The Agency's laboratory at Seibersdorf has a mass spectrometer available for the analysis of samples on a routine scale. In the near future experiments will be organized for the study of nitrogen utilization by rice plants as affected by nitrogen transformation in the soil, interactions with other elements in the soil, and the methods and times of application of various kinds of nitrogenous fertilizers under upland and lowland conditions. Laboratory, pot and field experiments using compounds labelled with nitrogen-15 will be carried out under a co-ordinated research contract programme, and the samples will be analysed at the Seibersdorf laboratory when necessary. The laboratory is already starting preliminary experiments to work out suitable techniques.

As regards the supply and movement of nutrients in rice soils, emphasis will be given to a study of the mechanisms that are responsible for the chemical composition of the soil solution in the vicinity of the roots when nutrients are continuously taken up by the plant.

The Agency envisages a continuing programme of rice research with isotope techniques to deal with problems of direct practical interest to farmers. The uptake and metabolism of nutrients are among the most important problems of this nature. For example, it is well known that Indica rice varieties in South East Asia often fail to respond to nitrogen and that the level of production is low compared with Japonica varieties in subtropical regions. A detailed study of nitrogen uptake and metabolism of nitrogen into amino acids in both Indica and Japonica varieties may reveal the cause and thereby help in improving nitrogen fertilization practices in South East Asia. For investigations of this nature the need for a co-operative research effort, such as the one initiated by the Agency, has already been well demonstrated.

LARGE RADIATION SOURCES IN INDUSTRY

Chemical and physical changes that are caused by intense fields of high-energy radiation are sometimes useful ones. An IAEA conference held at Salzburg, Austria, (27 - 31 May) gave the participants a chance to see what has been happening in this field since the last similar conference held by IAEA in Warsaw in 1959. Most of the papers given at the conference were concerned with research studies in polymerization, chemical synthesis, chemical catalysis and rubber vulcanization. One paper described a method with which a large chemical company in the USA is manufacturing a product on a large scale using radiation as a catalytic agent. Several others described plants that are being used for commercial sterilization. When these new processes are added to others that have already been reported, one finds that large radiation sources are very active in industry.

Polymers, Synthesis, Catalysts

Most of the Salzburg papers were devoted to polymerization (in which molecules like ethylene, called "monomers", are caused to link to one another to form such polymer plastics as polyethylene) and synthesis (in which new chemicals are produced by the action of radiation). Among polymerizations that are being studied are combinations in which monomers, which are usually liquids, are put into woods and textiles by soaking and then polymerized by irradiation. The products have some of the properties of the natural material and some of those of modern plastics. Many other papers reported work on the kinetics of polymerization and various grafting processes for causing monomer molecules to attach themselves to polymers already formed.

Two papers reported some success in efforts to make hydrazine, useful as a rocket fuel, by irradiating ammonia. Two others were devoted to nitrogen fixation. Other syntheses that are being studied include formation of compounds of biological interest.

Chemical catalysts always present problems to the chemist; it is very difficult to find out how they function. With the use of radiation the chemists would like to answer three questions: How do catalysts work? Can one increase their activity by irradiating the system while the reaction is occurring? Can one change the activity by irradiating the catalyst before it is put into a chemical system? Four of the Salzburg papers were devoted to various studies of catalysts.

Radiation Makes Chemicals

A process for making ethyl bromide (widely used in medicine and industry) with radiation as a catalyst has progressed through preliminary experiments and pilot-plant tests and since last March has been in full-scale operation in the US chemical firm mentioned earlier. D.E. Harmer, who described the process at Salzburg, says that it has totally replaced the firm's earlier method of ethyl bromide production and is capable of producing about a million pounds of the chemical per year.

The chemical reaction involved is very simple. Two streams of gas, hydrogen bromide and ethylene, are mixed and then bubbled into the bottom of a container filled with the liquid that is the final product, ethyl bromide. The bubbles never reach the top; under the influence of gamma rays from 1800 curies of cobalt-60 within the vessel, the two gases combine to form the product with up to 99% yield and no by-product.

The ethyl bromide liquid is continually recirculated and cooled; the overflow is removed as product.

Early experiments from which the process was developed were done with a half-litre flask surrounded by radioactive cobalt-60. Gas streams could be introduced at the bottom, and a valve permitted the experimenters to switch quickly between two flow systems. In one system the gas streams entered separately; in the other they were mixed before entering and then entered the flask as a single stream. Different solvents could be put into the flask and the experiment could be operated at different temperatures.

Fortunately the product itself turns out to be the best solvent. Under ideal conditions of -10^{o}C, a hydrogen bromide feed of 1.2 gm/min, an ethylene feed of 0.40 gm/min and a radiation intensity of 254 kilorads*/hr, the preliminary experiment had a 96% yield.

At first the experimenters were puzzled by observations that whenever they started their process, it took three hours before the chemical reaction began to go. The explanation was found in minor traces of impurities that remain in ethyl bromide made by other processes. No such impurities inhibit the process when ethyl bromide made with radiation catalysis is used.

The process has many advantages as a commercial enterprise. It is simple. There are no impurities and no by-products. (In another process that is sometimes used much of the feed material is eventually discarded as water.) Costs are small. The 1800-curie source of cobalt-60, which has a 5.2-year half-life, can be replenished at about $360 per year. There are few safety hazards. The radiation source is kept underground in a locked container; meanwhile the product stream and a special nitrogen flushing stream are monitored to see that there are no leaks of either radioactivity or the feed gases.

* *Rad is the unit of radiation dose corresponding to an energy absorption of 100 ergs per gram of matter. For X- and gamma-rays one rad is approximately equal to one roentgen.*

Radiation Kills Germs

When it is used as a sterilizing agent, radiation has important advantages over its two principal competitors, heat and gas. All three of these agents can kill harmful micro-organisms. But while heat is killing germs, it is likely to break down chemical compounds and damage the mechanical properties of fibres and plastics. Fast-moving electrons and gamma rays kill micro-organisms without heating. Although such radiation may damage the product, in many situations it will not damage it as much as will heat.

Gas sterilization has the difficulty that the sterilizing gas must go through holes to reach all portions of the objects that are sterilized. In contrast, since radiation can be made to penetrate packaging material, it can be used to sterilize objects after they are completely sealed and packed for shipment in paper, metal, plastic or glass. Thus the user does not have the difficulties of avoiding further contamination after an initial sterilization.

Salzburg papers displayed continuing interest in the use of radiation for sterilization. What is described as the world's first fully automatic, commercially owned radiation sterilization plant is being operated at Slough, England. The radiation source is at present 50 000 curies of cobalt-60, but the plant is so designed that the source can be made ten times as large if need warrants the increase.

Objects to be sterilized (mainly disposable syringes) are packed in 34 x 28 x 21 cm boxes and carried twice around the source by a monorail conveyor. Each carrier holds eight boxes, and the boxes are inserted four at a time. As a carrier comes into the loading area, four boxes are pushed into the carrier from below, displacing four fully sterilized boxes from the top. Next the carrier moves through the source chamber on the monorail and returns to the loading area. A new group of four boxes is pushed into the bottom of the carrier; the group that has been through the source chamber once is pushed from its position at the bottom up to the position at the top; the group that was above it, now fully sterilized, is discharged; the carrier goes once more through the source chamber. Thus each group of four boxes moves twice past the source, once in the bottom of its carrier and once at the top.

Unlike other sterilization facilities, most of which have water shielding, the one at Slough uses only dry shielding. The source consists of cobalt rods that are mounted in horizontal tubes. Loading and unloading are accomplished by dropping the source holder into a pit where any one of its tubes can be brought into alignment with another tube that penetrates the shield. When a plug is removed, radioactive rods can be inserted and removed from the source holder.

The company which operates the Slough plant has already pioneered radiation sterilization of surgical sutures with electrons at an American subsidiary; it also foresees other applications of radiation sterilization in the future. For example, one might fill disposable syringes before sterilizing them and then sterilize both syringe and contents at once.

Also reported at Salzburg was experience gained in operating a suture-sterilization plant in Edinburgh, Scotland. The source is 40 000 curies of cobalt-60, and the plant has been in operation since early this year.

A sterilization problem of a different sort - one in which the process must not cause undesirable chemical changes - is being studied at the nuclear research centre in Saluggia, Italy. The subject is the sodium salt of a complicated organic compound used in the treatment of certain tubercular infections. It is difficult to sterilize the substance by ordinary methods. Tests are being made of the efficacy of gamma sterilization with a cobalt-60 source and of the biological tolerance displayed by test animals to the gamma-sterilized product.

Radiation Vulcanizes Rubber

Makers of rubbers and the synthetic substitutes for it (called elastomers) are studying radiation processing as a substitute for currently used vulcanization processes. In the usual process an additional substance, such as sulphur, is added to the straight-line rubber molecules, and through chemical action between the original material and the additive, or "filler", bonds are formed that make a firm, cross-linked substance of what is otherwise a thick and sticky liquid or semi-solid. The main drawback is that the links formed by the additive are usually the weak ones in the final substance. Radiation offers the substitute method of causing stronger cross links to occur between the rubber molecules themselves.

At Salzburg one paper from the Soviet Union and one from France described efforts to improve the vulcanization, or "curing", of latex films. In France the method is to irradiate the latex first with electrons from a 15-kilowatt, 1.5 million-electron-volt accelerator and then add filler. Electrically charged molecular fragments, usually called "free radicals", that are formed in the latex by irradiation can be expected to initiate chemical reactions that eventually lead to a cross-linked product. The authors, A. Lamm and G. Lamm, report that they can make latex films that are different and generally better than those made by chemical vulcanization.

V. L. Karpov and his colleagues from the USSR report similar work on latex. They use radiation vulcanization without any filler and then make detailed studies of chemical and physical changes. The changes depend considerably on the chemical nature of the rubber and its origin. The radiation-vulcanized rubber has different aging properties and better stability than the conventionally produced counterpart.

In studies to find out just what happens in radiation vulcanization and how the process occurs, A.S. Kuzminsky, T.S. Fedeseeva and V.F. Chertkova have been using recently developed electronic analytical techniques to study the behaviour of the free radicals formed by irradiation. They are particularly interested in what happens when rubber makers add radiation cross-linking to rubber that is already vulcanized with sulphur. Such a rubber is likely to show the maximal improvement of physical and mechanical properties. The mode of study is to irradiate at low temperatures and then follow the fates of free radicals as the specimen is gradually warmed. One finds that after a three-dimensional network is formed by cross-linking, the mobility of free radicals and hence their recombination rate are tremendously decreased.

At the Wantage Laboratory in England, S.M. Miller, M. W. Spindler and R. L. Vale have been making direct attacks on the principal drawback of radiation vulcanization - its cost. They are searching for substances that will act as sensitizers and reduce the radiation dose required for vulcanization. They have been able to find such sensitizers, which, by a chain-reaction mechanism in which the ingredients required for reaction are reproduced when the reaction takes place, reduce the required dose from between 40 and 50 megarads to between 3 and 5 megarads.

Design of Radiation Sources

To make any radiation process commercially useful one must have a source that is cheap, safe and efficient. Ideally one would use a nuclear reactor, because in a reactor one has quantities of radiation that are in the first place huge and in the second usually wasted. The difficulty is that mixed with the gamma radiation that one would like to use there are usually neutrons that are likely to make the product itself radioactive.

Attempts to use reactors for irradiation were described at Salzburg in a paper by Yu.S. Ryabukhin, A.Kh. Breger and their colleagues in Moscow. They reported their latest progress in the use of radiation loops, systems in which a fluid is circulated through a reactor to make it radioactive and then into a radiation cell where its gamma radiation is used for processing. The neutrons remain in the reactor and do not affect the final product. The USSR already has three loops of this kind in operation. The first is a loop containing an indium-gallium alloy installed in 1960 at the Georgian Academy of Sciences. The others use an indium-gallium-tin alloy, one at the Institute of Atomic Energy in Moscow, the other at the Latvian Academy of Sciences.