

# U.S./USSR COOPERATIVE AGREEMENT ON HOUSING AND OTHER CONSTRUCTION: BUILDING FIRE SAFETY

## BACKGROUND

Periodic visits by U.S. experts to the Soviet Union and Soviet experts to the U.S. are part of the U.S./USSR Cooperative Agreement on Housing and Other Construction, which was signed in 1974. The overall exchange program includes projects in the fields of urban problems; new towns; construction in seismic, cold, and arid regions; organization and management of construction projects; new construction methods and materials; and mass transportation. My particular project concerns building fire safety and related problems. While this project is under the sponsorship of the Department of Housing and Urban Development, the lead agency for my team's work is the National Bureau of Standards (NBS).

In general, a work cycle consists of one visit by a Soviet team to the U.S. followed by a reciprocal visit of the U.S. team to the Soviet Union. One of the highlights of each visit is a symposium on a relevant fire problem during which each side updates the other on current research progress and results. Since the agreement took effect, two cycles of project work have been completed: the first took place in 1977-78, the second in 1980-81. Between visits, technical and scientific literature is exchanged and work is carried on by correspondence.

Typically, teams visit industrial plants, building construction sites, research laboratories, technical schools, scientific institutions, and other facilities. The ultimate intent is to share advances in science, engineering, and technology, to learn from each other, and to gain new, possibly novel, insights into common problems. Such results have, in fact, been realized through the exchanges that have occurred to date.

The U.S. team that visited the Soviet Union in July 1981, consisted of R. S. Levine (Chief, Fire Research Resources Division, NBS), B. J. Thompson (Acting Administrator, U.S. Fire Administration), M. Leiff (Morris College), H. Mittler (Harvard University), R. Friedman (Vice President, Factory Mutual Research Corp.), and myself.

The objectives of the visit were:

1. To survey Soviet training in middle- and higher-level fire schools;
2. To hold a seminar on fire modeling, with papers presented by Soviet and U.S. specialists;

3. To develop a comprehensive glossary of fire safety terminology.

The itinerary included a visit to the Highest Fire Protection Engineering Academy in Moscow (July 5-7). From Moscow, we traveled by air to Tbilisi, (July 7-11), where a three-day seminar was held on fire modeling. From Tbilisi, we flew to Leningrad (July 11-13) for a visit to the Shipbuilding Scientific Research Laboratory and the Leningrad Fire Protection Engineering College. From Leningrad, we took the Red Arrow Express overnight to Moscow (July 13-16) for a visit to the Physical Chemistry Institute of the Academy of Sciences.

## HIGHEST FIRE PROTECTION ENGINEERING ACADEMY

Our first stop, in Moscow, was a visit to the Highest Fire Protection Engineering Academy,<sup>1</sup> dedicated to training fire service officers. The Academy, founded in 1974, provides a four-year university-level program and is the only one of its kind in the Soviet Union.

The Soviet fire service, a department of the Ministry of Interior, is organized along military lines. The administrators and faculty at the Academy, for example, hold military ranks. The long-term head of the Academy is Gen. A. N. Smurov; his chief deputy is Col. M. P. Bashkirtsev.

Admission to the Academy is highly prized, for not only does it offer an excellent technical education, but successful graduates, who acquire the title of Fire Protection Engineer, are almost guaranteed upward mobility in the fire service. Tuition is free. In fact, students entering from the fire service or other employment continue to receive their normal pay.

## Curriculum

General education, including social and political science courses, are accounted for in the program, but emphasis is on mathematics, chemistry, and physics, especially hydraulics and thermodynamics. Students carry out five research projects before graduating. If a student does exceptionally well and wins a prize for his project, his instructor/advisor receives a monetary award.

A 3-month internship must be served to qualify for a diploma. The usual assignment is to a city fire station, where the student obtains first-hand experience

in tactical command and fire service administration.

Innovative teaching in the form of cooperative training, gaming, and simulation are used and appear to be effective in producing top-of-the-line officers for the fire service. Audiovisual equipment, including closed-circuit TV, is widely used in all courses. Audio has been found particularly suitable for teaching foreign languages to Soviet students and Russian to others. Classes are limited to 25 students; laboratories to half that number. Part of the education process occurs outside the Academy. For example, if fire prevention in industry is the topic, students visit an appropriate industrial plant and inspect its fire prevention and suppression facilities and equipment.

In general, the school building is equipped with modern laboratory facilities, and though the classrooms are small, they are cheerful and adequate. The large charts showing nuclear explosions and fallout patterns that had been prominently displayed on classroom walls during our 1977 visit were nowhere to be seen.

### Typical Courses

Space permits only a glimpse of the 38 disciplines that are being taught.

*Combustion Processes Course* — Professor I. Abduragimov's first-year course is in two parts: "Principles of Combustion" and "Physical-Chemical Principles of Fire Growth and Suppression." Each part includes 30 to 40 lectures that cover basic theoretical concepts, supplemented by 20 hours of laboratory work. Laboratory work involves hands-on experimentation with ignition, small-scale fire development and extinguishment, and paper calculations of combustion and fire parameters.

The difficulty in teaching about fire growth is that the process is never more than approximately predictable. As in other countries, buildings in the Soviet Union are becoming taller and larger,<sup>2</sup> new types of structural assemblies are being developed, new architectural configurations are being designed, and new materials are being introduced. All of this tends to complicate the problem for the fire service. In addition to assessing the impact of various fire loads in structures and the importance of fire gas analysis in the evaluation of fire risks, Abduragimov's department is attempting to develop practical models for teaching the behavior of natural-gas-well fires and flammable-liquid tank fires.

*Fire Prevention and Protection Courses* — Fire prevention, taught over three semesters, covers physical-chemical aspects of fire (e.g., ignition, fire hazards, dust, toxicity of combustion products), explosion and fire hazards in manufacturing processes, fire-hazardous products and materials, ignition sources, and leaks and spills. The subject of fire prevention in construction includes information on building design, erection, and use, and covers fire resistance, fire prevention, interior planning for fire

safety, evacuation problems, smoke protection, and control of fires. Research on evacuation problems is coordinated with other organizations, principally the State Committee on Civil Construction.

*Automation in Fire Protection* — Automation in fire protection is taught in the third and fourth years. A well-equipped electronics laboratory is available to the students. Lectures deal with the principles of automation and fundamentals of fire detection and suppression systems. Research is being conducted on automatic fire protection and safety, as well as on pre-fire and pre-explosion suppression systems.

An intensive effort has been undertaken in the Soviet Union to equip new and existing buildings with automatic heat and smoke detectors. A significant reduction in serious fires has been noted and is attributed directly to this program.

*Administration and Management* — The course on scientific organization and management includes principles of management, fire statistics, and principles of fire laws. It is intended to replace statistics with applied mathematics and to include linear and nonlinear programming, simulation and modeling, game theory, and graph theory. The department responsible for this course is concerned with updating the norms that apply to the Soviet fire service.

### Student Body

Students are selected by countrywide competitive examinations. Admission is open to physically fit fire-service officers up to 32 years of age. Requirements include three years of firefighting experience, adequate academic credentials, and good references (which, in practice, must be provided by senior-level fire service officers).

Most students are graduates of fire engineering colleges. Both Soviet and foreign students are enrolled. (We were told that a Cuban was a recent honors graduate.) About 200 students are graduated each year.

### Staff and Faculty

Faculty members engage in independent research, write scientific and technical papers, and are expected to take courses to enhance their expertise. More than half have advanced degrees, many at the doctoral level.

The Academy regularly contracts research and consulting services from other government agencies. It is common practice for the Academy to conduct joint research projects with the All-Union Scientific Research Institute for Fire Protection. Proceeds from such work are used to buy materials, instruments, and equipment.

Many of the textbooks used in the school have been written by members of the faculty. A sampling of recent titles includes:

- Hydraulics and Water Supplies
- Thermodynamics and Heat Transfer in Fire Practice
- Tactical Problems in Fire Suppression
- Automated Fire Detection
- Fire Inspection Methods for Industrial Processes
- Automatic Smoke Protection Systems for High-rise Residential Buildings
- Means and Methods for Extinguishing Flammable Liquid Fires
- Organization of Fire Suppression Forces in Cities and Populated Centers
- Suppression of Underground Fires
- Use of Surface Active Agents in Fire Suppression

Some other courses taught at the Academy may be surmised from these titles.

### MIDLEVEL FIRE ENGINEERING SCHOOL

This midlevel college in Leningrad, founded in 1933 but having roots extending back to 1906, is said to be the oldest fire engineering school in the world. It offers a three-year residency for young firefighters, almost all of whom have been recommended by heads of fire departments. Admission is by competitive examination.

Correspondence courses are also offered, from which diplomas may be earned. Prior to graduation, however, a period of residency is usually required.

Foreign students, mostly from Soviet Bloc countries, are also accepted, but with a prerequisite of one year of Russian language study. The college graduates about 200 Soviet students and roughly the same number of foreigners each year. Graduates become junior officers in the fire service.

There are seven other such colleges in the Soviet Union: in Moscow, Irkutsk, Tashkent, Kharkov, Ivanov, Sverdlovsk, and Lvov. Graduates may apply to the Highest Fire Protection Engineering Academy for further education.<sup>3</sup>

Academic studies are augmented by various projects assigned to small teams of students. Many of these projects result in models, some quite intricate. One was a refinery model that featured a water supply grid, special fire suppression agent stores, and delivery system configurations.

Between academic sessions, students are assigned to short periods of on-the-job training with active fire departments. Because graduates become junior officers in the fire service, this hands-on experience is essential. While specialization is not encouraged, students may request particular types of on-the-job assignments. For example, if a student is interested in airport fire protection, an effort is made to assign him to an airport fire company.

Some classrooms are equipped with a question-answering system. Each student's desk has a box with several buttons, each representing an answer to an instructor's question. The boxes are wired to signal lights on a console on the instructor's desk. The lights show each student's response.

If many answers are wrong, the instructor knows immediately that he must repeat the material or explain it in greater depth. If one or two answers are wrong, he knows who failed to grasp a concept or do his homework. Instructors at the school claim this simple system is indispensable to them. With it, they can pace the rate of instruction easily without wasting time on material that has been mastered, and can devote more time to topics that the students find difficult to assimilate.

The Fire Engineering School encourages physical fitness by holding regular intramural firefighter competitions. Firefighter games are held throughout the Soviet Union. In Tbilisi, for example, we heard about the annual firefighter jamboree to which competitors flock each summer to compete in hose laying, ladder climbing, and other activities that require speed, agility, dexterity, strength, and stamina.

### FIRE MODELING SYMPOSIUM

The second objective of our visit was the Fire Modeling Symposium held in Tbilisi, Georgia. The proceedings are now being translated and will be published simultaneously in the United States and the USSR in 1982. Most of the Soviet authors are on the faculty of the Highest Fire Protection Engineering Academy. Their papers are:

1. "Investigation of Compartment Fires and Their Modeling," Yu. A. Koshmarov;
2. "Analysis and Development of an Algorithm for a Fire in a Compartment with Openings," V. M. Astapenko, Yu. A. Koshmarov, and A. N. Shevlyakov;
3. "Investigation of Velocity Fields, Temperature, and Concentrations in Compartment Fires by Mathematical Modeling," I. S. Molchadskiy and A. M. Ryzhov;
4. "Integral Methods for Investigating Temperature Behavior in Compartment Fires," V. N. Gutov and I. S. Molchadskiy;
5. "Investigation of the Initial Stage of Fire Growth," M. P. Bashkirtsev, M. Ya. Roytman, and F. M. Shlyomin;
6. "Fire Development and the Improvement of Fire Codes," V. N. Zigern-Korn and I. G. Romanenkov;
7. "Improving Fire Codes with the Aid of Mathematical Modeling Methods," N. N. Brushlinskiy;
8. "Fire Growth in Industrial Buildings," D. I. Mikhaylov and V. V. Fyodorov.

The American papers include:

1. "Survey and Organization of Mathematical Fire Modeling in the United States," R. S. Levine;
2. "Status of Mathematical Modeling of Fires," R. Friedman;

3. "Validation Tests of the Harvard Computer Fire Code V," H. Mittler;
4. "Using Mathematical Models to Solve Fire Problems," R. S. Levine and J. Rockett.

Comparison of Soviet and U.S. results should prove interesting and useful because the Soviet approach emphasizes field modeling, whereas the principal U.S. attention is devoted to zone modeling.

### VISIT TO TBILISI FIRE DEPARTMENT HEADQUARTERS

Our official hosts, the Georgian Fire Department, invited us to tour the Tbilisi Fire Department Headquarters. One glistening, no-nonsense vehicle of each type in the department's rolling stock was lined up for our inspection when we arrived: a ladder truck, a pumper, a rescue vehicle, a tanker, crash truck, hose wagon, and utility van. Soviet fire vehicles lack the packaging that characterizes Western fire equipment, but they are functionally able to do the jobs for which they are intended. Lacking trim and chrome and frills, they have at least one significant advantage over Western models: affordability.

After we reviewed the trooped fire apparatus, our hosts guided us to a large arbor with huge clusters of grapes hanging above a long table with large bowls of Georgian fruit, pastries, and lunch treats. (The wives of Headquarters personnel, anticipating our arrival, had stayed up the previous night baking a rainbow of pastries in the shapes of giant exotic flowers.)

### SHIPBUILDING SCIENTIFIC RESEARCH LABORATORY

The Shipbuilding Scientific Research Laboratory (SNIL) was the focus of our visit to Leningrad. This laboratory, founded in 1959, has the mission of ship safety both at sea and in inland waterways. The Soviet Union has numerous institutions that include the characters NI in their acronyms. These characters stand for "Nauchno-Issledovatel'skiy," literally, "Scientific Research." One should be careful not to read too much or too little into this designation. At SNIL, for example, with the possible exception of the new combustion toxicology program described below, the ongoing work that we observed was entirely in the realm of materials testing. If any real scientific research (as we understand it) was being conducted, we were not informed of it. During our visit we witnessed a fire test of a bulkhead that was mounted on one of two approximately 6 by 8 foot wall furnaces.

#### Ship Mockups

SNIL has three approximately half-sized mockups of ship cargo holds and crew quarters in its yard. The models of cargo holds have built-in tanks that are filled with water during fire tests to protect the structures. A variety of tests can be performed, including the effectiveness of various extinguishing agents on different cargos. The crew quarters mockup has an

abbreviated hull, a main deck, cabins, and a modified bridge. It can be used to map the propagation paths of smoke and toxic products and to vary both the material that is burning and the site of ignition in order to determine degrees of hazard.

### Smoke Generation and Animal Toxicology Experiments

We were shown a new combustion toxicology laboratory in which live animal experiments were being conducted. This is a recent addition to SNIL's overall mission.

SNIL is working closely with the Subcommittee on Fire Protection of the Inter-Governmental Maritime Consultative Organization on the smoke-generation capacity of burning shipbuilding and shipboard materials and the relative toxicity of their combustion products. (Ships are just as susceptible and vulnerable to fires as are residences and for much the same reason: a high incidence of cigarette ignitions of mattresses and bedding. Soviet experience is that bedding appears to be a more common first ignition material in cabin fires than upholstered furniture.) The principal goals of the program are to assess the relative obscuration potential of various pyrolyzing materials and their toxic risk, both under flaming and non-flaming conditions. (Smoke is indeed a major hazard to people caught up in fires because it obscures vision and thereby can frustrate escape, and also because it gravely interferes with respiration.)

#### Full-Scale and Model Experiments

SNIL's preliminary efforts are aimed at categorizing shipboard materials as high, moderate, or low smoke-generating and toxic risks. Critical smoke density is reached when visibility decreases to 1 meter. Critical lethality in the animal experiments is that which causes 50% mortality of test animals in 30 minutes in a standard exposure chamber.

Tests are performed according to a 10 by 10 protocol: ten mice are used in each test and ten tests are run on each material at 400 and 750°C. Results are based on the weight of material burned to produce 50% mortality. The lowest critical weight determined in this way is then checked at 600°C. Combustion products are analyzed for several toxic gases, and animal carboxyhemoglobin levels are measured. Materials tested include cellulose (e.g., veneer and expanded insulation), synthetic polymers, and plastics.

A series of tests has been performed in which a 63-cubic-meter simulated cabin was used as the exposure chamber. The optical characteristics of smoke were measured and combustion product composition was evaluated. Full-scale results compare in predictable ways with those obtained from small-scale model experiments.

SNIL's immediate goal is not to determine absolute values, but rather to rank materials of interest along a more or less arbitrary toxicity scale in order to establish a practical measure for selecting the least hazardous materials for shipboard use.

## JET-PROPELLED FIREBOAT

One day during our Leningrad visit began with a thrilling 45-mile-per-hour dash for a distance of about 13 miles up the Neva River in a streamlined, waterjet fireboat as guests of the Leningrad Fire Department. The boat, about a 75-footer, was propelled by two water-jet propulsion pumps driven by twin diesel engines. The Leningrad Fire Department has two other boats that are larger, heavier, and more heavily equipped. The waterjet boat was light, fast, and lightly equipped. It had one deck gun, a foam monitor, and several hydrant connections for small hoses.

## SOVIET BUILDING CONSTRUCTION BOOM

In each city we visited, we saw evidence of building construction wherever we looked. The skylines bristled with cranes. We were first impressed by this building boom in 1977, but we assumed then that it was engendered by the upcoming Olympic games. However, the scene hasn't changed a bit; buildings continue to be constructed everywhere, in city centers as well as in the suburbs.

President Leonid Brezhnev has stated that more housing was built in the Soviet Union in the 1970's than the entire stock of urban housing that existed at the beginning of the 1960's. But despite that massive building effort, housing is still scarce in Soviet urban centers. Many families share flats that have only scant conveniences, and many newlyweds wait years for private housing. The urban housing problem is exacerbated by an influx of people from rural areas that goes on despite government opposition.

Soviet builders are proud and even boastful of their standard building designs, pointing out the economies of prefabrication.<sup>4</sup> Moreover, if the learning curve holds in the Soviet Union as it does elsewhere, building erection time should progressively decrease.

But standardization has its drawbacks too. The sameness of block after block of Soviet apartment houses is becoming, apparently, as palling on the Soviet leadership as it has been on ordinary citizens who have to live in them. Brezhnev himself has remarked, "... as a whole, urban development stands in need of greater artistic expressiveness and diversity. We should avoid cases such as that of the film character, who, by irony of fate, found himself in another town and was unable to distinguish either the house or the flat he got into from his own."

Although Soviet building construction efforts are aimed squarely at standardizing designs and construction methods, some attention is being devoted to innovation and experimentation. We saw an experimental building along the Georgian Military Highway, outside Tbilisi. The easiest way to describe it is Rubik's cube with some of the blocks missing. The blocks that made up the building appeared to be nearly identical modules, probably built elsewhere

and simply assembled and finished on-site. None of our Soviet hosts could answer our questions about the building.

## CHEMICAL PHYSICS INSTITUTE, ACADEMY OF SCIENCES

The Chemical Physics Institute, Academy of Sciences, in Moscow is a prestigious research installation that has done significant work in combustion and chemical kinetics. The emphasis of current work is on the combustion of solids, turbulent combustion of gas, and chemical kinetics of gas explosions.

A major new program has been undertaken by the Institute in the field of biology by the establishment of a Department of Chemical and Biological Kinetics, which addresses problems in biomedicine, oxidation, degradation and stabilization of polymers, and fire. Prof. G. E. Zaikov, head of the department, described some of their new biomedical efforts in the study of radicals involved in cancer. A drug has been produced that appears to have positive effects in treating lung and bladder cancer. In connection with gerontological studies, the life span of mice has been doubled by controlling diet.

## GLOSSARY

Progress on the compilation of a Russian/American glossary of building construction and fire safety terms was the third objective of our visit.

The Russian and English languages share many cognates in their respective technical lexicons. The word "radio," for instance, has crossed into many languages, and in both English and Russian it is used in the same way and in the same senses. In a bilingual dictionary, English "radio" and Russian "radio" are juxtaposed, and everything is as it should be. The word is used identically in both languages. But the dictionary juxtaposition also holds for "architect" and "arkhitektor," its cognate, and here we have a problem. A Soviet architect, by training and area of competence, is quite different from an American architect. He does not design and engineer buildings; he is concerned primarily with planning building interiors and has little to do with the technical and engineering aspects of building design. Dictionaries and translators, however, invariably equate such words and thereby mislead themselves as well as their readers or hearers.

A more difficult problem concerns words that have no counterparts in the other language. In technical situations, the interpreter or translator must express ideas by description rather than by term-for-term substitution, and he can do so accurately only if he understands the significant differences between the two cultures. In the Soviet Union, for example, there is usually only one source of supply and one center of authority; cost is cost and price is price and chances are that the projected building is an approved standard design. The U.S. mode of building construction is marked by diversity and competition — a multi-

plicity of sources and alternatives. This difference alone causes numerous mistranslations and enormous trouble in bilingual meetings, where frequently as much time is spent trying to understand one another as in pursuing the purpose at hand.

In preparation for the visit to the Soviet Union, I compiled a sample Russian/American glossary of building construction, fire safety, fire service, hydraulics, and fluid mechanics terms. On the last day in Moscow we discussed the glossary, which was accepted as the working draft, and agreed to exchange revisions, additions, etc. The glossary is a machine-readable file, so it is easy to list Russian and American terms and definitions side by side, alphabetically, in each language.

## FOLLOW-ON PROGRAM

The protocol, signed by both parties, reviewed the just-completed program and recommended continuation of ongoing activities. The most important of these are a follow-on Soviet/American symposium on Fire Test Methods for Building Materials to be held in the United States in September 1982, and continuation of work on the Russian/American glossary by correspondence. An interesting proposal was advanced regarding a possible exchange of one or two students between the Soviet Highest Fire Protection Engineering Academy and the U.S. Fire Academy. The proposed program is subject to approval by higher authorities on both sides. Prospects appear promising.

## WRAP-UP

In the course of periodic assessments of the U.S./USSR Cooperative Agreement on Housing and

Other Construction, the value of the program to the U.S. side has been questioned. Concern has been expressed that the Soviets, being more in need of technology transfer than the U.S., are receiving more than they are giving.

Although there may be reason for concern in some parts of the overall program, the Soviets have reached a high level of expertise in fire education and materials testing. While budgets are being cut in these areas in the United States, the Soviets appear to be well funded. The scope of their fire research activity is burgeoning. At present, the balance of progress in fire research is shifting in their direction.

The Soviets experience no significant problems in arranging comprehensive testing programs. In studying the highrise evacuation problem, for example, they carried out nearly 200 model tests and full-scale burns. A program of such magnitude would hardly be feasible in this country under present circumstances. For this and similar reasons, it would be well for us to follow the Soviet fire testing and research work closely and, we hope, profit from their results. Also, we can learn from the Soviets' superior fire-service education programs and their extensive experience in applying them.

## NOTES

<sup>1</sup>Though the cognate "school" appears in its title, the institution is essentially an "academy," even in the military sense, so it will be referred to as such in this article.

<sup>2</sup>A highrise building in the Soviet Union is ten stories or more. The most popular building height today is 16 stories.

<sup>3</sup>Several technical colleges exist in the Soviet Union that offer degrees in fire protection engineering. Among them are the Volokolamsk and the Syzransk Polytechnical Institutes, the Khabarovsk Construction Institute, and the Groznensk Petroleum Institute.

<sup>4</sup>Bathrooms and kitchens, for example, with built-in plumbing and services, are usually constructed on a factory assembly line and delivered as complete modules to building sites.