Engineering Education in the U.S.S.R.

by Frederick C. Lindvall

Someone made a very profound remark when he said, "There is no expert on Russia; there are merely degrees of ignorance." Russia has always been an unknown country. And there has always been suspicion and doubt as to whether what is seen by visitors is a piece of "show," or a true situation.

Concerning engineering education in the U.S.S.R., a great deal of information already exists in our country, in the form of published documents, or from occasional visits that people have been able to make to the U.S.S.R. We know a good deal about the formal structure of their engineering education, and their elementary education through their so-called middle school – or what we would call high school. But we are a little bit in the position of anyone who, in this country, reads our college catalogues. All engineering schools sound equally good. However, if teams of observers go to the different schools – as happens in this country, in our procedure known as accreditation of engineering curricula – we find that there are real differences and that we have good, bad and indifferent engineering schools.

So, when the State Department asked me last year (while I was still president of the American Society for Engineering Education) to set up a mission to visit engineering schools in Russia, we organized a group of eight people who represented various kinds of engineering schools in this country, and various fields of engineering. We did our best to determine which Russian engineering schools would be good, bad, or indifferent, and we asked to visit all three kinds.

We went under the auspices of the American Society for Engineering Education. The State Department arranged it through what is known as the Lacey agreement, which was instigated about a year ago for the exchange of cultural and scientific personnel. The object is to have U.S. groups and Russian groups interchange visits in the same general field. In the Lacey agreement, engineering education was one of the items specifically mentioned. The National Science Foundation financed the exchange.

Other groups have been on recent educational visits to Russia. But they were concerned with the general structure of education and, more specifically, with elementary and high school education – in other words the so-called ten-year school, which is the Russian pattern.

Of course, the development of Russian education has been phenomenal. In one sense, the Soviet Government abolished religion and substituted education for it, because education is almost a religion for the people now. They all believe in it, they respect learning, and they honor accomplishment in scholarship in a way that we don't even approach.

The object of many Russian youngsters is to do well enough in the first four years of school to be able to go on to the next three years of schooling and, at the end of seven years, to go on to the *next* three, which will prepare them to enter a university or a professional school. After seven years of school, the less-good students have a chance of going into what are called the *technicums*, for training of the technician

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type, as against the analytical or engineering approach.

The same pattern exists in many European countries, but the graduate of the technical school has no opportunity of going beyond this point. In Russia, this is not so. An honor student from a technicum may enter a university; it is not a dead-end street. So, for this particular feature, I think the Russians deserve a little praise.

After this ten-year school, there is, for the better students, a chance either at the university, or one of the professional schools. Engineering in the Russian system is not taught in the university. One finds science there, along with liberal arts, but engineering is taught in polytechnic institutes, or specialized institutes. The schools concerned with engineering education are directly under the Ministry of Higher Education – as are the universities. It is true that, within the universities, one can find research and instruction going on which, at Caltech, we would call "engineering," but this is incidental to the Russian pattern. Hence, our group confined itself to the polytechnic institutes and the technical schools.

Our group visited schools in Moscow, Kuibyshev, Frunze, and Leningrad. The trip from Moscow to Kuibyshev was by train – 22 hours, continuous; this is a big country. The remainder of the trip was by air – to Tashkent, where we stayed a day and visited with some of the people of the polytechnic institute there. Then over to Frunze, which is the capital of the Kirghiz Republic which borders on Chinese Turkestan. We were at that point very close to China and directly north of Central India.

The object of our mission was to try to assess the quality of engineering education as nearly as we could. Of course, we could look over the catalogues and read what they *say* they are doing, but are they really doing it? We wanted to sit down with the professors and talk about the class work: "What do you assign the students as problems? What is the textbook? Do you cover the whole book, or skip parts of it?" We were trying to get at these details at the working level.

We found it difficult to make the Russians understand. They were used to missions that had only an hour or two to look at a school. So what happens? Some general talk, a look around, a visit to some laboratories, "hello," "goodbye," and that's it. It took a great deal of time, working through interpreters, to convince our hosts that laboratories were fine but that we would like to sit down and talk to a professor of electrical engineering, a professor of thermodynamics, or a professor of physics.

Language was a handicap, of course, but fortunately in this kind of assessment the Russians print mathematics the same way that we print mathematics and they draw diagrams the way we draw diagrams, so it is possible to thumb through a textbook and see familiar things, then get the interpreter's attention and ask the question, "Do you really give problems on this particular subject?" "Oh, yes, yes." Then buttons are pushed and telephones are rung and assistants bring in the problems to show us.

We did get around to the laboratories and found that in some ways the Russians use their laboratories as teaching devices more effectively than we do. There are some routine experiments with rather detailed instructions for the beginning students, but as they progress, the instructions are less definite and the students are given more opportunity to use their own initiative. In several of their major subjects students do what are called course projects. These are small theses, or term studies that may occupy several weeks of the student's time in the laboratory. The student presents quite a comprehensive paper on the subject. This is a little bit comparable to what happens in our schools for a few students who decide to enter students' prize competitions for the American Institute of Electrical Engineers or the American Society of Mechanical Engineers, for example. But only a few of our students do this, whereas all of the Russian students have the experience.

But there is no use talking about engineering education and trying to make a comparison with the United States or Western Europe without getting into a completely different frame of reference. The U.S.S.R. has made phenomenal progress through a series of five-year plans. Over here, we simply don't realize the thoroughness and comprehensive character of these plans. We live in an unplanned society in the United

States – but the U.S.S.R. is completely planned.

Overall objectives are established by the Council of Ministers. A central planning bureaucracy works out details so as to establish that, five years from now, steel production will be so many million tons per year; aluminum production will be so much; the miles of railroad built in this period will be so many; the miles of electrification of existing railroad will be so many; or so many millions of kilowatts of generating capacity will be brought on the line. This general planning determines steel allocation to military and civilian needs, for example. With quotas and priorities established, then further detailed planning follows. Ministries participating in this overall planning then determine what these objectives mean to their operations.

The steel people will decide that five years from now a certain number of new metallurgical engineers trained in steel metallurgy will be needed to enter new plants which will be ready by that time. The railroads will decide how many new engineers are needed. These needs all go to the Minister of Higher Education and he totals requirements for the thousands of graduates in different types of engineering specialties.

Engineering specialties

Some of us are unhappy with the large numbers of designated engineers that *we* have: civil, electrical, mechanical, aeronautical, refrigeration, heating and ventilating, ceramic, agricultural, industrial, and so on. But in Russia the specialties now number about 177, not counting those in the military area, which are not published and which we didn't observe.

For example, there will be a specialist for the electrical equipment of hydroelectric stations. There will be a mechanical engineer whose specialty is materials handling, and he will be concerned with overhead cranes, conveyor belts, lift trucks, and other things that move materials. He stays inside the factory; he doesn't worry about transportation to the factory.

This kind of specialization would be considered to be completely wrong for our free economy. We would think we were doing a disservice to a student to give him such specialized education – to circumscribe his choice of jobs so narrowly. We want him to be free to move into any job opportunity that appeals to him.

How do the boys – and girls – get into engineering school in Russia? (30 percent of the engineering students in Russia are girls, and in some specialties the ratio is as high as 50 percent.) The schools have their particular quotas in the various specialties and these quotas are generally known to the students. The schools do a certain amount of "advertising" to attract the best students. For instance, the Moscow Power Institute gets out a little booklet which shows the swimming pool, the happy life of the girls in the dormitory, the dancing and the masked ball, the glee club and other extra-curricular activities. Moscow Power Institute wants to have a choice of the best students – and, indeed, they can choose from among the best.

There is a general examination at the end of the ten-year school, conducted on a state basis. All of the engineering schools use the scores of the students on this state examination, much as we use the college board exams. Moscow Power Institute will take a cut of the upper two or three percent and schools that are less good will dig a little deeper.

The students know what specialties are open and they apply for these. A student can apply for any one specialty in any one year; there is none of the multiple application that we have here. If he misses and is not admitted he can go to work and apply another year. The best students apply for the most glamorous specialties; the less-good students, the less-glamorous; and the poorer students take whatever they can get.

Night school programs

The man or girl who applies and isn't admitted need not mark time, because the U.S.S.R. has very comprehensive night school programs at the collegiate level, as well as correspondence programs. In the night school programs a man works full-time in industry and goes to school three or four evenings a week. He has an opportunity in this night school program, and in the correspondence program, to be examined in the same way that the day school students are, and to benefit from laboratory experience as well. Students have a month's leave to the particular polytechnic institute that is supervising their night programs or their correspondence programs. In that month, they get a concentrated dose of laboratory work and take their examinations, a portion of which are oral. These are the same examinations the day students take. The night program student who stays with it in Russia will take about six and a half years to complete his course as against about five and a half years in full-time day residence.

Let's look at Ivan, who did succeed in getting into the Moscow Power Institute. He has reasonably good grades, he looks promising, and he fills out forms as we do here for scholarship aid. A faculty committee passes on his application, basing the decision on a combination of indicated ability and need. After all, some people in Russia have high incomes and can well afford to send their children to school. But there are also a few students whose scholastic records are so high that they are honored with scholarship grants regardless of need.

In all, about 85 percent of Russian students receive grants. The minimum grant is 300 rubles per month – enough to pay for board and room. If Ivan does well in school and goes on to the second year and the third year, his salary goes up each year; if he gets high marks, he gets a bonus amounting to 25 or 30 percent

of his pay. So, the superior students in a school such as Moscow Power Institute are paid in the range of 700 to 800 rubles a month by the time they graduate. (In comparison, workers in the steel industry in Russia average about 1200 rubles per month.)

The starting pay for a young engineering graduate is about 800 to 900 rubles per month, so that, looking over the whole picture, one can say that when Ivan has been admitted to the school, he has started to work for the state. If a student doesn't do well in school, of course, the bonus system works in reverse and his pay is docked; and if he is doing very badly, his assistance is canceled.

Program of study

The program of study for Russian students is quite regimented. Each specialty has a published curriculum known as a study plan. A study plan for a specialty in mechanical engineering would have the general title, Mechanical Engineering, but the specialty might be Hydraulic Turbines and Other Hydraulic Machinery.

The plan includes "Foundations of Marxism and Leninism," "Political Economy," "Foreign Language," "Economics, Organization and Planning of Enterprises" and "History of Engineering." These represent the non-technical content of the curriculum.

Students in a specialty are not conscious of narrow education. They know that if they finish the specialty in Hydraulic Turbines and Other Hydraulic Machinery, there will be a job waiting for them in a plant that manufactures such things, because this is all part of the plan.

For three years, students take what we might call general or core subjects which are quite thorough in physics, mathematics, chemistry, foreign language, basic mechanics, fundamental electricity and magnetism. In the fourth year, they have more advanced phases of these subjects and they begin to pick up a little of their specialty. The fifth year concentrates on the specialty. In the first half of the sixth year, an entire semester is spent on a "diploma project" – what we might call a thesis. This is a very comprehensive design study involving theoretical calculations, an actual design layout, and a sheaf of detailed drawings that might drive some of our students away from engineering altogether.

A typical engineering curriculum at one of the better schools such as Moscow Power Institute takes five and a half years plus six months of obligatory industrial experience. This means that there are six years of engineering education and training following a quite thorough high school preparation. These students graduate about two years older than bachelor of science students in this country, and have a good deal more maturity, together with a certain amount of art and practice of engineering. In this country we expect industry – rather than educational institutions – to furnish this kind of experience and training.

Again, we must remember the Russian economic framework. The industry concerned with hydraulic machinery develops non-competitive designs. So, if the student learns how to design some hydraulic machinery in school, he follows standard practice and not the standards of one of several competing manufacturers. Consequently these students of the polytechnic institutes are quite useful immediately in the particular industry of their specialty.

Do graduates have a choice of jobs? The better students do, because the managers of the different plants concerned with this segment of industry send representatives to interview the top quality students and sell them on the idea of coming to work in Minsk or wherever the plant happens to be. The good students have a choice – as they do all over the world. The good students get concessions during the course of their education. They can omit certain required subjects and take others. They are allowed to take electives which the average or poor students are not permitted to take. Everywhere in Russia there are rewards for achievement and praise for success.

Each school we visited had a huge bulletin board, usually with a fancy gold frame, and with the red star, the hammer and sickle and Lenin's picture above it. And on these bulletin boards were almost lifesize photographs of the honor students – about 30 or 40 of them. If a student's work slips, down comes his picture. Also we saw student work in the hallways – cartoons and student newspapers, poking fun at students who do poorly.

One of the functions of the Young Communist League is to prod the laggards a bit, to find out why they are not getting along, and give them some honest-to-goodness coaching if this is what is required – or to make life miserable for them until they get busy and work. The atmosphere is that of striving toward success, and everywhere there is a feeling of pushing forward toward some kind of a goal and some kind of achievement.

Work experience

A new factor which threw a bit of confusion into our study of Russian engineering education is the principle recently enunciated by Khrushchev that all students who go on to higher education must have two years of work experience. A number of explanations are offered for this. One is that industry is short of hands. There is no unemployment in Russia, and workers are needed in the factories. Then, at the end of the two years, those who have worked their two-year period and who had good marks in school not only have priority for admission to higher education at the universities and the polytechnic institutes, but also will approach their advanced studies with greater maturity and purpose.

This principle has been suddenly thrown at the

whole school system and the Ministry of Higher Education hasn't completed plans for adapting to it. (One can just imagine what would happen here if suddenly all the high school students graduating in June put off going to college for two years.) In the entire U.S.S.R. the night school and correspondence programs will be expanded considerably so that students will not be marking time, going stale intellectually while they work in the foundry or the machine shop.

The schools themselves may find other ways. Many of the polytechnic institutes, having specialties which are directed toward what we might call industrial engineering (production control and subjects of that sort) have large work shops, where students as well as full-time employees work, turning out products which go into the general economy. Many such colleges are planning to enlarge their shops so they can employ their students – or those who *will* be their students. Then ways will be found for adjusting the work in the factories to permit study periods.

Higher degrees

Now, just a brief word about education beyond the diploma. The diploma graduate has an education which is roughly equivalent to a level between our master's degree and our doctor's degree – from the better schools. But the advanced work is on quite a different basis in Russia than ours. The next degree beyond the diploma is the so-called *kandidat* degree. After working two years beyond the diploma in some industry (and this industry may, for the better students, be a research project in the college that is trying to hang on to him) a student may register for advanced work. He will then study additional subject matter, pass certain comprehensive examinations, and do a very thorough thesis for the kandidat degree.

This degree is not within the power of the particular school to award; the school can only recommend. All degrees beyond the diploma are under the control of what is called the Higher Attestation Commission, which operates on a national basis. The man who prepares his kandidat dissertation does so under the supervision of some school having a Chair which is authorized to look after this kind of subject matter. When the dissertation is ready, the man publishes a rather fat abstract of the paper – several hundred copies – and these are distributed widely throughout the schools of the U.S.S.R. well in advance of the time of his final examination. The Higher Attestation Commission appoints two or three examiners who are supposed to question this dissertation. Then, at a scheduled time, there is a public examination and a defense of the thesis. Any objector can come to this meeting and if there is enough objection the candidate is required to modify his work or prove its validity. If this is a successful examination, the particular school recommends to the higher commission that the degree be awarded. The thesis is then further screened by a committee within the Commission, and if this committee likes it, it is approved and the candidate gets his certificate.

The same procedure is followed for the Doctor of Science degree. This degree is not possible, normally, immediately following the kandidat degree, but is usual after several years of teaching or research, or work in industry, and a substantial number of publications. The degree is for a suitable dissertation, with no additional course work in school. There will be certain qualifying examinations, plus the defense of the thesis. Occasionally the Attestation Commission considers a kandidat dissertation to be of such excellence that the Doctor of Science degree is awarded without further formality!

The word "science" in this sense really means "higher learning." The Russian Academy of Sciences in turn is much broader in scope, and greater in influence, than our National Academy of Sciences here: it includes subjects in the liberal arts and engineering. A Doctor of Science degree may be awarded for work in language, history, engineering, physics, biology, or philosophy.

This high degree of Doctor of Science is more or less a prerequisite for a position as professor. Professors are very well paid in Russia. The standard professor's salary is 5000 rubles a month. Hence, it is possible to attract good engineers from industry for professional jobs on the basis not only of prestige, but also of salary. That isn't the way it works in this country.

Summing up

To sum up very quickly, we found excellent, good, and fair engineering education in Russia. We found that there were at least four times as many students wanting to get into engineering schools as the schools could take. The Russians are graduating more engineers than they immediately need in their present economy. Hence, they will be in a position very soon to export engineers to developing countries throughout Asia and the Near East. They will have plenty of engineers to help build up their internal economy. The production rates of the basic things that concern engineers are high.

Throughout Russia there is the great objective to pass the United States in everything. Much of this is friendly and not bitter at all. Everywhere we went, we were well received; the professors were eager to talk about their students and their problems. The Russian students are no different from other students. They have their troubles and their fun and their successes, just as our students do; and the professors like to talk about them and to talk about ways of improving engineering instruction. Everywhere we went, there was the hope expressed that there could be many such exchanges because if we know each other better, we will have less fear of each other.