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Scientific and Technical Intelligence Report

Soviet Research, Development and Applications of Composite Materials and Structures

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August 1975

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Project Officer

[redacted]

PRÉCIS

The evaluation of Soviet materials and structures provides important intelligence regarding the capabilities, vulnerability, and possible missions of Soviet weapon systems. Early indications of new weapons and valuable information on R&D and manufacturing techniques also are obtained. For example, the Soviets substantially reduced the weight of rocket motor cases in the SS-X-16 (a developmental ICBM), compared with those of its SS-13 predecessor, by introducing fiberglass reinforced plastic composites to replace the SS-13's metal structure, thereby improving its prospects for both mobile and silo-launched versions. The use of composites accounted for two-thirds of the SS-X16's improvement in range and throw weight. Composite technology also has been used in other weapons systems, such as the SS-18, SS-19, SS-X-20, and command and control capsules.

The US and USSR are almost equal in the overall technology of composite structures and materials with R&D programs of both emphasizing filamentary and sandwich designs. The Soviets have had many administrative and production problems in applying composites even to priority items. Attention received from the highest levels of the Soviet Government and improving quality and fabrication procedures have helped this situation.

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SOVIET RESEARCH, DEVELOPMENT AND APPLICATIONS OF COMPOSITE MATERIALS AND STRUCTURES

Project Officer

[redacted]

OSI-STIR [redacted]
August 1975

CENTRAL INTELLIGENCE AGENCY
DIRECTORATE OF SCIENCE AND TECHNOLOGY
OFFICE OF SCIENTIFIC INTELLIGENCE

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PREFACE

Success in the development of composite materials and structures has made it possible for designers to prescribe desirable materials properties to attain minimum weight as well as maximum rigidity and resistance to thermal effects. All are characteristics of great interest to designers of military systems. Today both the Soviet Union and the United States are fabricating armor and components for aircraft and missiles from composite materials. In both countries there is ever increasing utilization of composite materials in major components of military and civilian hardware.

This study was carried out to assess Soviet capabilities in research, design, manufacture and application of structures of various composite materials. In situ composites and dispersion hardened alloys are not treated in this study.

Two studies are available which complement this report—one discusses the configuration and capability of the SS-X-16's (15Zh42)* and the other covers the Soviet strategic missile production process [redacted]

This report was prepared by the Office of Scientific Intelligence and coordinated within CIA. [redacted]

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TECHNICAL FOREWORD

Composites are combinations of at least two chemically different materials separated by interfaces which are created to obtain properties not achieved by any of the components alone. Almost any material—metals, plastics, ceramics, glasses, and alloys—can be used in various combinations to produce composite structures. During the past two decades the availability and diversity of structural composite materials in industrialized nations have increased very rapidly, largely because of the needs of aerospace and defense industries. New stiffer, high-modulus fibers have been developed, new manufacturing methods have evolved, and lighter weight, stronger structures have become available for a wide range of applications. Composite materials are attractive to designers of various military and space systems because of weight savings, improved fatigue characteristics, and improved performance at elevated temperatures. These materials may be tailored to meet specific load and thermal environments. In rocket motor casings, composites have advantages over metals by avoiding burn-through, hot spots, and loss of pressure.

The three principal types of composite structures are: filament-reinforced, sandwich, and multilayered (figure 1). Each type of composite possesses certain inherent advantages over the other types and over conventional materials; for example, (1) the major advantage of the filamentary type lies in the directional strength characteristics which may be tailored to produce a desired stress distribution; (2) a significant advantage of the sandwich type is that it permits the designer to work the outer facings of the sandwich at high stress levels and thereby reduce stress concentrations; (3) multilayered types provide heat or corrosion resistance in addition to required strength properties. Composite structures usually permit the designer to work the component materials more efficiently and to produce minimum weight, maximum strength systems. Low cost is sometimes a significant advantage, but the high cost of some modern composites has deterred designers from their use. It is likely that improved design and increased demand will lower these costs so that today's prohibitively expensive composite will become competitive tomorrow. The use of composites also may offer the opportunity to conserve relatively scarce materials.

For the past two decades theoretical models have been developed for predicting strengths of composite material structures, and for the past decade composites have been used in missile casings, canisters, reentry vehicles, fixed and rotary wing aircraft, radomes, turbines, and armored vehicles.

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[redacted]

SOVIET RESEARCH, DEVELOPMENT AND APPLICATIONS OF COMPOSITE MATERIALS AND STRUCTURES

PROBLEM

To evaluate Soviet progress in developing structures made of composite materials and in using them in military applications.

SUMMARY AND CONCLUSIONS

The overall quality of Soviet technology in composite materials and structures approaches that in the US. The applications of such technology are slightly less varied in the USSR than in the US but include components of missiles, aircraft, tanks, and radars. The Soviets have had many administrative and production troubles in applying composites to priority items such as the SS-X-16 developmental ICBM, particularly in quality assurance and fabrication procedures. Direct intervention in these matters by Brezhnev, Kosygin, Ustinov and, probably, Marshal Grechko has been noted. Such high level intervention and improving quality assurance and fabrication techniques have helped to solve these problems.

The most important application of Soviet composites is the widespread use of fiberglass reinforced plastic structures in major components of strategic missile systems. Significant weight reduction using composites has been noted in the SS-X-16 which is expected to replace the SS-13. The motor cases of the three stages of the SS-X-16 are made of composites and with their liners weigh about 2500 lb (1100 kg) less than their metal counterparts on the SS-13. This weight reduction probably has accounted for two-thirds of the improved throw weight of the SS-X-16 over the SS-13. Additionally, the SS-X-16 has a composite canister which appears suitable for transport, storage, and launch of a mobile missile. A similar but larger composite canister is being produced for the SS-18 ICBM. The Soviets may be developing their largest solid propellant rocket motor. Although there is no direct evidence of Soviet use of composites in the motor casing, the Soviets have the capability to build the casing using a filament-wound composite. The large rocket motor may be part of a system or technological development which could eventually become part of a strap-on space booster or of a new ICBM.

One canister, designated TPK type B200A, is a complex composite structure of fiberglass and plastics similar to the SS-18 canister. The B200A is possibly a new developmental canister for an unspecified antiballistic missile (ABM). The B200A is built from four wound shells with foam sandwiched in and filled with ferroboron. This provides neutron hardening and better mechanical and thermal properties. There is also a hermetic system for maintaining proper environmental conditions for the missile which should improve its shelf life. The known Soviet ABMs are launched from canisters, except for a new conical missile which is associated with rail and lattice type launchers. Although much is known about Soviet ABM canister structural design, practically nothing is known about materials used in the canisters, except for the Galosh canisters which appear to be metallic.

The Soviets and Czechoslovaks have developed two composite antiradiation liners to protect troops in armored vehicles from nuclear radiation. Another multilayer composite armor which appears to be under development, also may contain borated polyethylene slabs between two steel plates which should provide radiation protection as well as better resistance to high explosive antitank rounds.

Conventional Soviet radomes are mostly multilayer composite structures with some fiberglass reinforcements. The Safonovo Plastics Plant has been making radomes since 1967 for military communications, tracking and space applications as well as making a few experimental thick composite radomes of the BANDAZH-1 type. Shock resistant mullite/nitride composites are being evaluated and probably are suitable as windows and radomes in missiles operating up to about Mach 7.

A composite structure consisting of ten wound fiberglass cylinders and two metal sections is used as the launch control capsule in command and control silos, designated by the US as Type IIIX, at Strategic Rocket Force missile complexes.

The composites R&D programs of the US and USSR are roughly equal in quality and magnitude. The USSR, however, places more emphasis than does the US on theoretical analyses. Soviet designers use these analyses successfully for military and civil applications but the translation of their designs into structures has caused the USSR continuing difficulties. The Soviets are exerting great effort in rectifying inadequate fabrication and poor nondestructive evaluation procedures. Six conventional institutes do most of the relatively unclassified Soviet composites R&D whereas a more heterogeneous group of facilities is involved in work on classified weapon systems.

Soviet designers of filament reinforced composite structures appear to have inadequate information for handling very rapidly applied loads and thermal environments. In other areas, for example structural effects of various openings including cut-outs or penetrations, US designers have much less information than their Soviet counterparts. Although Soviet glass-epoxy composites are less rigid and weaker in tension than comparable US materials, overall Soviet capabilities in glass-resin wound composites approximate those of the US.

Soviet winding machines for filaments and tapes are based on US designs. They also have a huge vertical winding system from West Germany which could have produced many of the large fiberglass wound components for Soviet developmental ICBMs and other military systems. The same West German company is said to be manufacturing an even larger machine for the Soviets to filament wind fiber reinforced plastic structures capable of withstanding compressive loads. Though these structures are reportedly for Soviet submarine hulls, it is unlikely that they will use them in pressure hulls for full size submarines.

Western work on nickel alloys reinforced with tungsten fibers has been exploited by the USSR. Samples with very high tensile strengths at reentry temperatures have been produced. Soviet interest in high modulus boron filaments has fluctuated but probably will remain low because of the attractive properties and lower cost potential of aramids and graphites. Graphite/resin composites are being developed for large rocket cases but, as in the West, there are problems in fiber/matrix bonding. The Soviets also are working on carbon/carbons for reentry vehicle leading edges and wing tips. A unique Soviet ceramic/ceramic shock-resistant composite based on mullite filaments in oxides or nitrides is capable of being used at temperatures up to 1900° C.

Some of the more prominent Soviet investigators have been studying sandwich plates and shells with a hollow core which can be used to circulate liquid coolant to protect missiles and reentry vehicles. Hollow core systems are easier to produce than the honeycomb-type with which the Soviets are continuing to have manufacturing troubles. Therefore, they have tried to exploit US technology through honeycomb samples obtained from US aircraft downed in Vietnam. Complex sandwiches are used widely in the USSR's new developmental strategic missile systems where they provide light weight, rigidity, and thermal insulating properties.

Soviet analytical studies of multilayer composites under static loads are quite modest but investigations of dynamic loads are much more important. One significant Soviet project relates directly to blast effects on ship bottom plating.

The Soviet Union's development and production program for large composite components of strategic missiles has been troubled with delays and technical and administrative problems, and therefore it is difficult to put the program into proper perspective. But improved Soviet nondestructive evaluation techniques should help solve many of the problems associated with the production and use of composites.

By 1980 Soviet use of composites, particularly filamentary reinforced composites, in primary load carrying applications should be significant, and sandwich type constructions, to a lesser degree. Operating limits for polymer based composites are expected to be about 700° C, while metal/metal composites may operate up to 1400° C and ceramic/ceramics approaching 2000° C. Manufacture of metal/metals should be relatively simple and prototype components may be available by the end of this decade, as well filamentary ceramic/ceramics for missile radomes, MHD generators, turbine parts, and armor.

DISCUSSION

RESEARCH AND DEVELOPMENT

Introduction

There are three principal types of composite structures: filament-reinforced, sandwich, and multilayered (figure 1). The advantages of using composites are:

- Tailored properties in various directions
- Utilization of best properties of each material
- High strength and/or stiffness to weight ratios
- High thermal resistance
- Low cost
- Vibration and fatigue resistance

The Soviets have studied and extensively used all three types of composite structures and are aware of the advantages offered by the use of such structures.

Since the early 1950s the Soviets have been placing heavy emphasis on development of theoretical analyses to predict behavior of composite structures under a wide variety of load and environmental conditions of interest to designers of military hardware. These excellent mathematical analyses were carried out in great detail and used with considerable success for a wide variety of military and civil structures. The Soviets, however, have encountered continuing difficulties in translating their successful designs into structures, such as the honeycomb sandwich, because of inadequate fabrication procedures. Despite these problems the Soviet R&D program in composite structures is approximately equal to that of the US in both quality and magnitude.(1-13) (151) (158) (163) (166)

The Soviet Union's analytical capabilities in composites are comparable with or perhaps slightly exceed those in the US. Both countries are emphasizing R&D on filamentary and sandwich construction, with minor efforts on multilayered types. Although the Soviet Union does not appear to be developing some of the innovative composite designs being pursued in the US, such as those for the F-14 fighter's wing boxes, there probably is some parallel classified work underway in the USSR.(1-20)

The materials being investigated or used by the Soviets in their composite structures closely approximate those of interest in the West (table 1). Emphasis on reinforcement materials varies from country to country but the Soviets are putting a great amount of effort into ceramic filaments, especially those derived from a mineral named mullite, and are showing great interest in high modulus organic filaments, like US Kevlar. The most intriguing difference between Soviet and US techniques is the Soviet use of additives or fillers in plastics, such as the addition of boron compounds to epoxy resins. Moreover, the Soviets claim that addition of silicates and transition metal oxides to organo silicon-based materials makes them suitable for long-time service in the 700° to 1000° C temperature range. The US has experienced problems in using such materials above 370° C.(32-54)(166)

Figure 2 shows the key Soviet facilities associated with composite R&D, raw materials suppliers, and some of the more important users of composite structures. The facilities are rather widely dispersed across the Western half of the USSR, and thus, may contribute to delays in Soviet production schedules, but such dispersion appears to have little effect on the quality of Soviet weapon systems.(107)(108)(163)

TYPES OF COMPOSITE STRUCTURES:

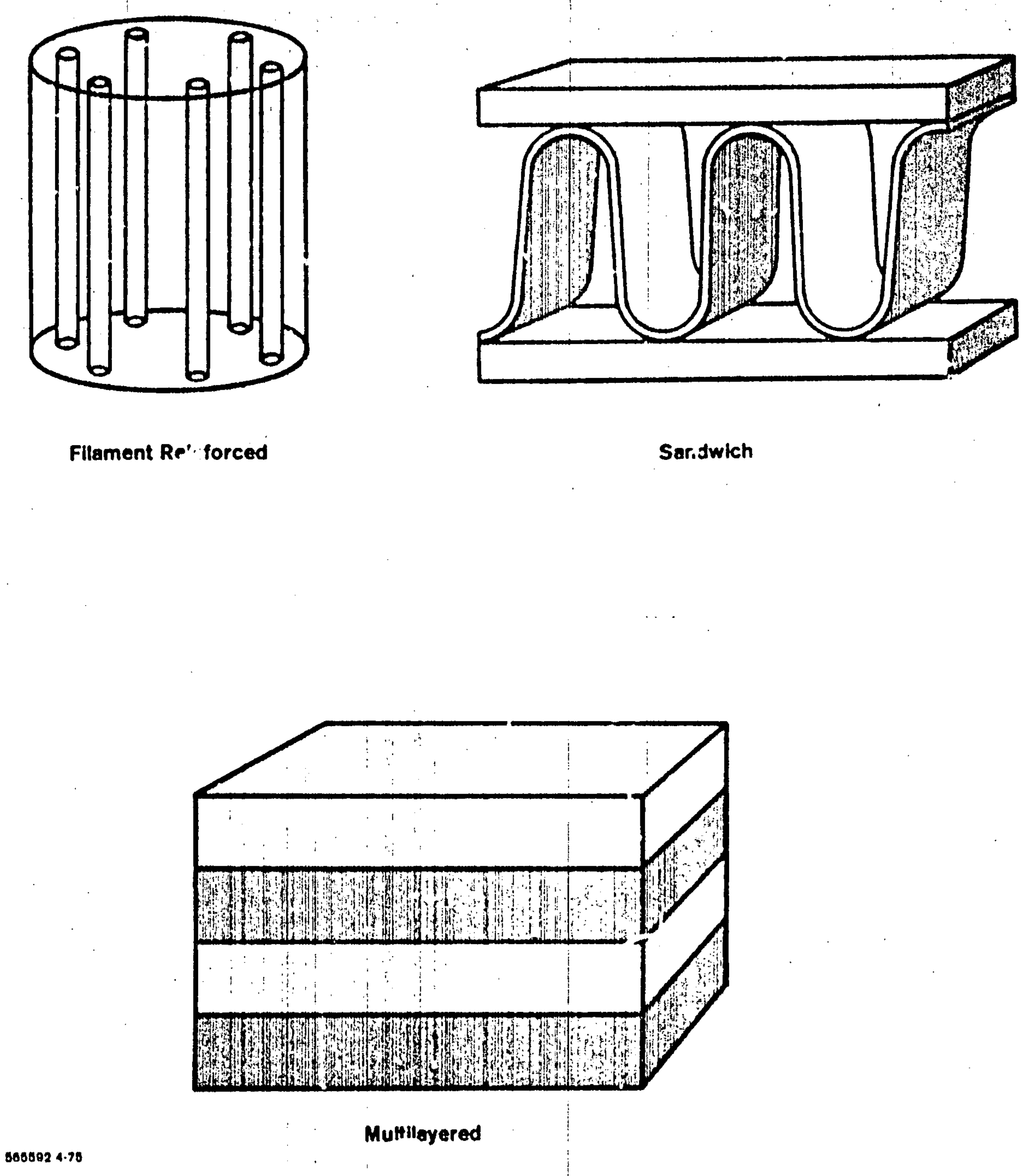

Figure 1. Types of Composite Structures

Table 1

Materials in Soviet Composites

- **Filaments**
  - **Glass, Boron, Graphite**
  - **Metals, Ceramics, Plastics**
- **Matrices**
  - **Plastics**
  - **Metals**
  - **Ceramics**

Six institutes in the Soviet Union carry out most of the relatively unclassified research and development in structural characteristics of composites. They are: the Institute of Polymer Mechanics in Riga, the Institute of Mechanics in Kiev, the Institute of Problems of Strength in Kiev, the Research Institute of Machine Design in Moscow, the Institute of Energetics in Moscow, and the Institute of Hydrodynamics in Novosibirsk.(107)(108)

[redacted]

Filament Reinforced Structures

Since 1966 the Soviets have had an extensive program to determine the structural characteristics of filament reinforced composites, particularly those of interest to designers of aerospace and missile systems. This exhaustive effort is providing the Soviet designer with completely worked-out solutions for most structural problems. There are, however, serious gaps, where the Soviet designer appears unable to handle problems involving very rapidly applied loads and very rapidly changing thermal environments. In other areas, such as structural effects of various openings including cut-outs or penetrations, the Soviet designer has much more information available than his counterpart in the US.(1-20)(31)

Comparisons of strength characteristics of filament reinforced test samples produced in Soviet laboratories with those made in the US are difficult because of uncertainties associated with Soviet test conditions. In the case of Soviet tests of glass/epoxy specimens from their AN-2m aircraft, they have reported tensile breaking strengths less than half those of US high-strength S-glass/epoxy composites. Contemporary Soviet glass/epoxy composites also have structural rigidities less than those of the S-glass type epoxies made in the US. However, Soviet capabilities in glass/resin wound composites approximate those of the US.(21-35)

Research investigators in the Soviet Union and the United States have devoted considerable effort to the development of metal/metal composites, i.e., a metal matrix reinforced by fine metallic filaments. West German work initiated interest in the reinforcement of nickel alloys with tungsten fibers, and this idea has been exploited in the Soviet Union at the Institute of Materials Science in Kiev and at the Institute of Solid State Physics in Moscow. The Soviets have developed laboratory test samples of this composite with very high tensile strengths, even at elevated temperatures encountered by reentry vehicles.(36-39)

Other metal/metal combinations which have been investigated include titanium matrices reinforced by tungsten wire, copper reinforced with tungsten (for electrical applications), aluminum reinforced with steel wire, and nickel strengthened with molybdenum fibers. Soviet interest in use of boron filaments as a reinforcement has fluctuated but at present they show a stronger interest in the use of graphite fibers in an unknown resin. But they are experiencing a problem of bonding the fibers in the resin, particularly in large rocket cases. The Soviets also are experimenting with carbon/carbons for missile RV leading edges and wingtips. High modulus organic fibers, such as duPont's aramid Kevlar, have attracted a great deal of Soviet attention in the last year or two.(40-49)(115)(117)

[redacted]

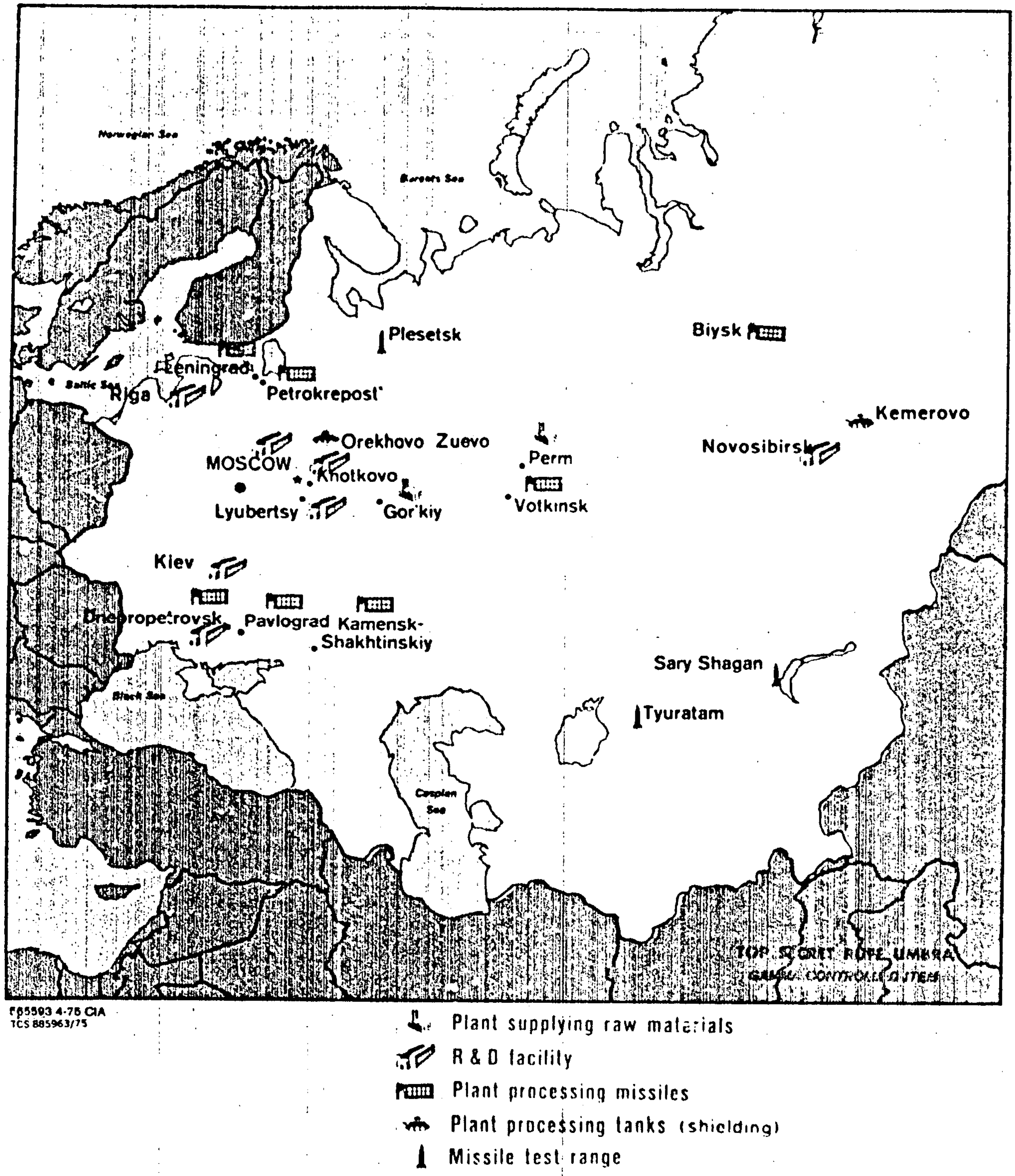

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Figure 2. Key Facilities Associated with Soviet Composites

A unique shock-resistant filamentary composite has recently been developed by the Soviets. It not only is capable of being used at temperatures up to 1900° C but also is chemically inert. The composite consists of a matrix of aluminum nitride or the oxides of aluminum, zirconium, chromium, or titanium, reinforced with filamentary ceramic single crystals of aluminum and silicon oxides, termed mullite. The oxidation resistance of the all-oxides composite would facilitate fabrication, probably by hot pressing. There is no known counterpart of this work in the US, although NASA has investigated mullite filaments in rigidized, fibrous forms for potential use as surface insulation of space shuttle or orbiter vehicles.(50-52)

Designs for Soviet filament and tape winding machines were inspired by study of US publications. Although the Soviets have not published any significant winding innovations, they claim to have delved further into winding theory than their US counterparts. In addition to Soviet-built winding machines, whose capabilities are little known, the Soviets have imported a huge vertical winding system from the [redacted] in West Germany. This system is capable of manufacturing wound cylinders somewhat larger than can be series wound in the US. The capacity of the West German system is 5 m (16.5 ft) in diameter, 18 m (59 ft) in length, and 0.2 m (7.9 in) in thickness.(31)(53-55)(115)(117)(118)

The entire 100-member staff [redacted] is reported to be committed until the end of 1975 to a project to manufacture a machine "to make hulls for Soviet submarines." The machine reportedly is for "reciprocal" filament winding of fiber reinforced plastics. The meaning of the term "reciprocal" is not known at this time. But the machine is supposed to be capable of winding structures for resisting compressive loads.(177)

Although winding technology might be used for the construction of small submersibles, such as those used in ocean research, it is unlikely that present technology is capable of providing satisfactory pressure hulls for submarines [redacted] indicated that a fiber reinforced plastic pressure [redacted] would not be able to resist low cycle fatigue and underwater explosions. In addition, it would be impractical to repair such a hull and to remove large items, such as turbines, from a submarine. Several European countries have used primitive methods to make parts of submarine hulls from filament reinforced epoxy, but these attempts were not very successful.(176)

The [redacted] is capable of producing machines for winding pressure vessels and pipes with a diameter probably larger than 6 meters. In 1969 the Soviets asked the [redacted] to build a unit with a diameter of 10 meters, but the Company declined because of anticipated problems with hydraulic equipment. The Soviets could produce other submarine components, such as the outer hull of double-hulled submarines and sonar domes using winding technology. Additionally, small items such as torpedoes and underwater buoys could be made by winding.(176)(177)

Sandwich Structures

Soviet investigators have been concerned with structural behavior of sandwich plates and shells having a core that would permit a cooling liquid to be circulated between the facings. These studies have been carried out at the Institute of Hydrodynamics in Novosibirsk, the Institute of Mechanics in Kiev, and the Moscow Aviation Institute. Such a sandwich structural configuration would be of value in missiles and reentry vehicles, because of extreme thermal environments encountered and as a supplement to the insulating effects of any external ablative layer surrounding the load-carrying structure. In addition, such a system is relatively simple to fabricate in comparison with honeycomb. Some of the more prominent Soviet investigators have carried out these studies, which is an indication of the importance of this problem to the Soviets.(56-69)

Soviet contributions to the open literature on response of sandwich structures subject to dynamic and shock loadings have been of little significance since 1968. This probably is because the Soviet work is classified. The Soviets are continuing to experience difficulty in the manufacture of sandwich structures involving honeycomb material. They have made efforts to exploit the expertise of US investigators as well as successfully examining components of US aircraft downed in Vietnam for the purpose of copying available technology.(70-79)

Multilayered Structures

Soviet analyses of statically loaded multilayered plates and shells have been at a very modest level since 1968. This is because of the weight saving advantages offered by filamentary and sandwich constructions.(81-86)

In the area of dynamically loaded multilayered structures the Soviets have produced more significant results during the past few years. One example is a Soviet investigation directed to the analysis of blast effects on ship bottom plating. Another example appeared in a very recent report by a well-established Romanian investigator who in cooperation with Soviet scientists determined the flutter characteristics of multilayered conical shells in supersonic flight. The publication indicated direct applicability of the work to rocket and reentry systems. The Soviets have also continued their analysis of thermal effects on multilayered systems, but no new techniques have been introduced.(87-100)

During the past 5 years the Soviets have not published any experimental studies on multilayered structures. Soviet investigators have reported the use of rolling (both hot and cold) and welding techniques to produce multilayered structures. Their literature has indicated that in rolling procedures some technological problems were encountered, such as achievement of uniform deformation. Other techniques previously investigated by the Soviets, such as pressing and explosive bonding have not been mentioned during the past few years. However, Prof. N. F. Kazakov's diffusion bonding laboratory at the Moscow Technical Institute of the Meat and Dairy Industry is being expanded. Kazakov is the Soviets' top expert in diffusion bonding and has produced large multilayered components with more than 25 layers of metals, ceramics, glass, metal oxides, and other chemical compounds. His products and processes are widely used by Soviet design bureaus, industrial research institutes, higher schools, and industrial plants. Since multilayered structures have limited weight saving characteristics, it is considered unlikely that there is any extensive classified Soviet effort in these structures.(101-104)(119)

APPLICATIONS

Introduction

This section, [redacted] evaluates some key military applications of Soviet composite structures (table 2). A large amount of the available information concerns the widespread introduction of fiberglass reinforced plastic composites into major components of new developmental strategic missiles, such as the SS-X-16, and the development, fabrication, and testing of missile canisters. Although the exact functions of the canisters are still unclear, the canisters appear associated with transport, storage, and launch of both mobile and strategic missiles. Some of these canister type units also appear to be associated with antiballistic missiles (ABMs) and command and control (C&C) capsules. Other Soviet military applications for composites include radomes and controls in aircraft, ship hulls and major structures in Yevgenya class minesweepers, and antiradiation liners in T-55 tanks.

[redacted]

Missile Canisters and Motor Cases

Offensive Missile Canisters—Soviet interest in using composite material structures for strategic missile applications can be traced back to 1966. One of the main projects of the Institute of Polymer Mechanics in Riga, AS Latvian SSR, during 1966-1971 was the development of a machine for destructive testing of fiberglass cylinders. [redacted]

Table 2

Selected Soviet Applications for Composite Structures

	[redacted]	Components
Aircraft		
COKE/AN-24		Radome
FIREBAR/YAK-28		Radome & Ventral Fin
YAK-18T		Wingtip & Propeller Blades
HOODLUM/KA-26		Rotor Blades, Vertical Stabilizers, Skin & Rudder Leading Edge
Missiles		
SS-9		Reentry Vehicles
COSMOS 50		Reentry Vehicles
SS-X-16		Canister, Motor Casings
SS-18		Canister
SS-X-20		Canister, Motor Casings, RV's
Ships		
Yevgenya (Minesweeper)		Ship Hull, Major Structures
Tanks		
T55		Antiradiation Liner

[redacted]

The Soviets also are using composites in major components of a new ballistic missile the [redacted] (SS-X-20). This is probably a mobile IRBM, based on the first two stages of the SS-X-16. The SS-X-20 has a canister, [redacted] which is probably similar to the SS-X-16 canister, [redacted] Plant 221 in Volgograd does the finishing work on the canisters and Arms Plant 235, Votkinsk, is the integrating contractor/final assembly plant for the SS-X-16 and SS-X-20. There is evidence indicating that SPP is involved in producing some of the fiber-reinforced plastic components for the [redacted]78)(179)(182)

Another composite canister, the [redacted] for the SS-18 ICBM, [redacted] is very long and consists of two parts, one is 30 meters (97 ft) long and the other 8 meters (26 ft). They are shipped on a set of three flatcars, one of which is a specially designed car. [redacted]

*The Chief Directorate of Plastics and their Processing in Moscow of the Ministry of Chemical Industry. In 1971 Glavplastmass became "Soyuzkhimplast."

It is believed that the 30-meter part consists of eight cylindrical sections; each has a glass/epoxy filament-wound composite inner and outer shell with an undetermined sandwich filling. Included are built-in ducts and channels, and an electrically conducting metallized fabric, VPR-10M. The metallized fabric probably has a function related to maintenance of a controlled environment for the SS-18 missile but also may have implications regarding protection from lightning and even EMP (electromagnetic pulse) effects.(183)(186)

DMPDC is the customer for the SS-18's canister and performs or supervises extensive testing of the canister, such as resistance to burning, and various hydraulic and hermetic tests. [redacted] Fabrication winding techniques used in other Soviet composite missile canisters also were developed a[redacted]

The Soviets were fabricating the [redacted] canisters from "glass fabric." They were probably laying-up and winding structures using fiberglass tape, strip, and cloth on a rotating mandrel. The resulting wound structures were filament reinforced shells; however, the [redacted] included cellular foam blocks and boron in a sandwich-type composite. Until August 1970 boron was incorporated in these composites as fine powder of refractory boron nitride, called Product 6, which raised the heat resistance of the missile launch canister. After 1970, because of a decree issued by Brezhnev and Kosygin, [redacted] began to use ferroboron (Product 9) to replace boron nitride. The Soviets found that not only was ferroboron much cheaper than the nitride, but it also provided a better quality product by offering: adequate corrosion and thermal resistance, reduced weight, and improved stiffness.(110-113)

At lease five types of glass fabric have been associated with the [redacted] launch canister. [redacted]. But some of the many design changes may have caused other types to be used. According [redacted] fabric T-1 was [redacted] to contain titanium, and TS-8/3 was [redacted] to contain titanium. Although nothing is known of the chemical and physical form of the titanium, it could be used as a binder or to reinforce the fabrics. Statements by Soviet composite scientists, however, indicate that titanium metal was used for missile end fittings and nozzle attachments. Steel and aluminum also were used by the Soviets for these same components. The use of titanium should have provided an optimum mixture of light-weight and strength, plus corrosion and thermal resistance.(114-115)

THE SS-X-16, SS-X-20, AND BIYSK MOTOR CASINGS—Table 3 is a comparison of some of the important characteristics of the SS-X-16 and SS-13. Both are three-stage solid-propellant rockets, relatively close in overall size, but the SS-13 does not have a canister. [redacted] the composite rocket cases of the first two stages of the SS-X-16 are considerably lighter in weight than those estimated for the SS-13 (figure 3). The payload of the SS-X-16, including its post-boost vehicle, is 950 kg (2100 lb) at 5000 nm NRE while that of the SS-13 at the same range is 540 kg (1200 lb). Two-thirds of this improvement is due to the use of composite cases and the remaining third is the result of better propulsion.(121-123)(184)

The first stage composite motor casings for the SS-X-16 and SS-X-20 probably are identical. The second stages have different designators: [redacted] for the SS-X-20, but they appear from [redacted] to be closely related and should have similar characteristics.(178-181)

Although quite a bit is known about the materials used for the SS-X-16 casings, our primary source of intelligence on those of the SS-13 (SAVAGE) is ground photography taken on May Day, 1965 in Moscow. From these photographs it was possible to observe metal-type welds in all three stages of the SS-13 and conclude that the casings were metallic. Based on this conclusion and an estimate of Soviet materials/structures capabilities during 1965, it is believed that the first stage probably was fabricated from steel. Some analysts believe that the second and third stage cases were aluminum alloy. [redacted]

There are indications that the USSR may be developing its largest solid propellant rocket motor. Although there is no direct evidence as to which materials will be used in the motor casing, there are advantages which favor the Soviet use of composite materials for the Biysk motor casing over metals such

Table 3

Comparison of Key Characteristics of Soviet SS-13 and SS-X-16 Solid Propellant ICBMs (121–123, 167)

[redacted]

as steel, aluminum, and titanium. The advantages are: weight savings, lower costs, and avoidance of metal cases' problems of burn-through, hot-spots, and loss of pressure.(124)(125) Furthermore, as noted earlier in this report, the Soviets have the capability to make large 9-foot diameter motor casings using composite materials on a vertical filament winding machine imported from West Germany about 1968-69. [redacted] The West German winding unit and perhaps others copied from it by the Soviets could have been ready for use in the early development or production phases of [redacted] fiberglass motor cases.(124)(125)

[redacted]

[redacted] the rocket motor probably has a thrust between 500,000 and 1,000,000 lb. [redacted] indicates that the motor is [redacted]. While the estimated thrust suggests it will have a space application, such a thrust does not preclude its use in an ICBM. This would be the largest known Soviet solid propellant rocket motor casing. Such a large rocket motor may be part of a system or technologi-

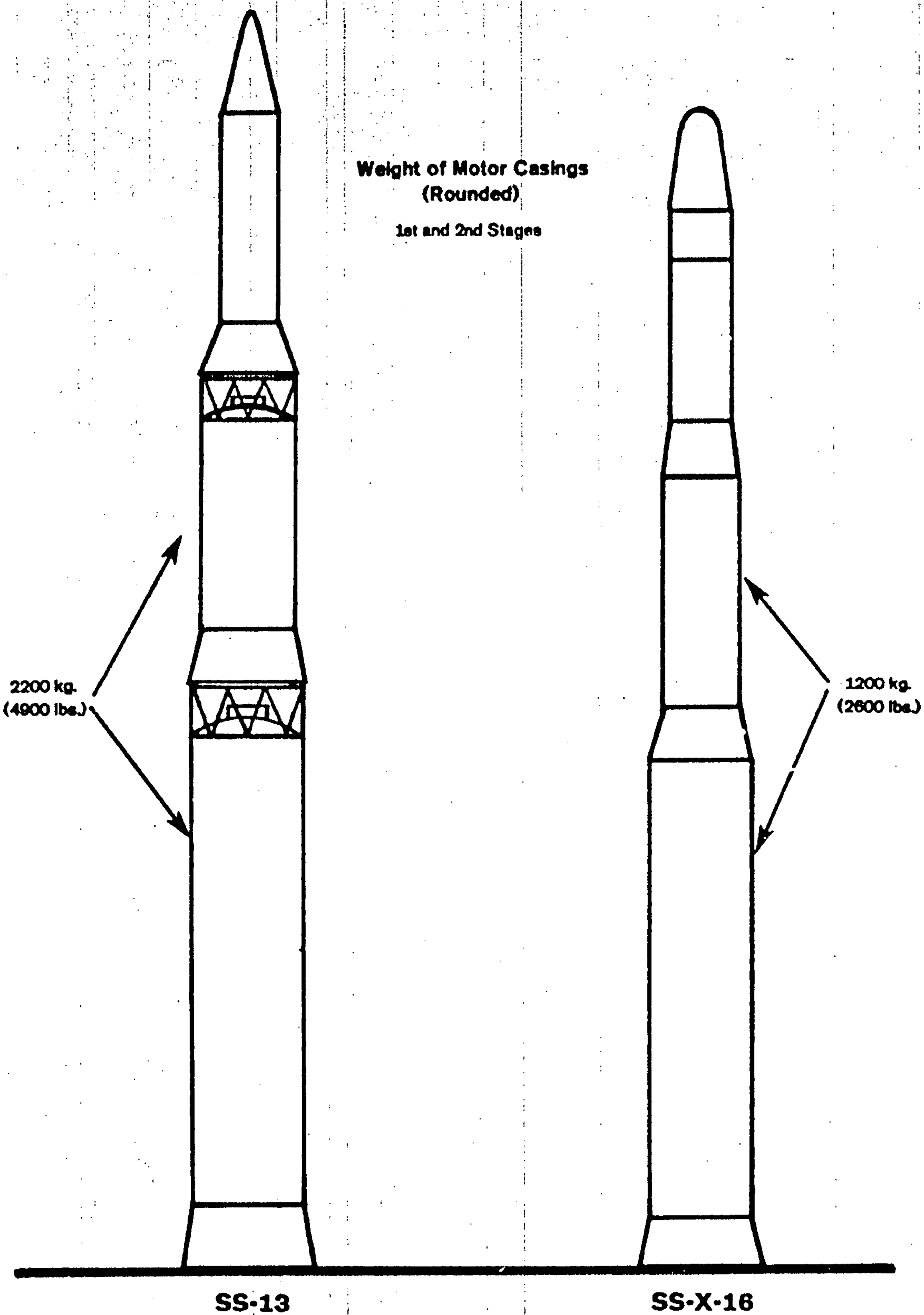

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Figure 3. Composites Allow Soviets to Reduce Missile Motorcase Weight by About 50%

cal development which could eventually become part of a new ICBM or possibly a strap-on space booster.(124)(125)(170)

ABM Composite Canisters—A large amount of intelligence is available on materials, design and fabrication of a composite structure which is probably an ABM canister, [redacted] The term TPK has been definitely tied to the B200 and to the SS-18 ICBM canister, [redacted] TPK is believed to denote a canister or container used for launching as well as for shipping or storing a missile. The B200A weighs 6 metric tons, is "a little lighter and smaller" than the B200, and is similar in materials and design as the [redacted] There is good evidence, [redacted] that Soviet ABMs usually are fired from their canisters. [redacted] some valuable data on Galosh missile and canister structures have come from photographs taken at 1964 and 1968 Moscow parades celebrating the Anniversary of the October Revolution.(127)

Structurally, the B200A consists of four, 5600 mm long, filament-reinforced shells which are wound with fiberglass to make a sandwich containing about thirty plastic foam blocks per shell. These contain ferroboron (Product 9) which gives the composites resistance to heat, improved mechanical properties, and absorbs neutrons—possibly as a bonus. Additionally, Soviet "TZP" (thermal-resistant coating), Type SSP-1, may have been applied to the inside of at least one B200A container. [redacted] Each canister also has a polyester hermetic [redacted] device or system [redacted] The hermetic system is believed to protect the missile until it is launched. The system consists of 12 or 24 sectors and two or three plugs. To assemble the canister/system two to 13 rings are used. Additional information indicates that missiles inside the B200A and [redacted] canisters also enjoy thermostatically controlled environments, based either on circulation of heated air in internal ducts and channels or on electrical resistors in a composite longitudinal stringer structure. The B200A composite canister offers nuclear hardening, light weight, possible reusability, and longer shelf life (figure 6).(126)(138)(142)

The B200A is probably a developmental canister for an unspecified ABM. [redacted] Based on the size of the B200A canister and the size of the new conical missile [redacted] it is unlikely that they are associated. Moreover, [redacted] indicates that the conical missile probably could be flight tested after mid-1974, using a rail or open lattice-work structure, without a canister. If this conical missile proves successful, then it would be logical for the Soviets to launch it from either a silo or a mobile canister made of composites.(127)(128)(139-141)

Other Applications

Radomes—Composites, mostly of the multilayer variety with some fiberglass reinforcement, are widely used in the USSR for conventional radomes and radio-transparent covers. SPP has been producing such items since 1967, mainly for military customers. Some military organizations use these products for support of the Soviets' overall space efforts as well as for conventional radar and communications units.(144-151)

[redacted]

[redacted]

Another application for composites was in Project VETER (wind). Project VETER used a 10-piece set of radomes (four RS-11, two SHALASH, two D-25 and two D-35 covers) [redacted] Inadequate strength of the components, however, required that the thickness of the covers' facing be increased from 6 mm to 10 mm and the seam on top of the covers be reinforced. Also the shaped pieces and semitubular components were to be made using a new type of fiberglass cloth, probably type TS which was impregnated and pressure-molded.(145)

[redacted]

[redacted]

Shock resistant filamentary ceramic/ceramic composites mentioned in the R&D portion of this report were developed by D. M. Karpinos of the Institute for the Study of Materials (also called Institute of Problems of Material Science) AS, UKrSSR, in Kiev. This work, which is continuing, includes fabrication and testing of composites based on mullite whiskers in aluminum and boron nitrides.

[redacted]

These are applicable to fabrication of components for sensor windows and radomes suitable for uses at velocities on the order of mach 7.(152)(153)

Antiradiation Liners and Armor—The Soviets and Czechoslovaks have jointly developed two antiradiation liners to protect troops from nuclear radiation in tanks and probably in armored personnel carriers. The designator LEPAN has been associated with the materials used in both liners. The first liner was part of a layered shielding system which appeared by January 1962 in T-55 and T-55A tanks. Figure 7 shows a T-55 tank photographed during the 1963 May Day parade in Moscow with an internal liner, probably about 10 cm thick. [redacted] Shielding was provided by lead, steel tank armor, and 10 cm of borated plastic to shield the crew from neutrons and gamma rays. Automatic hatch closing and engine shutoff devices help prevent intake of radioactive materials.(154)(155)

The second liner was 5 cm thick and appeared to be a multilayered composite structure of highly colored shielding material, reinforced with filaments in the form of net and laminated fabric layers. Lead and boron probably were incorporated in the structure to shield against gamma rays and to absorb neutrons. Not only was this truly composite structure more compact, by half, than the first liner, also it probably provided some protection against spalling. The second liner was reported to have been installed for the first time in Czechoslovak T-55A tanks in March 1969. [redacted]

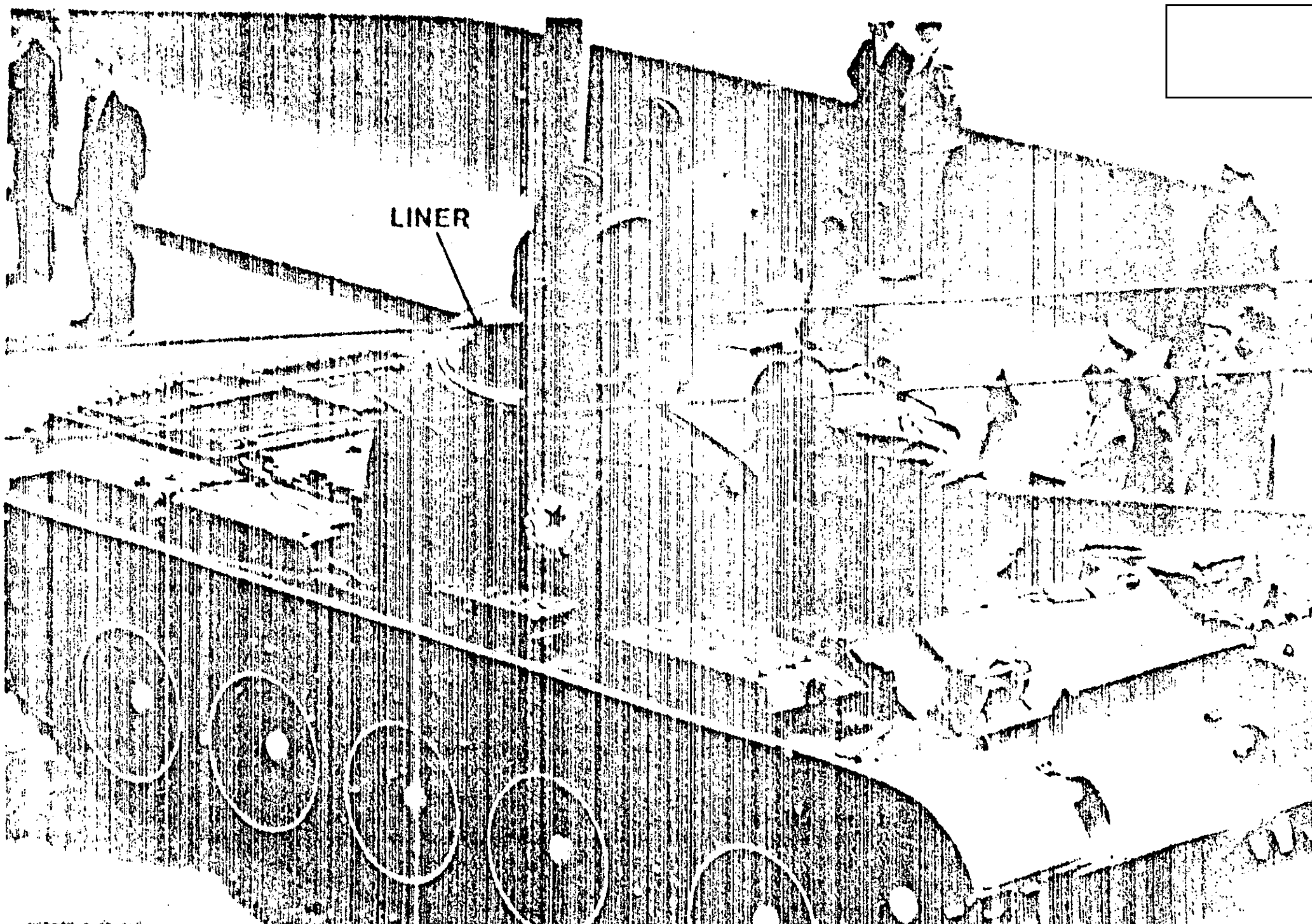

Figure 7. Soviet T55 Tank with Composite Antiradiation Liner

[redacted] Soviet bloc countries when they first appeared in January 1962, article STB-302 produced in 1964 probably is the 5-cm liner.(155-162)

SPP also has been producing tank liners since 1968 but appears to be considered a less desirable source by Soviet tank plants and the Ministry of Chemical Industry. In fact, in February 1972, an official of the Ministry of the Chemical Industry stated that because of poor profits, all textolites (resin-impregnated fabric laminates) were being taken from SPP and allocated to the Plastics Plant imeni Kalinin and to a plant in Kemerovo, the Karbolit Plastics Plant.(154)(155)

The Soviets are working on multilayer metal/plastic and metal/metal structures for tanks and armored vehicles. One such composite consists of two layers of steel separated by laminated polyethylene plates containing boron filler [redacted] This layered or spaced armor design [redacted] performance against HEAT (high explosive antitank) and HEP (high explosive plastic) projectiles, as well as the capability to absorb neutrons. The metal/metal composites consist of various combinations of steels including the high-strength, low alloy KVK series, and technically pure iron, designated PZh-3M. Careful control of layer thickness and special complex heat treatments provide the Soviets with armor having high strength, toughness and ductility. A laminated armor containing a basalt* type material, possibly as fibers, in the core is being investigated. Since basalt is widely available and probably low in cost, it could be of great value in ceramic and other composites for numerous military and civilian applications.(154-164)

COMMAND AND CONTROL CAPSULES—Composite items [redacted] probably are parts of the [redacted] command and control silos (designated by the US as Type IIIX) at SRF missile installations (figure 8). The [redacted] are fairly similar in design and mat[redacted] canisters built at SPP. The items are composed of two metal sections probably made at Plant 232 in Leningrad and of ten wound fiberglass shells made at SPP. Together the items form prefabricated capsules which are installed in command and control silos. The type IIIX silos should provide excellent protection to SRF personnel and/or launch and communications equipment from blast, vibration, and possibly radiation. At Derazhnya and Pervomaysk the Soviets are replacing the type IIID silos, which contain SS-11 Mod 1 missiles, with Type IIIG silos. The Soviets have begun installing the SS-19 ICBM or Chelomey "N" missiles in the type IIIG silos. There is one type IIIX command and control silo for each group of ten type IIIG silos. A type IIIX command and control silo also is used with each group of ten type IIIH silos (associated with the SS-X-17) and with each six or ten type IIIF silos (associated with the SS-18).(142)(159-162)(187)

A [redacted] composite capsule probably was install[redacted] IIIX silo at Site 23 of the Shagan River Test Area at the Semipalatinsk Nuclear Weapon Proving Ground [redacted] for nuclear effects testing. [redacted] The function [redacted] is structural and may be electronics-related.(146)(148)(169)

STATUS AND FORECAST

Information on applications of composite materials/structures to Soviet Strategic systems [redacted] Plastics Plant, to major components of the B200A probable ABM canister, and to SS-X-16 and SS-18 ICBMs. Therefore, it is difficult to evaluate composite materials/structures as they relate to the USSR's overall missile program. Nevertheless, the Soviets have had significant problems with the development and production of composites for missile components and parts. There have been continuing composite-related troubles, such as delamination, which is because of inadequate NDE (nondestructive evaluation). In addition, there have been instances involving splitting of missile motor cases, overweight and uneven canisters, and many smaller composite parts having defects or not meeting dimensional tolerances.(157-159)

The USSR's missile program also has been plagued by handling accidents and problems with maintenance of large presses. Many troubles have occurred because of delays in administrative guidance,

*Basalt is a rock composed mainly of alumino-silicate compounds, with iron and manganese oxide additions.

Top Secret

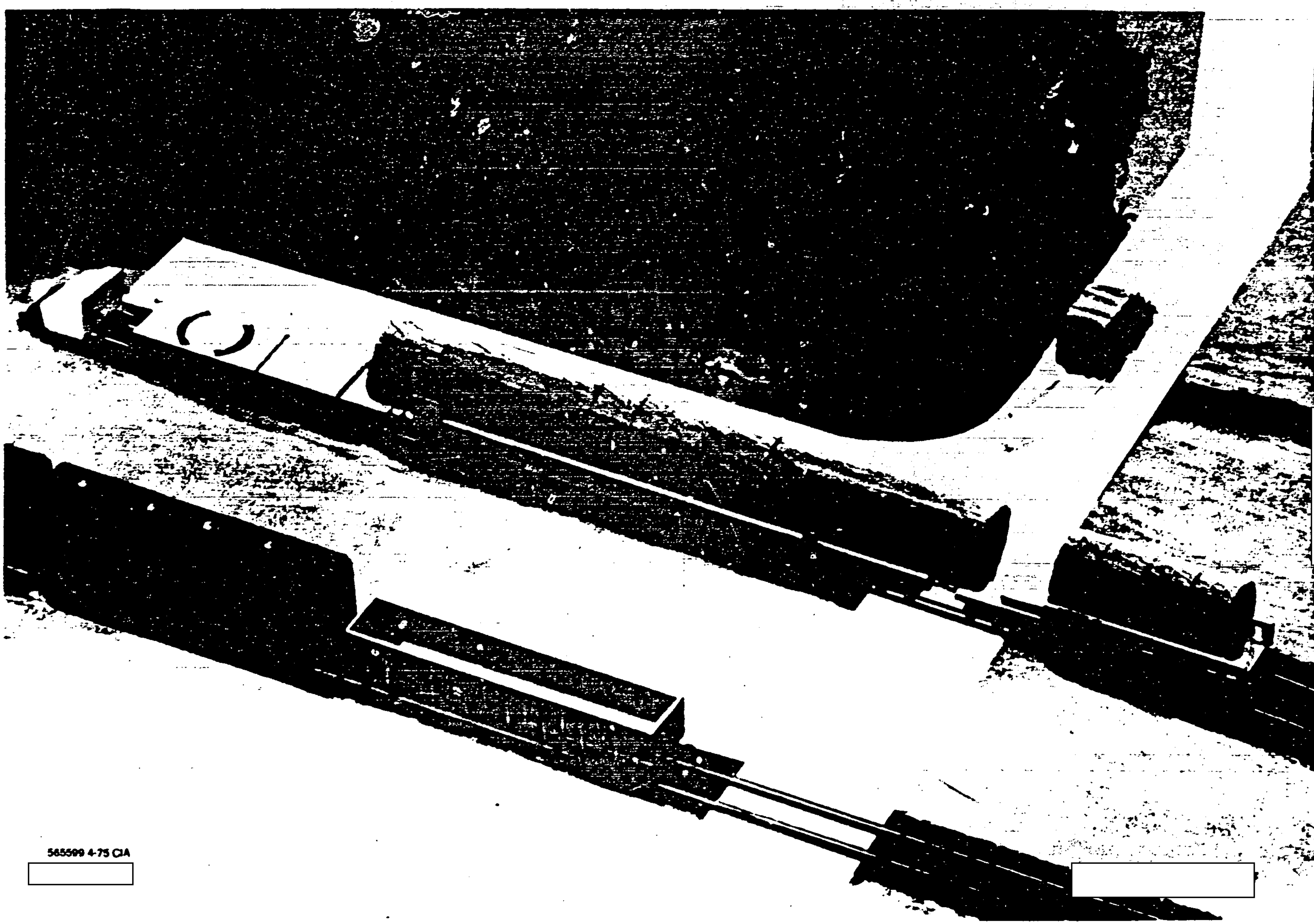

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Figure 8. Artist's Conception of Type IIIX Canister on a Rail Transporter

technical documentation, and delivery of equipment and supplies, as well as competing top-priority defense programs.(157-159)

There has been high level Soviet interest in resolving many of the problems encountered in their missile program. [redacted]

[redacted]

It is probable that the 1975-80 period will see ever increasing use of composite materials for load-carrying components of aircraft and missile systems. This increased use also will include radomes, fins, cases, canisters, reentry vehicles, control surfaces, reinforcements around doors and access panels, and helicopter rotor blades. The composite structures to be employed will be filamentary reinforced as well as sandwich construction in that order of importance.

It is anticipated that Soviet polymer based composites will be capable of resisting loads under operating temperatures up to approximately 700° C, by the end of 1980. It is also probable that Soviet development of metal/metal composite structures will advance sufficiently to make their employment possible at temperatures of approximately 1400° C. It is not anticipated that the Soviets will encounter so many manufacturing problems with the metal/metal composites as they have been experiencing with fiberglass reinforced plastics and honeycomb sandwich structures. Therefore, prototype employment of metal/metal composites may well be a reality by the end of the current decade. The huge effort in improving Soviet and bloc nondestructive evaluation should be invaluable here. There is also an excellent possibility, toward the end of the present decade, of Soviet employment of ceramic matrices reinforced by filamentary mullite and basalt crystals in armor, and the use of such ceramic composites in missile radomes, MHD generators, and turbine engine blades, where temperatures approaching 2000° C are encountered.

[redacted]

ANNEX

Selected Key Soviet Facilities Involved in Composite Structures and Materials

Top Secret

[redacted]

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