2. Major Soviet natural gas pipelines.

START LOCATION	MAXIMUM DESTINATION	PIPELINE LENGTH - MI	PIPELINE DIAMETER - IN	CAPACITY 10^6 CU METERS/DAY	CONSTRUCTION START	CONSTRUCTION COMPLETE	CONSTRUCTION TOTAL
UKHTA							
VUKTYL	UKHTA	115	40			1968	
NIZHNYAYA	UKHTA	80					
UKHTA	TORZHOK	1000	48		1967	4-1969	2 1/4
UKHTA	LADYTHANGI/SALEKHARD	420					
VOLOGDA	SEVERODVINSK	390					
VUKTYL	TORZHOK	1100	56	25			
NORTH CAUCASUS							
GROZNYY	ROSTOV	465	40			1959	
CHERKESSK	STAVROPOL/BATAYSK	235				1956	
NOVOROSSIYSK	ROSTOV	255	28			1959	
ORDZHONIKIDZE	TBILISI					1963	
TRANS-CAUCASUS							
BAKU	ORDZHONIKIDZE	400					
YEREVAN	AKSTAFA	95			1959	1960	1
ASTARA	SHIRVAN	115	44		new	1968	
OKAREM	KRASNOVODSK	220				1964	
BARSA-GELMES	NEBIT-DAG	37					
KOTURDEPE	BELEK	60					
KOTURDEPE	CHELEKEN	40					
KYZYL-KUM	KUMDAG/NEBIT-DAG	45	22			1968	
OFF-SHORE	BAKU	25	40				
UKRAINE							
DASHAVA	CZECHOSLOVAKIA	90				1968	
DASHAVA	MOSCOW	600			1945	1941	6
DASHAVA	MINSK	435	32	18.6	1960	1962	1.5
SHEBELINKA	KIEV	290					
SHEBELINKA	BRYANSK						
YEFREMOVKA	KIEV	250				12-1969	
SHEBELINKA	ODESSA	360	40	27.5			
KISHINEV	ODESSA	100					
KOSOV	CHERNOVTSY	35				1960	

Table C-2. Major Soviet natural gas pipelines. (Continued)

START LOCATION	MAXIMUM DESTINATION	PIPELINE LENGTH - MI	PIPELINE DIAMETER - IN	CAPACITY 10^6 CU METERS/DAY	CONSTRUCTION START	CONSTRUCTION COMPLETE	TOT
VOLGA-URALS							
VOLGOGRAD	FROLOVO	70					
SAUSHIN	SARATOV	175				1963	
SARATOV	MOSCOW	520	20	2.27		1946	
SARATOV	GORKIY/CHEREPOVETS	735			1959	1961	2
UFA	GORKIY	483					
SARATOV	CENTRAL ASIA	500					
POKHVISTEVO	MOKROUS	230				1962	
KUMERTAU	UFA	132					
ISHIMBY	TUYMAZY	145					
IZHEVSK	ALMETYEVSK	135					
ORENBURG	KUYBYSHEV	25[illegible]	40				
ORENBURG	UZHGOROD	2000				planned	
ORENBURG	SALAVAT	150	15			1972	
TURKEMEN							
MAYSKOYE	ASKHABAD	445	20	3.3		12-1969	
MUBAREK	KELIF	215	40				
MUBAREK	INGICHKA/DZHIZAK	240	40				
KAGAN	DZHIZAK	220					
KAGAN	GAZLI	75	32				
GAZLI	SVERDLOVSK	1350	40	27.8	1966	10-1967	2
GAZLI	MOSCOW	1650	48	41	1969	6-1972	3
NIAP	SHEVKHARYK	30	40	28		6-1972	
NIAP	KHIVA	90	32	13		7-1972	
SHATLYK	KHIVA	290	56		1973	3-1974	1
GAZLI	CHELYABINSK	1240	40	28	1963	1965	[illegible]
SIBERIA							
BEREZOVO	SEVERDLOVSK	560	32				
PUNGA	SEROV	455	40	27.8	1964	1966	2
PUNGA	IGRIM		40			1968	1
IGRAM	NADYM						
BEREZOVO	IGRIM				1953		
PUNGA	MEDVEZHE	367	78	41	1974		

Table C-2. Major Soviet natural gas pipelines. (Continued)

START LOCATION	MAXIMUM DESTINATION	PIPELINE LENGTH - MI	PIPELINE DIAMETER - IN	CAPACITY 10^6 CU METERS/DAY	CONSTRUCTION START	CONSTRUCTION COMPLETE	CONSTRUCTION TOTAL
EAST SIBERIA							
TAS TUMAS	YAKUTSK	185	20	1		11-1967	$3\frac{1}{2}$
SREDNE VILYUYSK	ARGAS	115	20	2.7			
YAKUTSK	SKOVORODINO/NAKHODKA	2000	20-50		1974	1980	6
WESTERN SIBERIA							
OKHTEURE	KEMEROVO	500					
MEDVESHYE/PARGODY	NADYM	60	56				
NADYM	KAZYM		48			1971	
MEDVEZHYE	MOSCOW	1880	48	39.7	1972	10-1974	$2\frac{3}{4}$
TAZORSKOYE	NORLISK	400					

TOTAL LENGTH OF PIPELINES LISTED = 24,226 MILES

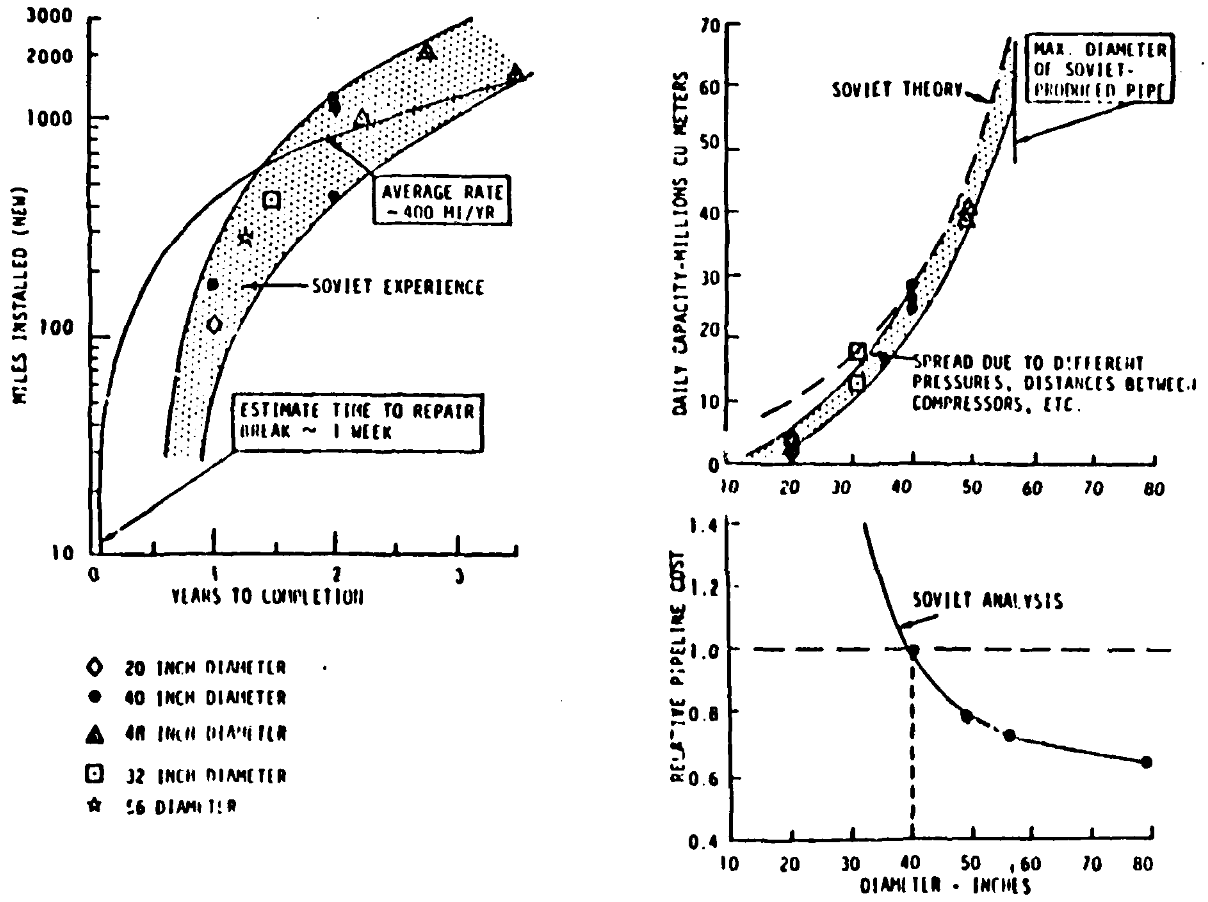


Figure C-8. Soviet pipeline construction considerations.

Figure C-9 illustrates the three primary methods of pipe laying used by the Russians. Methods "a" and "b" provide fairly hard installations and would be more appropriate for cratering attacks. On the other hand, method "c" results in exposed pipe which is sensitive to dynamic pressure loading. Pipelines built in the manner of method "c" can probably be destroyed by the equivalent of 20 psi blast overpressure.

In summary, although pipelines may represent vulnerable targets capable of being destroyed by low yield weapons, they can be repaired or bypassed in a matter of days. This rapid repair/replacement was experienced during the U.S. bombing of pipelines along the Ho Chi Minh trail in Vietnam where the enemy restored flow capacity overnight. Hence, the pipelines are not considered attractive strategic targets.

NATURAL GAS STORAGE

The overall consumption of natural gas in Russia experiences a factor of three fluctuation during the year as indicated in Figure C-10. Although the industrial uses remain fairly constant, gas for heating and boiler fuel undergoes a major increase during winter months. Therefore, stockpiling and storage of gas during summer months becomes a necessity.

The various storage methods for natural gas are presented on the right of Figure C-10. In the past, most storage was done in large volume, above ground tanks. These generally have very limited capacity. Liquefaction of the gas greatly reduces the large storage volume requirements but introduces the necessity of high pressure, low temperature operation which is costly. It is reported that Russia had 23 liquefaction plants by 1965 and a new plant was under construction near Moscow in 1969.[27] These plants would make good candidate targets for attacks aimed at destroying stored natural gas; however, they have only small capacity. On occasions the Soviets have increased the pressure on their pipeline systems by about 10 percent as a means fo. ·rarily storing more gas. This technique also has limited capacity nd is c. nstrained by the formation of hydrates.

The largest capacity method for storing natural gas is to pump it into underground reservoirs. The reservoirs are generally depleted gas fields, old mines, or man-made caverns which have suitable geologic characteristics.* As a result of a near disasterous winter in 1968-69, top priority has been given to expanding underground gas storage. In the five-year plan (1966-1970) about 6.5 billion cubic meters of active gas storage in aquifers and 2.5 billion cubic meters in depleted fields (9 billion total) were developed as indicated in Table C-3. It should be noted that the total storage indicated in Table C-3 only satisfied about 80 percent of the annual fluctuation in demand by these regions in 1970. Furthermore, in aquifer storage only about half the capacity created can be used as active reserve (50 percent remains in buffer); hence, these storage sites must be capable of an overall capacity of 13 billion cubic meters.

In 1965, there were 19 underground gas reservoirs in Russia with a capacity of 3.8 billion cubic meters. By 1979, it is estimated that there were about 31 reservoirs with a total capacity of roughly 17 billion cubic meters. This storage capacity represents only about 5 percent of the annual production. A few of the major underground storage sites are described below.

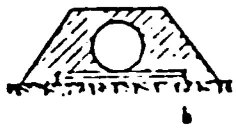
Kaluga: This aquifer storage facility is located 110 miles southwest of Moscow. It was started in 1954 and became operational in 1963. It covers an area 1.25 miles by 8.75 miles in a faulted anticline, sandstone geology at a depth of 780 to 960 meters. The caprock is clay and the deposit operates at a pressure of 80 atmospheres. Its capacity is 400 million cubic meters.

(U)*In November 1969, the USSR announced that they had successfully exploded an underground nuclear device to create a cavity for oil storage in a salt layer. This concept may benefit gas storage in the future.

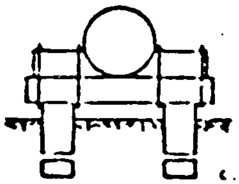
Table C-3. Added underground gas storage in 1966-70 (billions of cubic meters).

Regions & Cities	In Water-Bearing Strata	In Depeleted Deposits
Moscow Center & Asia Center Pipeline Route	1.5	2.5
Ivanovo-Vladimir Pipeline	0.3	
Baltics	0.8	
Belorussia	0.5	
Leningrad	1.1	
Urals	0.7	
Kiev Industrial Center	0.5	
Odessa	0.2	
Tashkent	0.3	
Tbilisi	0.4	
Yerevan	0.2	
TOTALS	6.5	2.5

a. Underground installation. Pipe is laid in trenches of varying depth. With pipe 2.5 meters in diameter the depth of the trench must be about 3 meters and the width must be about 3.5 meters. After the pipe has been laid the trench is filled.



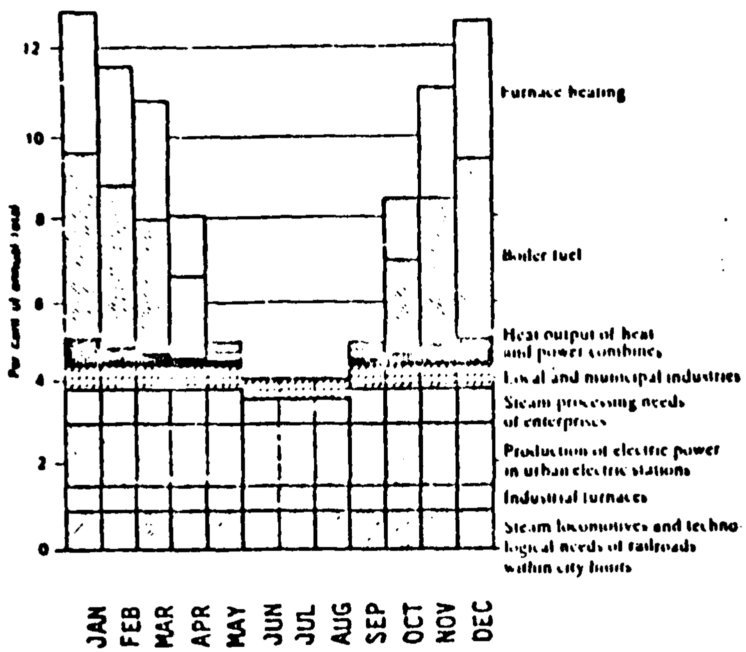
b. Installation on the surface. The pipe is laid on special floors and is covered with earth. In certain instances the earthen cover is not required.



c. Above-ground installation. The pipe is laid on reinforced concrete supports. The height of the support may vary, depending upon the relief of the locale, from several tens of centimeters to 1.5 to 2 meters.

Note: The approach depicted in (c) of supporting pipelines in the permafrost apparently is the result of the success of this type of construction used in supporting apartment and office buildings in the permafrost area near Yakutsk in Eastern Siberia, where area concrete pillars were draped with steam hoses and jets of steam melted the frozen soil around them, allowing them to sink into the frozen permafrost area. The area was permitted to re-freeze after the pillar had reached the desired depth.

Figure C-9. Means for layout gas pipelines.



STORAGE METHODS

- ABOVE GROUND TANKS
  - LARGE VOLUME/LIMITED CAPACITY
- LIQUIFICATION
  - 23 PLANTS BY 1965 (SMALL PRODUCTION)
  - HIGH PRESSURE, LOW TEMPERATURE
  - HIGH COST STORAGE
- INCREASE PIPELINE PRESSURE
  - LIMITED CAPACITY
  - FORMATION OF HYDRATES
- UNDERGROUND RESERVOIRS
  - REQUIRES SUITABLE ROCK FORMATION
  - CONTAIN GAS WITH RING OF PUMPED WATER WELLS (PRESSURE BOUNDARY)
  - 1.0 NEAR MOSCOW (1964) HOLD 1.5 BILLION M^3
  - ONE NEAR LENINGRAD
  - BY 1965, 19 RESERVOIRS WITH CAPACITY 3.8 BILLION M^3 (ABOUT 2% OF OUTPUT)
  - LARGE GAS LOSS - DISCOURAGING
  - HIGH COST (20 TO 30 RUBLES/1000 M^3)
- CUTOFF HEATING CUSTOMERS DURING WINTER MONTHS--UNDERUTILIZE PIPES IN SUMMER (USED PRIOR TO 1958)

- GAS CONSUMPTION EXHIBITS MAJOR HOURLY, DAILY, AND SEASONAL DEMAND VARIATIONS
- STORAGE FOR SEASONAL VARIATIONS IS SERIOUS ECONOMIC ISSUE -- SHORT TERM STORAGE CAN BE HANDLED

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*"THE ECONOMICS OF SOVIET OIL AND GAS", R. W. CAMPBELL, JOHNS HOPKINS PRESS, (Melentev & Shteingauz, 1963).

Figure C-10. Seasonal demand variations and storage problems.

Shehelkovo:	This second facility also serves the Moscow region. It is an aquifer formation holding about 1.4 million cubic meters as of 1967. The cost for injecting gas is 0.61 rubles and for removal is 0.92 rubles per 1000 cubic meters.
Gatchina:	This facility is located 38 miles southwest of Leningrad and has a capacity of 250 million cubic meters (active) and 350 million cubic meters (buffer). Recent expansion (1969) has increased total capacity to 1.2 billion cubic meters. The geology is a monocline, sandstone at about 400 meters depth and 8 meters thick. The caprock is a plastic shale 7 to 8 meters thick.
Kolphno:	A second facility near Leningrad has a capacity of 200 million cubic meters. A third is planned at Novgorod.
Olishevka:	This facility serves the Kiev area. The storage formation is 40 meters thick at a depth of 500 meters. It is also sandstone under a plastic clay caprock 20 meters thick. The facility covers an area of 18 square kilometers. Its total capacity is 360 million cubic meters of which about 50 percent is active storage.
Poltoratsk:	This aquifer facility is located close to Tashkent. Its formation is 20 to 40 meters thick sandstone capped by 60 to 80 meters of clay at a depth of 500 meters. Storage pressure is 63 atmospheres and the daily capacity is estimated at 1 to 4 million cubic meters.

The above examples indicate that destruction of the underground storage sites would be a very difficult problem due to the depth and geologic structure. Furthermore, since the combined capacity of these storage sites is small, they do not represent high value targets. Finally the Soviets response to loss of stored capacity has been to cut off heating supplies which they did during the winters of 1958 and 1968. Table C-1 and Figure C-10 indicate that if this procedure were used (no gas for heating), over 11 percent of the total gas production capacity could be saved without hurting production of other commodities.

Based on the preceeding discussion it appears that the most critical elements of natural gas production are at the processing plants associated with the gas fields. In general, one weapon will destroy the plant provided the accuracy is sufficient for the yield in question. Figure C-11 provides the percent of total Soviet natural gas capacity destroyed as a function of the number of gas fields and processing plants that must be attacked.

A typical natural gas compressor station is much harder than a collection station and since there are about 455 compressor stations the weapon requirements are most severe for destroying compressor stations than for processing plants, it would require about twice as many weapons to draw down gas production by destroying compressors as with attacks on processing plants. Furthermore, results would not be assured because many pipelines can be operated at reduced efficiency without compressor stations.

Attacks on the gas pipeline systems would have a more immediate effect on other industries but the pipelines can probably be repaired in a matter of days. Attacks on gas storage capacity do not appear productive with the exception of destruction of the liquefaction plants. Finally, it does not appear attractive to attack the underground storage since the weapon requirements (deep earth penetration) are severe, there is no guarantee that the gas could be destroyed at depth, and these facilities only represent about 5 percent of Soviet capacity.

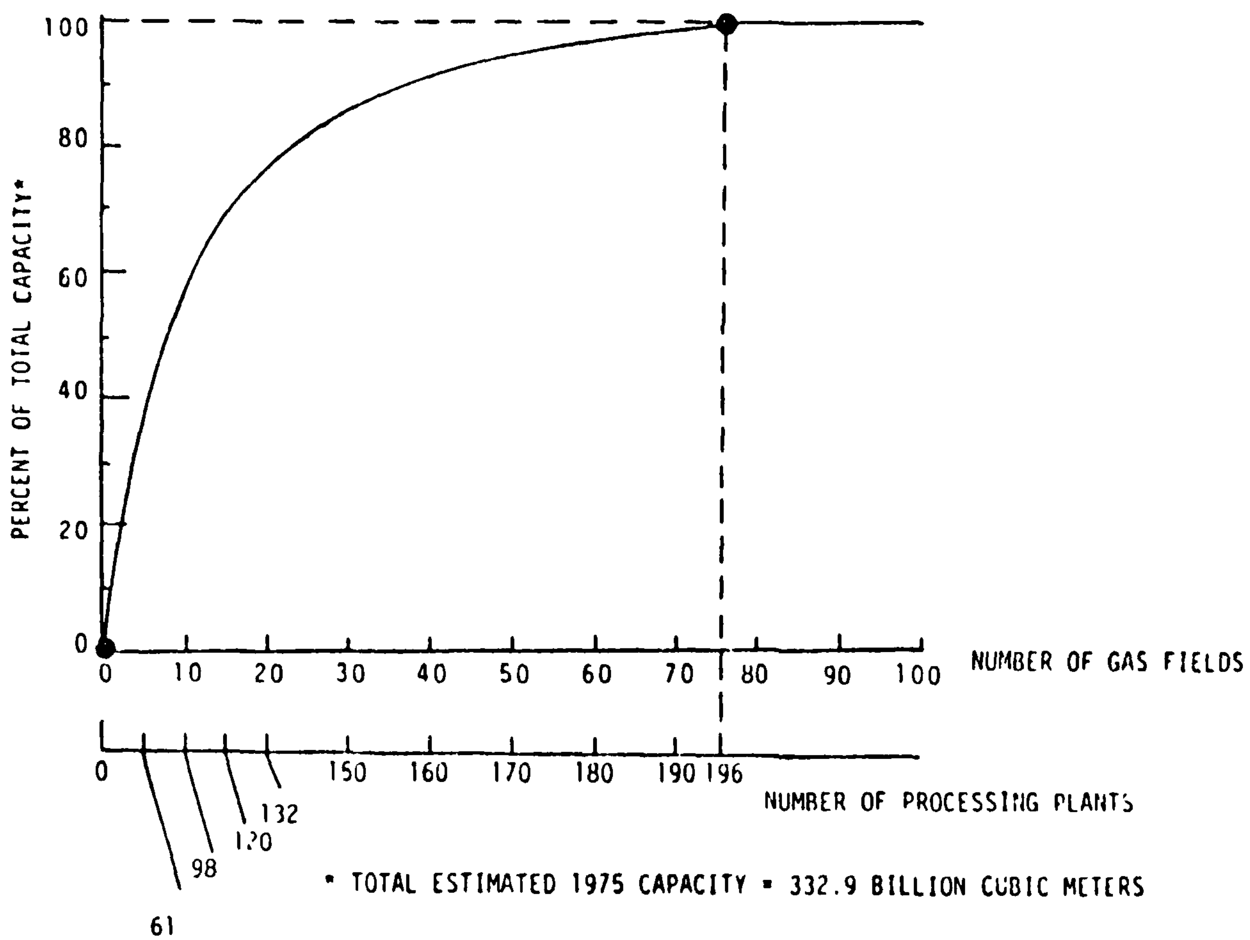

Figure C-11. SU natural gas capacity versus number of aimpoints.

APPENDIX D

CAPACITY FUNCTION FOR COAL
(Appendix D is Unclassified)

So far as is known, there has been only one attempt to analyze the weapon requirements to destroy coal as a basic Soviet energy and this was also a part of the recovery denial work carried out by SAI for the General Electric Company.[18] The basic approach was to isolate the coal fields by destroying the railroad bridges, tunnels and other key point surrounding each field. The primary fields were located and map exercises were carried out to determine the number of bridges and other bottleneck points which would have to be destroyed. Finally the capacity of each field in thousands of tons was assigned uniformly to the surrounding bottleneck points to provide the capacity data of Table D-1.

Table D-1. Coal capacity function.

3114	2737	2737	1298	830	791	473	473	267	161
2768	2737	2737	908	830	791	473	473	267	
2768	2737	1765	908	830	791	473	332	267	
2768	2737	1730	908	830	473	473	332	267	
2768	2737	1730	908	791	473	473	332	267	
2768	2737	1298	865	791	473	473	332	267	
2768	2737	1298	865	791	473	473	332	161	
2737	2737	1298	830	791	473	473	267	161	

As with electric power, these installations were divided into sets as indicated by the bars and each set was represented by its average capacity.

Although bridge destruction will surely stop the flow of coal temporarily, there is considerable question about how long it would last. Additional analysis will be required to provide such estimates. Even if bridge piers and abutments are destroyed, temporary structures may be substituted and shipments may continue. For these reasons, coal was not considered a primary class in the body of this report.

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APPENDIX E

THRESHOLDS OF IMPACT
(Appendix E is Unclassified)

IMPACT OF LOSS OF ELECTRIC POWER

In Appendix A, it is shown that the targetable data base of electric generating installations extends down to 25 megawatts and includes over 95% of the total Soviet Union generating capacity. The removal of all of these units would shut down the high voltage system in the Soviet Union and leave, at best, single units of less than 25 megawatts, some of which might be portable. On the other hand, weapon constraints will likely dictate that smaller plants not be targeted and some higher limit may be of more interest. How would the removal of units above 20 to 50 megawatts capacity affect various Soviet industries? One way to answer this question is to determine the major purchases of electric power based on data from input-output tables[2] and for each of these to look for fundamental electricity requirements. Economic sectors from the 1972 input-output table are listed in order of purchase of electric power and percent of total industrial purchases in Figure E-1. The cumulative percent as a function of number of sectors is also shown. The first ten sectors purchased 60% of the electric power and these are the ones which are considered first. In particular, metallurgy and oil refineries will be important in the development of impacted MVA for electric power.

Electric power requirements for major elements of metallurgy and for oil have been determined for a 20 megawatt threshold as shown in Table E-1. For example, iron and steel production require 50 kilowatt hours per ton of output as a direct input.[28] Thus plants producing in excess of 1,720,000 tons per year would require input power in excess of 20 megawatts from the power distribution systems and those producing in excess of 4,300,000 tons per year would require in excess of 50 MW.* For this analysis, these plants are assumed to be limited to annual production proportional to surviving levels of power production in the sense of limit functions as defined in Section 4. In the case of high alloy steel and non-ferrous metals, the production thresholds are much lower since these metals are produced in electric furnaces or otherwise are heavy users of electricity.[29,30] The direct electricity requirements of 5 kilowatt hours per barrel for oil refining is based on U.S. experience[31] which generally does not conduct de-salting operations at the refineries. The Soviets generally conduct de-salting operations requiring large amounts of electricity at the refineries and their crude oil requires more of these activities, therefore 5 kilowatt hours per barrel is considered a lower limit in power requirements. The impact thresholds of table E-1 would be higher and the percentages of capacity would be lower if 50 megawatts was considered rather than 20.

Steel rolling mills are a special case and a more in depth analysis has been carried out for them. Steel rolling mills in the Soviet Union are listed in Table E-2 by type along with the average main drive power ratings in megawatts.[12] These plants either have two high power main motors each driving a separate roller or on the order of a dozen motors of 2 to 3 megawatts which must all operate for designed plant capacities. An example of the first type is shown in Figure E-2. This is a cross section of the main working stand of a blooming mill located at Novo-Lipetsk.[12] The two large D.C. motors are of particular interest since they are rated at a total of 13.6 megawatts. There are also two smaller motors of about 2 megawatts each which apply pressure to the top

(U)*Given a maximum power generating capacity of 20 MW, the total energy produced per year by the largest surviving unit is 20,000 x 8760 x .5 - 67.6 10^6 kw hr (assuming an historic average of .5 for utilization of power plants). At 50 kw hr per ton of steel, this implies that all steel plants with a capacity of more than 1.72 x 10^6 tons per year would be shut down or would at least be limited to production at this level. More than 71% of the '.? steel plants exceed this capacity.

RANK	ECONOMIC SECTOR	PURCHASES (MILLIONS OF RUBLES)	PURCHASES %
1	METALLURGY	1577.4	15.4
2	TRANS. & COMM.	820.0	8.0
3	CONST. MAT.	667.3	6.5
4	BASIC CHEM.	636.3	6.2
5	OTHER CHEM.	534.2	5.2
6	CONSTRUCTION	517.5	5.1
7	OIL REF.	429.8	4.2
8	COAL	362.7	3.5
9	TEXTILES	345.3	3.4
10	AGRICULTURE	317.3	3.1
11	REPAIR	291.6	2.8
12	RADIO % OTH. MB	253.7	2.5
13	SYN. RUBBER	228.2	2.2
14	TRADE & DIST.	227.5	2.2
15	AGRIC. M&E	182.8	1.8

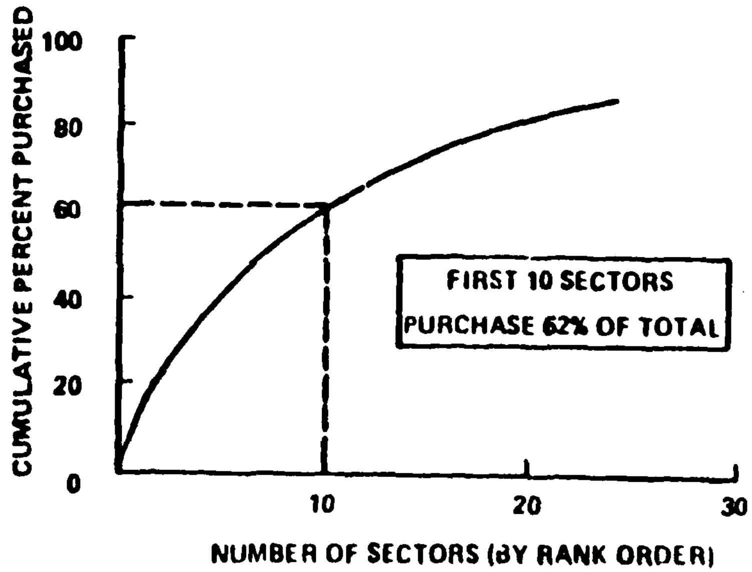


Figure E-1. Major purchasers of electric power - 1972.

Table E-1. Economic impact cut-off points.

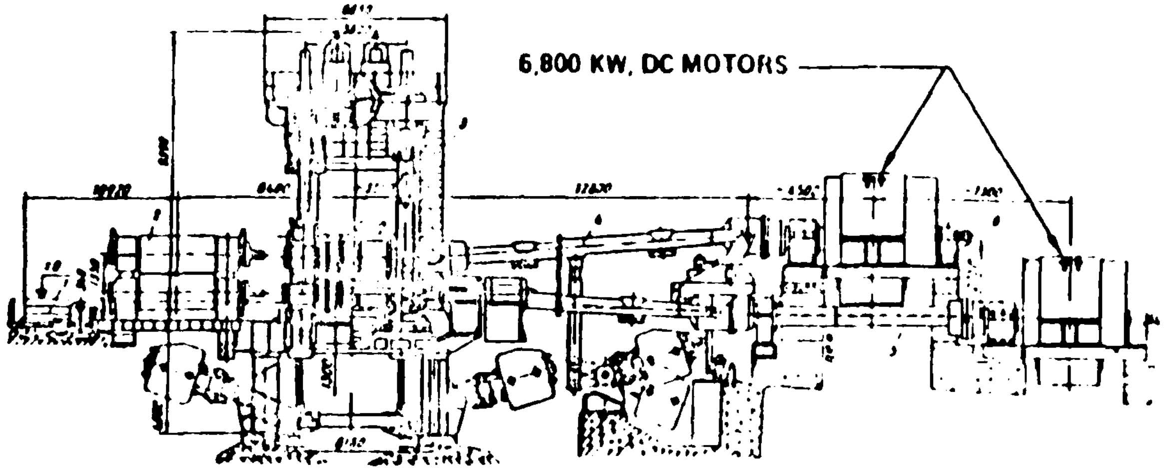
CATEGORY	ASSUMPTION	CUT-OFF POINT		PERCENT OF PLANTS WITH CAPACITY GREATER THAN CUTOFF
IRON & STEEL				
PRODUCTION	50 KW HR PER TON	OVER 1,730,000 TONS PER YEAR		71
ROLLING MILLS	HIGH POWER RQMT FOR DRIVES	OVER 10 MW MAIN DRIVES		100
HIGH ALLOY	4374 KW HR PER TON	OVER 20,000 TONS PER YEAR		100
NON-FERROUS METAL				
NICKEL	45,000 KW HR PER TON	OVER 2,000 TONS		100
MAGNESIUM	20,000 KW HR PER TON	OVER 4,320 TONS		95
ZINC	4,000 KW HR PER TON	OVER 22,000 TONS	PER	96
ALUMINUM	13,700 KW HR PER TON	OVER 6,300 TONS	YEAR	100
LEAD	300 KW HR PER TON	OVER 288,000 TONS		96
COPPER	1,000 KW HR PER TON	OVER 86,400 TONS		76
TITANIUM	39,000 KW HR PER TON	OVER 2,160 TONS		95
OIL	6 KW HR PER BARREL	OVER 47,400 BARREL/DAY		95

ALL VALUES ARE BASED 20 MW THRESHOLD

Table E-2. Steel rolling mills by mill type.

TYPE	AVERAGE MAIN DRIVE POWER (MW)
PRIMARY MILLS: ILYICH, KRIVOI ROG, CHELYABINSK, KARAGANDA, WEST SIBERIAN	16.3
BILLET MILLS: CHEREPOVETS, KRIVOI ROG, CHELYABINSK, WEST SIBERIAN	25.8
HOT ROLLING BROAD STRIP MILLS: CHEREPOVETS, ILYICH, MAGNITO GORSK, CHELYABINSK, KARAGANDA, NOVO LIPETSK	62.9
PLATE MILLS: ORSK-KHALILOVO, AZOVSTAL, AMURSTAL	20.7
MEDIUM & LIGHT SECTION MILLS: KRIVOI ROG (2), CHEREPOVETS, WEST SIBERIAN, DZERZHINSKY	16.0
WIRE MILLS: KRIVOI ROG, ENAKIEVO, WEST SIBERIAN	15.8
CONTINUOUS COLD-ROLLING SHEET MILLS: NOVO LIPETSK, CHEREPOVETS, ILYICH, MAGNITO GORSK, KARAGANDA	24.4

INPUT = INGOTS; OUTPUT = BILLETS/SLABS



Main line of 1300-mm blooming mill (designed by Uralmash):
1—roll-changing mechanism; 2—set of rolls; 3—working stand; 4—spindle device, 5—intermediate shaft, 6—main electric motors

$$\frac{\text{RATING X NUMBER}}{\text{CONV. EFF. X PLANT RATIO}} \approx \frac{6800 \times 2}{.8 \times .8} \approx 21.3\ \text{MW}$$

Figure E-2. Main line working stand, Novo-Lipetsk.

roller. If one considers the ratings of the two main motors, the fact that they are direct current devices and therefore involve conversion efficiencies from alternating current supplies and that the plant will require power for additional motors and control functions, it becomes clear that power inputs in excess of 20 megawatts will be required for the plant to operate.

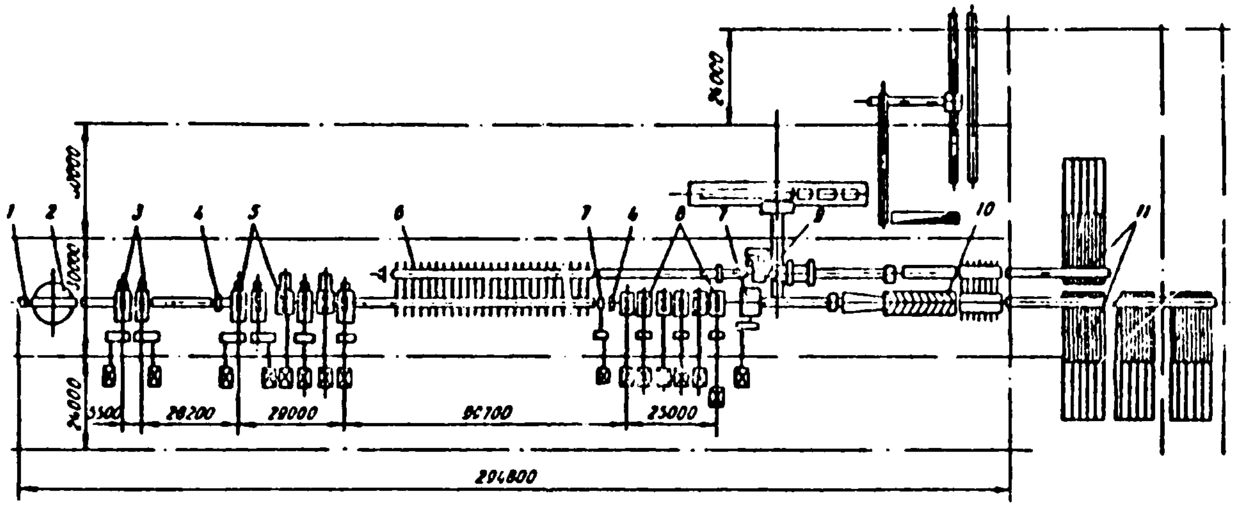
The second kind of mill is shown in Figure E-3. This is a plan view of a continuous billet mill located at Krivoi Rog.[12] There are 16 individual electric motors each driving a separate set of rollers. A belt of steel continuously moves through the plant at a rate of about 7 meters per second. All motors must be working for the plant to provide the designed output. The total power of all of the drive motors is 30.4 megawatts. It is unlikely that such a plant could function if power supplies in excess of 20 megawatts capacity were removed. At the 50 megawatt level, many of these plants could operate individually but the complexes within which they are located would have problems. This point will be discussed further subsequently.

The steel rolling mill process is shown in Figure E-4. The inputs to the process (shown on the left of the figure) include molten processed steel for the billet to produce slabs, blooms and rounds. The product flow is then to plate mills, hot rolling broad-strip mills and heavy section mills through the indicated intermediate mills and out the right hand side as rolled steel products including such items as turbine blades, axles, bearing blanks, transformer steel and reinforcing rods.

Also shown in the figure are the average power requirements for the various mills. There is a high probability that the entire flow of rolled steel products will be shut down by the removal of generating units above 20 megawatts.

As a final point in regard to steel rolling mill power requirements, they are shown by location in Table E-3 along with

14 STANDS
30.4 MW MAIN DRIVES



Layout of equipment of the 900/700/500-mm continuous billet mill of the Krivoi Rog Works (designed by SUEW). 1—inlet table; 2—turning gear; 3-breakdown group of working stands; 4—tilting gears; 5—roughing group of working stands; 6—transfer gear; 7—shear; 8—finishing group of working stands; 9—crop handling arrangement; 10—piling tables; 11—coolers

Figure E-3. Continuous billet MILL, Krivoi Rog.

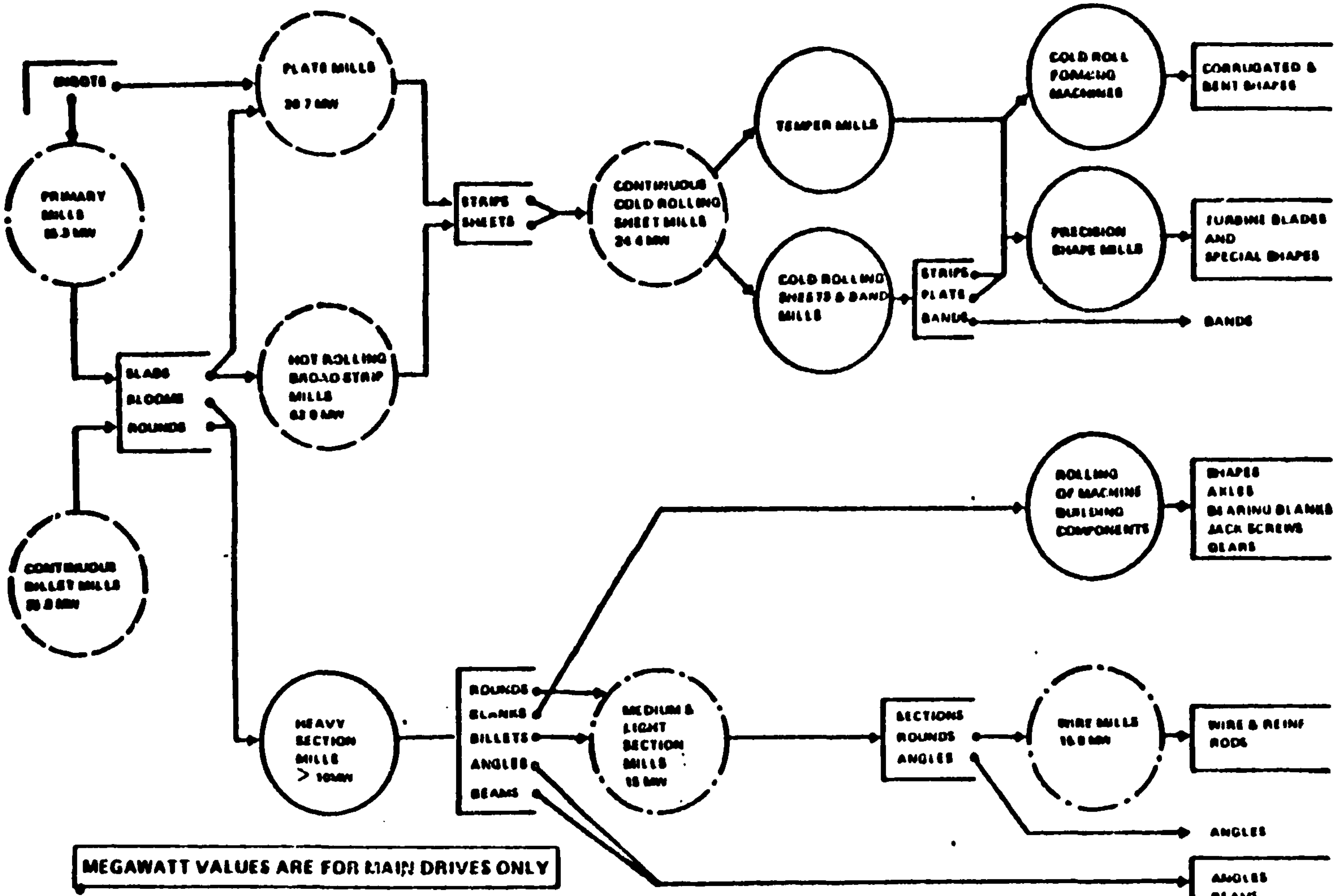


Figure E-4. Steel rolling mill process.

Table E-3. Steel rol'ing mills by location.

Plants	Total Drive Capacity (MW)
Ilyich	86.4
Krivoi Rog	80.9
Chelyabinsk	82.4
Karaganda	139.5
West Siberian	47.5
Cherepovets	85.2
Magnitogorsk	80.0
Novo-Lipetsk	136.6
Olsk-Khalilovo	9.8
Azovstal	31.5
Amurstal	--
Dzerzhimsky	16.6
Enakievo	20.2

the sum of their drive capacities in megawatts. There are large complexes of steel rolling mills requiring on the order of 100 megawatts of main drive power at most locations. Thus, it is likely that these complexes draw power from the high voltage distribution system or that they are co-located with a large generating station which supplies their power requirements and provides any remaining capacity to the distribution system. All such large installations are assumed to be included in the power generation installations which will be attacked and complexes of rolling mills would be effected even at the 50 megawatt threshold especially if the distribution system is not operable.

Given the loss of steel rolling mill products, what industrial sectors will be impacted? Table E-4 provides such an estimate.[28] We will assume that those sectors which manufacture the listed products (M&E) cannot continue to operate without rolled steel on high alloy steel products and thus are dependent on electric power. A detailed analysis of each of the elements making up the M&E sector is warranted and although, the bulk of them are expected to be totally dependent on rolled steel products, it is possible the substitution of cast and machined parts can circumvent the rolled steel requirements with some elements. Under the above assumptions, the impacted MVA for electric power potentially includes the sum of self MVA (5.8 billion rubles, oil MVA (6.7 million rubles, steel production and ferrous alloys MVA of metallurgy (6.0 billion rubles), M&E MVA (38.0 billion rubles) construction MVA (34.6 billion rubles), and the additional dependent value identified in the main body of the report. However, it should be noted that when interactions are considered many of these dependent classes will be directly targeted or will be assigned to other primary classes.

Table E-4. Impact of loss of rolled steel products.

PRODUCT	AMOUNTS REQUIRED	
MAIN LINE ELECTRIC LOCOMOTIVES	156.5	tons/unit
MAIN LINE DIESEL LOCOMOTIVES	122.5	tons/unit
MAIN LINE PASSENGER CARS	45.3	tons/unit
OIL BORING & DRILLING INSTALLATIONS	85.2	tons/set
MAIN LINE FREIGHT CARS	20.5	tons/unit
EXCAVATORS	16.4	tons/unit
COAL COMBINES	9.6	tons/unit
TROLLEY BUSES	7.6	tons/unit
STEAM BOILERS	9.8	tons/ton of steam/hr
AUTOMOBILE LOADERS	5.9	tons/piece
GRAIN COMBINES	6.3	tons/piece
SCRAPERS	9.4	tons/piece
FORGING MACHINES & PRESSES	4.5	tons/piece
AUTO BUSES	3.8	tons/piece
TRACTORS	3.8	tons/piece
MOTOR TRUCKS	3.6	tons/piece
POWER TRANSFORMERS	3.2	tons/thousand kw amperes
BULLDOZERS	5.9	tons/unit
COMPRESSORS	2.2	tons/unit
STEEL PIPE OF ALL KINDS	1.3	tons/ton
WIRE NAILS	1.2	tons/ton
WIRE, COMMON	1.2	tons/ton
STEEL ROPE & WIRE	1.2	tons/ton
PASSENGER AUTOMOBILES	1.7	tons/unit
CEMENT INDUSTRY MACHINERY	1.2	tons/ton
OIL WELL INSTALLATIONS & EQUIPMENT	1.3	tons/ton
DIESEL ENGINES	1.5	tons/unit
METAL CUTTING MACHINE TOOLS	2.0	tons/unit
METAL CUTTING TOOLS	1.1	tons/thousand rubles
BEARINGS, BALL & ROLLER, NEW	1.4	tons/thousands
ELECTRIC APPARATUS, HIGH & LOW VOLTAGE	.9	tons/thousand rubles
GRINDING & PULVERIZING EQUIPMENT	.7	tons/ton
BLAST FURNACE & STEEL MILL EQUIPMENT	.5	tons/ton
LOOMS	.8	tons/unit
WOODWORKING MACHINE TOOLS	.6	tons/unit
REFRIGERATING INSTALLATIONS	.6	tons/set
AUTOMATION MEANS & EQUIPMENT	.3	tons/thousand rubles

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