Reprinted from TEXTILE RESEARCH JOURNAL, Vol. 30, No. 4, April, 1960
Printed in U. S. A.

Russian and Satellite Research and Development in the Field of Synthetic Fibers

Roy C. Laible and Louis I. Weiner

Textile, Clothing, and Footwear Division, Headquarters Quartermaster Research and Engineering Command, Natick, Massachusetts

Abstract

Man-made fiber developments in the Soviet orbit are discussed in relation to Western achievements. At least three of the fibers—Enant, a nylon 7, Ftorlon, a fluorine-containing copolymer, and Vinitron, a combination of nitrocellulose with chlorinated polyvinyl chloride—have no counterparts in the United States or Great Britain.

Other fibers, such as Nitron, Lavsan, Anid, Steelon, and Khlorin are so closely related to Orlon,[1] Dacron,[1] nylon 66, nylon 6, and Pe Ce[2] respectively that the degree of originality in their development cannot be ascertained. East German experimental work on hollow fibers and the conjectural Latvian use of 2-methyl piperazine for the preparation of new polyamides show the possible contribution of the satellite countries to the total Soviet effort. The Russian scientific climate is briefly discussed to show the increasing effort in the field of new synthetic fibers that may be expected from Russia in the future.

Introduction

The ability of the Russians to conduct high-caliber research in many scientific disciplines is no longer denied. Before the specific areas of textile research are discussed, it is advisable to first look at Russian research in general, for the advanced state of that knowledge as represented by the production and efficient utilization of natural and synthetic fiber-forming materials is the result of a combination of efforts from many fields of endeavor.

A delegation from the United States plastics industry and two outstanding American scientists (Dr. W. A. Nash, Professor of Engineering Mechanics at the University of Florida, and Dr. Herman Mark, Director of the Polymer Research Institute at the Polytechnic Institute of Brooklyn) have visited Russia recently. All agree that Soviet research is strong, reasonably well-conceived, and motivated by a firm desire to accomplish useful results [20, 21, 26, 35]. The comments of these scientists are of interest because of the known relationship between competence in the polymer field and the ability to produce new man-made fibers, and between the principles of engineering mechanics and the effective utilization of fibers in fabrics. Russian scientists were found to have good equipment and to be well informed about foreign work in their respective fields. While some of this scientific progress, especially that immediately following World War II, can be attributed to cap-

[1] Du Pont trademark.
[2] Made by I. G. Farben, Germany.

tured German scientists, progress in recent years cannot, for the Soviet scientists are now confident enough of their own abilities to have returned most of their captured scientists. Western research, however, is being closely followed.

Although the linguistic ability of the average Russian scientist may play the most important part in his cognizance of foreign work, another factor is the availability to him of good and relatively rapid translation services. Within a month of receipt, a table of contents of each foreign scientific periodical and a brief abstract of each article are translated and made available to most Russian scientists working in that field. Within another month, the scientists may obtain a complete translation of each article. A single organization is responsible for these services: the All-Union Institute of Scientific and Technical Information at Moscow. This organization employs over 20,000 abstractors, and its budget is estimated to be in the millions of dollars. A similar set-up may be necessary in this country if we are to follow adequately the research in Russia and other countries.

At the present time, translation of Soviet scientific literature is conducted in the United States by the National Science Foundation, by universities, by industry, by commercial translating services, and by such Government agencies as the Atomic Energy Commission and the State Department. The Office of Technical Services of the Department of Commerce has attempted to coordinate these efforts by initiating an enlarged program of acquisition, translation, and announcement. A semi-monthly publication called *Technical Translations* is the result of this program [23].

In the Textile, Clothing, and Footwear Division of the Quartermaster Research and Engineering Laboratories, interest in translation is based on a need to keep abreast of foreign, especially Russian, textile potential for military applications. Research in polymer chemistry, engineering mechanics, radiation chemistry, and physiology can be indirectly related to the development of fibers and fabrics with better mechanical properties and chemical resistance and of end items that will provide more environmental comfort and thermal and CBR[3] protection. Much of this basic research information is available to the Quartermaster laboratories from Russian scientific journals which are translated *in toto,* but, to be absolutely sure of the tie-in between basic research in a field such as heat-resistant polymers and its application in textiles, the translation and interpretation of articles in Russian textile magazines is also necessary. At present, textile magazines are not being translated regularly by any Government agency or, as far as we know, by any industrial firm. If specific textile information is combined with that about related basic research in the fields of polymers, colloid chemistry, and mechanics, as reported in the journals of the Russian Academy of Sciences, one can more adequately appraise the present and future Russian textile potential. Our information must be as complete as possible to enable us to continue our lead over the Russians in textiles, especially those used for parachutes, ballistic applications, and combined CBR and thermal protection.

This report represents a first attempt by the Quartermaster Corps to gather together information on Russian fiber developments as obtained from domestic literature and as directly translated from Russian literature. Whenever possible, laboratory examination of the fibers has been used to confirm or supplement the published information about them.

Discussion

High-ranking scientific and political leaders in Russia have admitted dissatisfaction with their rate of progress in the development and production of new synthetic fibers [3]. Remarks made by such men as Premier Khrushchev and Professor Nesmeyanov, President of the Academy of Sciences, reveal the importance they place on fiber development [3, 35]. Exact figures on the Russian output of such synthetic fibers as nylon, polyester, and polyacrylic fibers are not available, but the best estimates place man-made fiber production years behind that of the United States [22]. Even those man-made fibers that have long been produced here in large quantities (nylon 66, Dacron, Orlon) still are not readily available to the Russian consumer. Of greater concern to the Quartermaster Corps, however, is the possibility that, in place of or in addition to the efforts expended in duplicating American synthetic fiber developments, the Russian scientists may develop new fibers having higher melting points, superior stress–strain properties, and greater inherent chemical repellency and resistance than any fibers known in this country. These fibers could be used to produce parachutes, personnel armor, and clothing

[3] Chemical-biological-radiological.

materials with a superior potential for supersonic use, ballistic protection, thermal resistance, and CBR protection.

The synthetic fibers known to be produced or studied in Communist countries at the present time are presented below, together with their special characteristics and other available information. They are discussed according to their type.

Polyamides

Anid. The Russian fiber Anid is nylon 66, the nylon polyamide widely produced in the United States by DuPont, Chemstrand, and others. The production of this fiber in the USSR is relatively limited [41].

Kapron. Nylon 6, called Kapron by the Russians, is the German Perlon produced in large quantities in Europe and receiving increasing emphasis in the industrial sales picture of the United States. The monomer, caprolactam, usually is obtained from phenol. The first plant for the continuous polymerization of nylon 6 in the USSR has been constructed at Kiev [4]. The Institut für Textiltechnologie der Chemiefasern, Rudolstadt, East Germany, has developed Perlon fibers that are hollow and/or possess unusually shaped cross sections. Fabrics prepared from such fibers could possess better insulation or different mechanical properties than conventional fabrics. Polyesters and polyurethanes are adaptable to this process as well as the polyamides [1].

Photomicrographs of several of these newly developed fibers are shown in Figure 1.

Steelon. Poland also has produced a nylon 6 polyamide called Steelon. A large modern plant at Gorzow is said to have a capacity of 3500 metric tons per year, with most of the production being channeled into textile fibers. The director of the plant claims that Steelon is a Polish achievement exclusively, from the research phase to production. The future production objective for the plant is stated as 12,000 tons by 1965 [10].

Enant. The Russian nylon 7, called Enant, has been mentioned in several issues of the Russian magazine *Tekstil'naya Promyshlennost'* (Textile Industry). This is a new fiber which has not been produced in the western world, although the basic polymeric material, polyenanthic amide, is known and has been briefly investigated. Glowing claims have been made in the Russian journals about the stress-strain properties of this material at high temperatures and its ultraviolet resistance. The writers usually compare Enant with nylon 6 (Kapron) [37, 40]. Shaaf, states that polymerization of enanthic lactam leaves only 1–2% of monomers or oligomers as contrasted with up to 10% for the polymerization of caprolactam [33].

TABLE I. Chemical Analysis of Enant

Element	Enant (as tested)	Nylon 7 (theoretical values)	Nylon 6 (theoretical values)
N, %	10.7	11.2	12.4
C, %	62.8	66.1	63.7
H, %	10.1	10.2	9.8
N/C ratio	*0.170*	*0.166*	*0.194*

A small sample of Enant yarn was obtained for study by the Quartermaster laboratories. Tests show it to be chemically closer to nylon 7 than to nylon 6. The chemical analysis of Enant, as found in the Quartermaster laboratories, is given in Table I together with theoretical values for nylon 7 and nylon 6.

Although the carbon and nitrogen values of Enant are somewhat lower than those of nylon 7, which could be explained by the presence of 4–5% of water

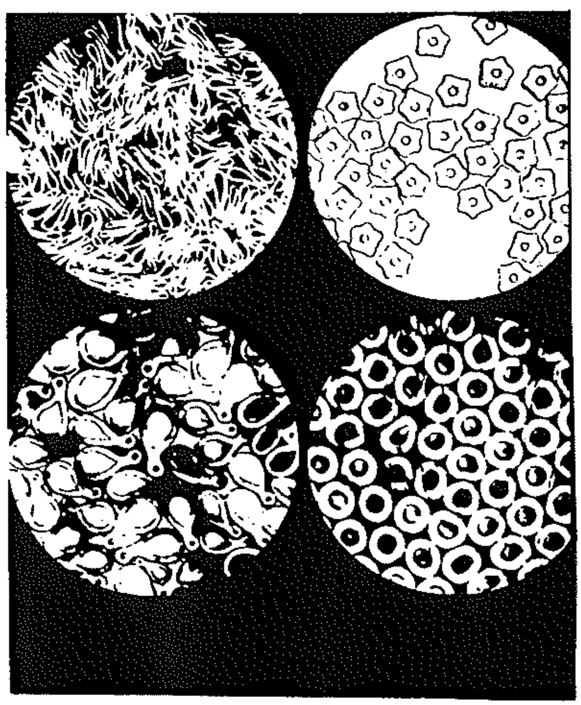

Fig. 1. Photomicrographs of cross sections of several hollow fibers (reprinted with permission from *Modern Textiles Magazine*).

in the sample, their nitrogen–carbon ratios are similar, and this ratio may be considered as the more reliable figure for identifying the material. It suggests the identity of Enant as nylon 7.

The melting point of Enant was found to be 225° C., which is slightly higher than nylon 6 (215° C.) but lower than nylon 66 (250° C.). This melting point is in agreement with the information on Enant published in Russian journals [27, 36, 37].

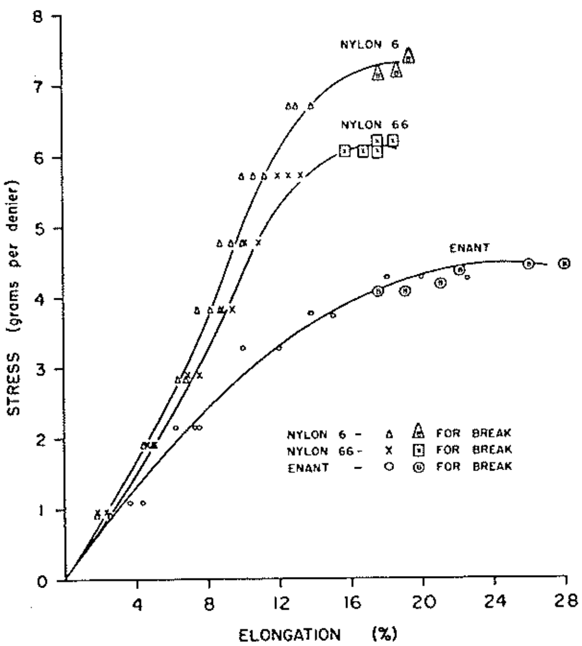

Fig. 2. Stress–strain surves for Enant, nylon 6 (Kapron), and nylon 66 (Anid).

Insufficient material was available to permit laboratory investigation of the stress–strain properties of Enant at various temperatures, although these would be better criteria of heat resistance than the melting point alone; therefore the sample was tested only under standard conditions of temperature and humidity and at a strain rate of 240%/min. The resulting stress–strain curve is shown in Figure 2, together with those for nylon 6 and nylon 66 yarns [19].

It would appear that the Russians have since produced an Enant with a greater degree of orientation than the Quartermaster-tested sample for, in a fairly recent article, they attribute to it a much higher tenacity (7 g./den.) and a somewhat lower elongation (18%) than was found here; they report a strength loss for Enant at 140° C. with the yarns fixed that is equivalent to that for Kapron or Anid [25]. These data have been plotted in Figure 3. Other data in the same article, however, show that the irreversible strength loss after heating at 140° C. is much less for Enant than for the other two types of nylon (Figure 4). It should be noted that these conditions are very specific and that these yarns were free to shrink.

Enant yarn was found to be multifilament, containing 12 single fibers of uniform and circular cross section and with diameters of 22μ. X-ray analysis (Figure 5) shows that, although Enant fibers are highly oriented, like nylon 6, they exhibit either low crystallinity or a highly disordered crystal lattice (perhaps caused by overstretching); this prohibits

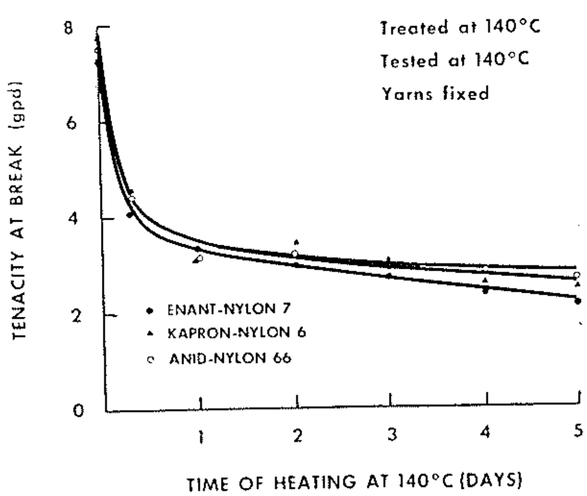

Fig. 3. Strength losses in Enant, Kapron, and Anid (yarns fixed).

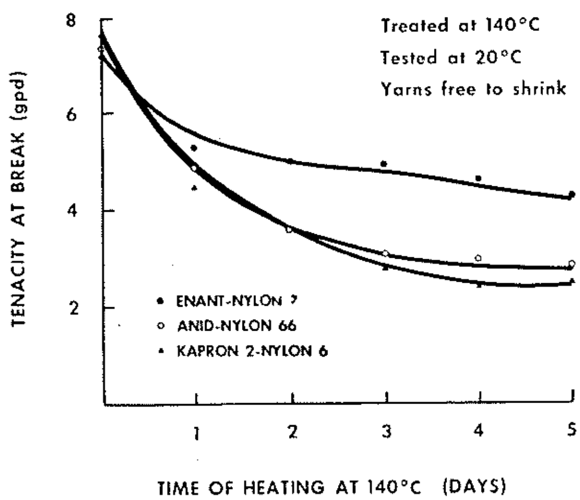

Fig. 4. Irreversible strength loss in Enant, Kapron, and Anid exposed to 140° C. (yarns free to shrink).

exact interpretation of the diagram. The identity period in the direction of the fiber axis is 17.6 Å. A comparable x-ray diagram for nylon 6 may be found in Susich's work ([38], p. 3). The chemical analysis, melting point, and x-ray identity period all tend to confirm the fact that Enant is a nylon 7, perhaps with the presence of some small amounts of other polyamides as impurities.

The present state of production of Enant in Russia is not known. Some references state that the fiber has never been produced beyond the pilot plant stage [28]. The Russians have clearly stated the connection between the development of this fiber and the basic research which led to it [14]. The fact that the basic research was conducted under the supervision of Professor A. N. Nesmeyanov, President of the Academy of Sciences, may indicate that it was assigned a high priority [27].

This basic work utilized readily available raw materials, carbon tetrachloride, and ethylene in an interesting reaction called telomerization. Telomerization is a polymerization in which chain transfer is dominant or extremely important. The chain transfer polymerization in this case is that between ethylene and carbon tetrachloride. The reaction scheme is as follows.

$$3(CH_2{=}CH_2) + CCl_4 \longrightarrow Cl(CH_2)_6CCl_3 \quad (1)$$

$$Cl(CH_2)_6CCl_3 \xrightarrow[H_2SO_4]{H_2O} Cl(CH_2)_6COOH \quad (2)$$

$$Cl(CH_2)_6COOH \xrightarrow[H_2O]{NH_3} NH_2(CH_2)_6COOH \quad (3)$$

Polycondensation of the third product, aminoenanthic acid, gives the resin from which Enant is produced [14]. The continuous-flow apparatus used for the telomerization reaction is shown in Figure 6.

It should be pointed out that the telomerization reaction gives a mixture of products with 5, 7, 9, and 11 carbon atoms which, of course, must be separated. The abundance and low cost of the raw materials for the preparation of Enant could make this fiber an interesting commercial item.

Pelargon. Pelargon, a nylon 9, is produced by the polycondensation of aminopelargonic acid,

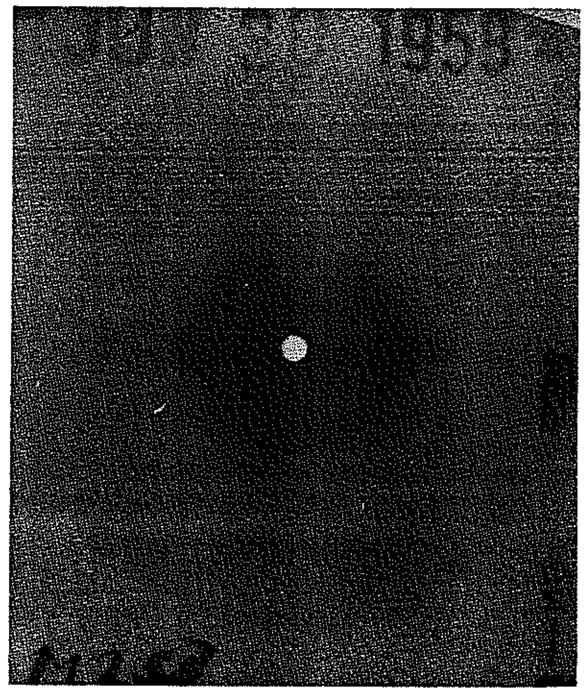

Fig. 5. X-ray diagram of Enant (Nickel-filtered CuK radiation; specimen fiber distance 1 mm., diameter of pinhole 0.1 mm.).

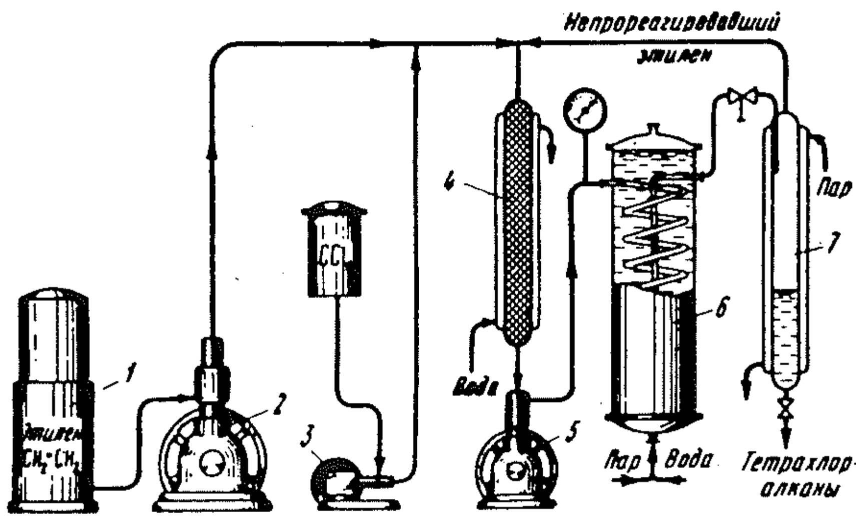

Fig. 6. Continuous-flow apparatus for the production of tetrachloroalkanes by telomerization. 1. Gas container, 2. compressor, 3. pump, 4. mixing tank, 5. circulating pump, 6. reactor, 7. separator (top) unreacted ethylene, (right) steam.

$NH_2(CH_2)_8COOH$, which is prepared by a similar telomerization reaction to that shown for the aminoenanthic acid from which Enant is derived [14]. Equation 1, given for the preparation of Enant, would in this case involve four monomer units of ethylene rather than three. In reality, a mixture results that must be separated to yield the desired product.

Pelargon is reported to possess exceptionally high resistance to multiple deformation. For example, Pelargon ruptures only after 40,000 double bendings as contrasted with Enant, which ruptures after 3000, and Kapron, which ruptures after 1500 [14]. No sample of this material has ever been made available to the Quartermaster laboratories for checking the validity of this claim. From its chemical nature, however, a lower moisture absorption and melting point would be expected than has been found for nylon 66, nylon 6, or Enant.

Rilsan. Rilsan, in contrast to Enant and Pelargon, is a French development of a nylon 11 polyamide. The monomer, aminoundecanoic acid, is produced in France from castor oil. The Russians are also interested in this fiber, but use a different raw material source. Again, the telomerization reaction between carbon tetrachloride and ethylene can be used to prepare the appropriate amino acid from which the nylon 11 can be prepared [14].

Polyamides from piperazine. Latvian scientists have reported the production of 2-methylpiperazine from glucose and ammonia. The 2-methylpiperazine is then used to prepare a fiber which is said to exhibit characteristics between those of nylon and Dacron [13]. Du Pont has produced polyamides from dicarboxylic acids and piperazine derivatives which possess unusual heat-resistant properties.

Sulfur polymers. Dr. Korshak, a corresponding member of the Russian Academy of Sciences, has reported that attempts are being made to produce fibers based upon thiodivaleric acid. These fibers could be cheap, from the raw material aspect, because he states that thiodivaleric acid is obtained as a by-product during the preparation of Enant [15]. The thiodivaleric acid could be reacted with a glycol to give a polyester, or with a diamine to give a polyamide.

A later Russian article states that a fiber prepared from the salt of thiodivaleric acid and hexamethylene diamine possesses increased softness and elasticity when compared with nylon [34].

Fluorine-Containing Copolymers

Fibers from fluorine-containing polymers and copolymers are of interest because of their high melting points and/or their resistance to the action of acids, bases, and other chemicals. Only one such polymer, Teflon (polytetrafluoroethylene), is available in the United States in fiber form, and its price prohibits its extensive use.

Ftorlon. The Russians mention a new fiber called Ftorlon in several of their publications [8, 29, 42]. They attribute to this fiber good resistance to chemicals and a much higher strength than Teflon. Ftorlon is a fluorine-containing compound which has no exact counterpart in the United States. Although many Russian, German, and American articles refer to Ftorlon, none gives any clue as to its identity other than to call it a fluorine copolymer. This secrecy is most apparent in an article by Shikanova that gives the chemical structure of Enant and other synthetic fibers but omits that for Ftorlon [36].

A very small sample of Ftorlon yarn was compared with Teflon at the Quartermaster laboratories, both by the Textile, Clothing, and Footwear Division and by the Microscopy Section of the Pioneering Research Division. It is soluble in selected solvents, hence spins more easily than Teflon. In the Kofler hot stage microscope, shrinkage was observed at 150° C. and decomposition between 228° and 265° C. This would indicate that the heat stability of Ftorlon is far below that of Teflon, which has an apparent melting point of 325° C. However, the stress–strain properties of Ftorlon, as obtained from the small sample, were found to be superior to those of Teflon. Figure 7 shows the breaking tenacity found for Ftorlon (4.5 g./den.) to be far in excess of that reported by Du Pont for Teflon [9].

Russian journals report more optimistically about the stress–strain behavior of Ftorlon than would appear justified from the sample tested. Zazulina states that a Ftorlon with a tenacity of from 100 to 130 kg./mm.^{2} and an elongation of from 8 to 10% has been produced [42]. Because Ftorlon is a heavy fiber with a specific gravity of 2.16 g./cm.^{3}, this tenacity figure can be translated into 5.2–6.7 g./den., which is at least 15% higher than the value found.

It is possible that Ftorlon is chemically closer to Kel-F (polytrifluorochloroethylene) or Polymer R (polyvinyl fluoride) than to Teflon and that the comparison with Teflon is not entirely warranted. However, Teflon is the only fluorine-containing poly-

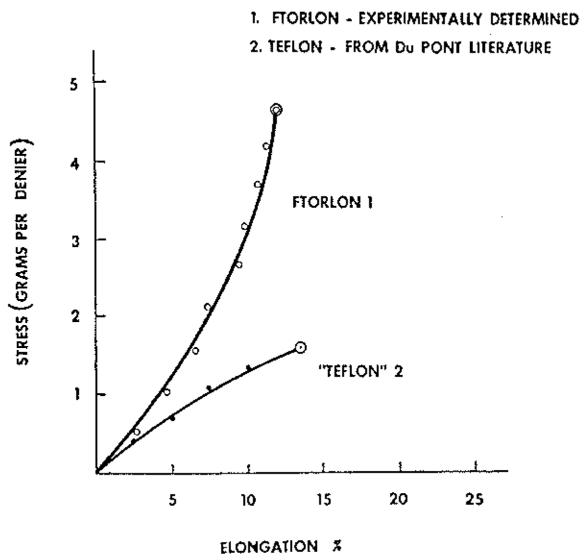

Fig. 7. Comparative stress–strain curves for Ftorlon and Teflon.

mer available in fiber form in the United States. The Ftorlon yarn was found to contain over 200 single irregularly shaped filaments of from 3 to 5μ in diameter. The x-ray diagram (Figure 8) shows an identity period of 2.6 Å along the fiber axis and that the material is crystalline and well oriented.

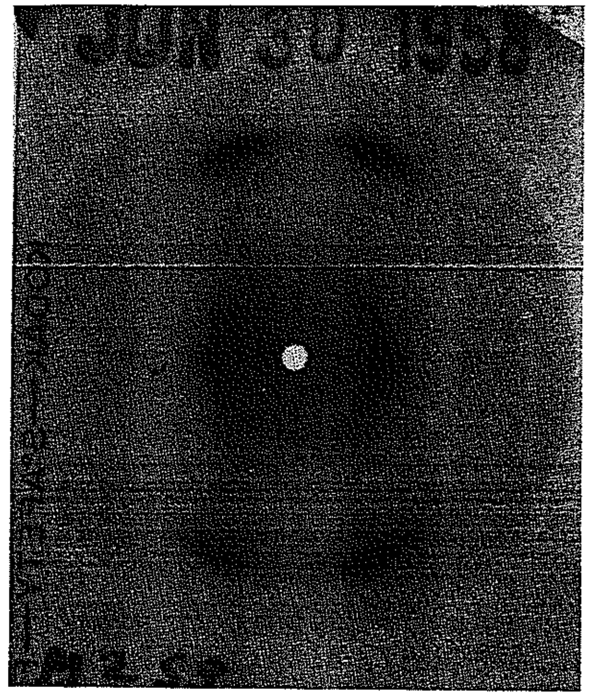

Fig. 8. X-ray diagram of the Russian fiber Ftorlon.

Polyester Fibers

Lavsan. Lavsan is the only Russian polyester fiber that has been discussed extensively in the literature. Shikanova gives the chemical structure for a repeating unit of the polymer; it is a polycondensation product of terephthalic acid and ethylene glycol [36]. Chemically, therefore, the Russian fiber should be identical with British Terylene and American Dacron.

The breaking strength of Lavsan has been given as 2.5–4.7 g./den., which is much weaker than the 6.0–7.0 g./den. characteristic of some of the Dacron fibers produced in this country. This is strange, because the Russians usually aim for tenacity at the expense of elongation (they maximize the orientation of the fiber by drawing).

In an article on heat stability, Motorina reports a polyester fiber as having an initial strength of 7 g./den. [25]. The author did not identify this fiber as Lavsan, so it might have been a sample of Dacron or Terylene.

Gorbacheva and Mikhaylov studied Lavsan by means of x-ray patterns and also by means of thermographic analysis, a type of differential thermal analysis [11]. Thermographic data were used to determine the heat of fusion; the value found (9–11 cal./g.) differs considerably from that found by American scientists (16 cal./g.).

Heterogeneous polyesters. V. V. Korshak, Deputy Director of the Institute of Organoelemental Compounds, is conducting a series of studies on fiber-forming polyesters. These studies to date have included systems of mixed polyesters of tetramethylene glycol and two dicarboxylic acids as well as polyesters of *m*-xylyleneglycol with various aliphatic and aromatic dicarboxylic acids [16, 17]. His principal objective is to determine the effect of various substituents and structures upon polyester properties, and most of the fibers resulting are not improvements upon Lavsan. However, it should be pointed out that Korshak was responsible for much of the work involved in producing Anid and Lavsan [6]. Because of this experience, Korshak would be in a favorable position to quickly exploit the breakthrough if any of these research studies concerning fiber-forming polyesters should lead to the preparation of a new fiber with properties superior to Lavsan or Dacron.

Vinyl or Acrylic Fibers

Nitron. Nitron, also called Nitrolon, is a polyacrylonitrile fiber that is chemically quite similar to the Orlon produced in the United States. Roskin's work at the Kirov-Leningrad Textile Institute on the redox polymerization of acrylonitrile is related to the development of this fiber [30, 31]. One Russian article reports that Nitron (molecular weight of 25,000–50,000) is spun from a 16–18% solution in dimethylformamide into a spinning bath containing polyethylene glycol phenyl ethers. It states that the fiber is stretched as much as 5000% to yield a product with a tenacity of 5.5 g./den. [32.] The Kalinin Artificial Fiber Combine has installed experimental equipment for the production of Nitron [5]. In addition, Russian scientists are also trying to improve upon Nitron and produce a modification that has greater elasticity and will blend better with wool [41].

Saniv. In order to avoid dependence on the supply of dimethylformamide necessary for spinning Nitron, the Russians have prepared a 40/60 copolymer of acrylonitrile and vinylidene chloride. This new copolymer dissolves readily in acetone and has been spun into the fiber Saniv. The strength of this new fiber is not known, but it is stretched 100–120% at an elevated temperature in order to increase its orientation and strength. Saniv is reported to be resistant to acids and alkalis [8, 29]. Its stability to heat and light is reported to be greater than that of Ftorlon [29].

In addition to the work on Saniv, Russian scientists are also investigating copolymers of acrylonitrile and vinyl chloride [43]. This would correspond to the fiber Dynel, which is produced by Union Carbide Corporation in the United States.

MTI-3. This fiber was named MTI-3 because it was the third fiber developed at the Moscow Textile Institute. Chemically, it is polymethacrylonitrile [29]. As could be anticipated, the methyl group interferes with molecular packing, and a poorer quality fiber than polyacrylonitrile results.

Soviden. This fiber is prepared from a copolymer of vinylidene chloride and vinyl chloride and would, therefore, appear to be a close relative of the American fiber Saran [12].

*Acrylonitrile-*p*-Aminostyrene.* A patent has recently been issued to several Russian scientists for fiber-forming copolymers of acrylonitrile and *p*-aminostyrene [44]. The properties of the resulting fibers have not been reported in the literature, and no additional information is available from *Chemical Abstracts.*

Miscellaneous Types

Khlorin. This is a Russian fiber which is prepared from chlorinated polyvinyl chloride. It softens at 80–90° C. Its nearest counterpart outside Russia would be the German Pe Ce fiber [8].

Vinitron. This fiber is made from a mixture of "Khlorin" and nitrocellulose. The presence of the nitrocellulose raises the softening point to 150° C. Also, thanks to the nitrocellulose, the Vinitron does not shrink in water, and it dyes better and has a higher moisture regain than Khlorin [2, 24].

The principle of combining two chemical constituents to produce a fiber with the better properties of each or with better properties than either constituent alone may be applicable to other combinations. The principle may then be of greater importance than its specific application to the preparation of Vinitron.

Deirin. This is a new high-molecular-weight polymer of formaldehyde which Professor Berlin claims has a fiber strength comparable to nylon [7]. Du Pont has prepared and marketed a superpolyoxymethylene, Delrin, with excellent mechanical properties, although Delrin in fiber form is not available from Du Pont at this time. It is probable that Delrin and Deirin are chemically the same.

Korsunskiy has recently reported on a "polyformaldehyde" polymer and says only that there are good reasons to believe that high quality synthetic textile fibers can be produced from it. He advocates the preparation of a pilot plant to produce this polymer and mentions the Du Pont production of Delrin [18].

Organosilicon fibers. Andrianov's work on the preparation of new high-molecular-weight organosilicon compounds containing atoms of tin, titanium, aluminum, and other elements is quite well known among polymer scientists. However, Voronkov's account of a Leningrad meeting on the chemistry and practical applications of organosilicon compounds mentions the actual or projected use of these polymers for the preparation of heat-resistant fibers [39]. Andrianov is quoted as stating that organosilicon compounds containing other hetero atoms such as titanium can be used for the production of fibers, elastomers, lubricants, and plastics which exhibit a high resistance to heat. In other statements at this meeting, Andrianov mentions the projected use of organosilicon polymers with organic side chains for fiber production. As far as is known, no American firm has developed heat-resistant fibers from organosilicon polymers, and any Russian development in this area would mean a possible breakthrough useful for military applications such as thermal protection.

Conclusion

Although these developments represent an increase in Soviet textile potential, Russian scientific and political leaders have expressed dissatisfaction with their rate of progress and a determination to do something about it. The president of the Russian Academy of Sciences has personally participated in the development of Enant. Russian literature has referred on numerous occasions to the establishment of new institutes and new divisions of old institutes that will concentrate on the development of new fiber-forming polymers. *A possible threat from Soviet textile research lies, not in the development of slightly improved counterparts of nylon, Orlon, etc., but in the possibility of a real breakthrough emanating from extensive work in this field of new and unusual polymers.* It is very possible that work on organometallic and inorganic polymers will eventually lead to the development of fibers with an entirely new order of magnitude of heat resistance, chemical resistance, and impact properties. The country that successfully develops fabrics of this type with the required mechanical as well as thermal properties could gain an advantage in such military end items as parachutes for supersonic use, personnel armor, and thermal protective clothing.

Summary

As of this date, the ability of the Soviet orbit to produce man-made fibers and textiles in quantity is far behind that of the United States. However, as shown in this report, Russia has produced at least three new fibers that have no counterparts in the Western world. The first of these, Enant, a nylon 7, represents a scientific achievement in applying chemical theory to the preparation of a new fiber from cheap raw materials. The second new fiber, Ftorlon, is a fluorine-containing copolymer with good resistance to chemicals. It possesses better mechanical properties than the only fluorine-containing fiber available in the Western world, Teflon. The third fiber, Vinitron, is a superior product resulting from the combination of a cellulosic material with Khlorin (chlorinated polyvinyl chloride). This is a combination principle that may be applicable to other combinations of natural and synthetic polymeric fibers.

Other so-called new Russian fibers are actually so closely related to well-known Western developments that the degree of originality in their development cannot be accurately determined. In this category are Lavsan, Anid, Nitron, Kapron, and Khlorin, corresponding to Dacron, nylon 66, Orlon, nylon 6, and the German Pe Ce.

The satellite countries are also active in many phases of man-made fiber technology. Steelon, although a nylon 6, is claimed to be a Polish development in many ways, from the research phases to production. The East German development of hollow fibers certainly shows competence in evolving new spinning techniques. Even the small country of Latvia seems to be developing new and inexpensive methods of producing raw materials for more heat-resistant polyamide fibers. This combination of the ability of the Russian scientists to develop new fibers and to exploit Western developments, with the increasing support to be expected from satellite countries such as East Germany and Poland, make the Soviet orbit a future contender for first place in man-made fiber technology.

Acknowledgments

The authors wish to acknowledge the support and advice of Dr. S. J. Kennedy, Chief, Textile, Clothing, and Footwear Division, QM R&E Command, and the technical advice of Dr. Herman Mark, Director, Polymer Research Institute, Polytechnic Institute of Brooklyn. The x-ray diagrams, chemical analysis, and microscopic and melting point data are due to the efforts of Dr. George Susich, Mr. Abram King, Mrs. Libera Dogliotti, Mr. Warren Sassaman, and Mr. Carmen Di Pietro of the Pioneering Research Division, QM R&E Command. Editorial assistance by Miss Editha Stone of the Textile, Clothing, and Footwear Division of this same installation is also acknowledged.

Literature Cited

1. Anon., *Modern Textiles Magazine* **38** (11), 70 (1957).
2. Anon., *Skinner's Silk and Rayon Record* **31**, 766 (1957).
3. Anon., *Izvest. Akad. Nauk SSSR, Otdel. Khim. Nauk* **n11**, 1285–1288 (November 1958).
4. Anon., *Skinner's Silk and Rayon Record* **32**, 1251 (1958).
5. Anon., *Pravda* (14 June 1958).
6. Anon., *Vysokomolekulyarnye Soedineniya* **1**, n1, 165–6 (1959).
7. Berlin, A. A., *Nauka i Zhizn'*, n3, 6–11 (1958).
8. Bystrov, A., *Promyshlenno-Ekonomicheskaya Gazeta* **3**, n81 (381) 2 (9 July 1958).

9. E. I. du Pont de Nemours & Co., Inc., "Teflon TFE-Fluorocarbon Fiber—Properties of Fiber and Fabrics," Bulletin T-6 (December 1958).
10. Formo, J., *Soc. Plastics Eng. J.* **15** (10), 858 (1959).
11. Gorbacheva, V. O. and Mikhaylov, N. V., *Kolloid. Z.* **20** (1), 38–42 (1958).
12. Gruzdev, V. A., Zhuchkova, N. G. Klimenkov, V. S., and Kotina, V. E., *Trudy Vsesoyuz. Nauch.-Issledovate. Inst. Iskusstven. Volokna* n2, 115–119 (1955); see also *Chem. Abstr.* **53**, 10836f (1959).
13. Kalnins, A. I., *Izvest. Akad. Nauk Latvi. SSR* n10 (135) 5–10 (November 1958).
14. Karapetyan, Sh. A. (Inst. of Elemento-Organic Compounds, Moscow), *Priroda,* n8, 65–68 (1958).
15. Korshak, V. V., *Promyshlenno-Ekonomicheskaya Gazeta,* 4 (10 February 1957).
16. Korshak, V. V. and Vinogradova, S. V., *Izvest. Akad. Nauk SSSR, Otdel. Khim. Nauk,* n2, 338–343 (1959).
17. Korshak, V. V., Golubev, V. V., Karpova, G. V., and Dubova, T. A., *Izvest. Akad. Nauk SSSR, Otdel. Khim. Nauk* n3, 540–545 (1959).
18. Korsunskiy, O., *Promyshlenno-Ekonomicheskaya Gazeta* **4**, n59 (514) 4 (22 May 1959).
19. Laible, R., "Evaluation of the Russian Nylon, Enant," QM R&E Command, Tex. Eng. Lab. MER 2937 (29 December 1958).
20. Mark, H. F., *Modern Plastics* **35** (11), 111 (1958).
21. Mark, H. F., *Plastics World* **16** (9), 6 (1958).
22. Mark, H. F., *Chem. and Eng. News* **36** (28), 22 (1958).
23. Martin, R. L., "Foreign Scientific Literature in Translation," QM R&E Command, Technical Library Report (January 1959).
24. Mikhaylov, N. V., *Promyshlenno-Ekonomicheskaya Gazeta,* 4 (10 February 1957).
25. Motorina, A. V. and Konkin, A. A., *Tekstil. Prom.* n7, 18 (1958).
26. Nash, W. A., *Industrial Laboratories* **10** (2), 101 (1959).
27. Nesmeyanov, A. N. et al., *Chem. Tech.* (Berlin) **9** (3), 139–150 (1957).
28. Rogovin, Z. A., *Vestnik Akademii Nauk SSSR* **28** (1), 45–53 (1958).
29. Rogovin, Z. A. and Zazulina, Z. A., *Izvest. Vysshikh Ucheb. Zavedenii, Khim. i Khimicheskaia Tekhnol.* n1, 137–146 (February 1958); see also *Chem. Abstr.* **52**, 15074d (1958).
30. Roskin, E. S., *Trudy Leningrad. Tekstil. Inst.* n6, 77–90 (1955); see also *Chem. Abstr.* **52**, 3348h (1958).
31. Roskin, E. S. (Kirov-Leningrad Tex. Inst.), "A Static Method of Acrylonitrile Polymerization," Abstracts from the IXth Congress on the Chemistry and Physics of High Polymers, Moscow, January 1957) (from *Resins, Rubbers, Plastics,* Russian Supplement I).
32. Roskin, E. S., *Zhur. Prikladnoi Khim.* **30** (1), 121–126 (1957).
33. Schaaf, S., *Faserforsch. u. Textiltech.* **10** (7), 328–330 (1959).
34. Shein, T. I., Chelnokova, G. N., and Vlasova, L. N., *Khim Volokna* n2, 19–20 (1959).
35. Society of Plastics Industry, Inc. "Report on Visit of USA Plastics Industry Exchange Delegation to USSR, June 2 to June 28, 1958," 250 Park Ave., New York.
36. Shikanova, I. A. and Sokolova, N. M., *Tekstil. Prom.* **18** (5), 57–59 (1958); see also QM R&E Tex. Eng. Lab. MER 2938 for translation.
37. Strepikheev, A. A., Topchibasheva, V. N., and Shein, T. I., *Tekstil. Prom.* **16**, (1), 33–34 (1956); see also *Chem. Abstr.* **50**, 10415 (1956).
38. Susich, George, Bosley, D. E., and Stone, Editha, "Tensile Behavior of New Textile Fibers," QM R&E Command, Tex. Eng. Lab. Rept. 199 (September 1957).
39. Voronkov, M. G and Losev, V. D., *Vestnik Akad. Nauk SSSR* **28** (12), 97–100 (1958).
40. Weiner, L. I., "Enant, a New Russian Fiber," QM R&E Command, Tex. Eng. Lab. Rept. 132 (April 1958).
41. Yastrebov, G., *Izvestiya,* 2 (April 15, 1959).
42. Zazulina, Z. A., Martsinkovskaya, R. N., and Rogovin, Z. A., *Tekstil. Prom.* **17** (5), 6–7 (1957).
43. Zelikman, S. G. and Mikhaylov, N. V., *Kolloid. Z.* **19** (1), 37–40 (1957).
44. Zharkova, M. A., Abkin, A. D., Kudryavtsev, G. I., and Sokolova, E. A., "Fiber-Forming Copolymers," USSR 114,908 (October 6, 1958); from *Chem. Abstr.* **53**, 12695 (1959).

Manuscript received October 26, 1959.